NumPy Reference

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Written by the NumPy community

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This reference manual details functions, modules, and objects included in Numpy, describing what they are and what they do. For learning how to use NumPy, see also user.
NumPy provides an N-dimensional array type, the `ndarray`, which describes a collection of “items” of the same type. The items can be indexed using for example N integers.

All ndarrays are homogenous: every item takes up the same size block of memory, and all blocks are interpreted in exactly the same way. How each item in the array is to be interpreted is specified by a separate data-type object, one of which is associated with every array. In addition to basic types (integers, floats, etc.), the data type objects can also represent data structures.

An item extracted from an array, e.g., by indexing, is represented by a Python object whose type is one of the array scalar types built in Numpy. The array scalars allow easy manipulation of also more complicated arrangements of data.

**Figure 1.1:** Figure Conceptual diagram showing the relationship between the three fundamental objects used to describe the data in an array: 1) the ndarray itself, 2) the data-type object that describes the layout of a single fixed-size element of the array, 3) the array-scalar Python object that is returned when a single element of the array is accessed.

### 1.1 The N-dimensional array (`ndarray`)

An `ndarray` is a (usually fixed-size) multidimensional container of items of the same type and size. The number of dimensions and items in an array is defined by its `shape`, which is a tuple of \( N \) positive integers that specify the sizes of each dimension. The type of items in the array is specified by a separate data-type object (`dtype`), one of which is associated with each ndarray.

As with other container objects in Python, the contents of an `ndarray` can be accessed and modified by indexing or slicing the array (using, for example, \( N \) integers), and via the methods and attributes of the `ndarray`. 
Different ndarrays can share the same data, so that changes made in one ndarray may be visible in another. That is, an ndarray can be a “view” to another ndarray, and the data it is referring to is taken care of by the “base” ndarray. ndarrays can also be views to memory owned by Python strings or objects implementing the buffer or array interfaces.

Example
A 2-dimensional array of size 2 x 3, composed of 4-byte integer elements:

```python
>>> x = np.array([[1, 2, 3], [4, 5, 6]], np.int32)
>>> type(x)
<type 'numpy.ndarray'>
>>> x.shape
(2, 3)
>>> x.dtype
dtype('int32')
```

The array can be indexed using Python container-like syntax:

```python
>>> x[1,2]  # i.e., the element of x in the second row, third column, namely, 6.
9
```

For example slicing can produce views of the array:

```python
>>> y = x[:,1]
>>> y
array([2, 5])
>>> y[0] = 9  # this also changes the corresponding element in x
>>> y
array([9, 5])
>>> x
array([[1, 9, 3],
       [4, 5, 6]])
```

1.1.1 Constructing arrays

New arrays can be constructed using the routines detailed in Array creation routines, and also by using the low-level ndarray constructor:

```python
ndarray An array object represents a multidimensional, homogeneous array of fixed-size items.
```

class numpy.ndarray
An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using array, zeros or empty (refer to the See Also section below). The parameters given here refer to a low-level method (ndarray(...)) for instantiating an array.

For more information, refer to the numpy module and examine the the methods and attributes of an array.

Parameters
(for the __new__ method; see Notes below)

- **shape**: tuple of ints
  Shape of created array.
**dtype**: data-type, optional

Any object that can be interpreted as a numpy data type.

**buffer**: object exposing buffer interface, optional

Used to fill the array with data.

**offset**: int, optional

Offset of array data in buffer.

**strides**: tuple of ints, optional

Strides of data in memory.

**order**: {'C', 'F'}, optional

Row-major or column-major order.

See also:

- **array**
  Construct an array.

- **zeros**
  Create an array, each element of which is zero.

- **empty**
  Create an array, but leave its allocated memory unchanged (i.e., it contains “garbage”).

- **dtype**
  Create a data-type.

Notes

There are two modes of creating an array using __new__:

1. If buffer is None, then only shape, dtype, and order are used.

2. If buffer is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level ndarray constructor. Refer to the See Also section above for easier ways of constructing an ndarray.

First mode, buffer is None:

```python
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[ -1.13698227e+002, 4.25087011e-303],
       [ 2.88528414e-306, 3.27025015e-309]]) #random
```

Second mode:

```python
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*items, i.e. skip first element
array([2, 3])
```

Attributes

1.1. The N-dimensional array (ndarray)
ndarray.T
Same as self.transpose(), except that self is returned if self.ndim < 2.

Examples
>>> x = np.array([[[1., 2.], [3., 4.]]])
>>> x
array([[[ 1.,  2.],
        [ 3.,  4.]]])
>>> x.T
array([[[ 1.,  3.],
        [ 2.,  4.]]])

ndarray.data
Python buffer object pointing to the start of the array’s data.

ndarray.dtype
Data-type of the array’s elements.

Parameters
None

Returns
d : numpy dtype object

See also:
numpy.dtype

Examples
>>> x
array([[0, 1],
       [2, 3]])
>>> x.dtype
dtype('int32')
```python
def x
def x.dtype
<
type 'numpy.dtype'>
```

**ndarray.flags**
Information about the memory layout of the array.

**Notes**

The `flags` object can be accessed dictionary-like (as in `a.flags['WRITEABLE']`), or by using lowercase attribute names (as in `a.flags.writeable`). Short flag names are only supported in dictionary access.

Only the `UPDATEIFCOPY`, `WRITEABLE`, and `ALIGNED` flags can be changed by the user, via direct assignment to the attribute or dictionary entry, or by calling `ndarray.setflags`.

The array flags cannot be set arbitrarily:

- `UPDATEIFCOPY` can only be set to `False`.
- `ALIGNED` can only be set to `True` if the data is truly aligned.
- `WRITEABLE` can only be set to `True` if the array owns its own memory or the ultimate owner of the memory exposes a writeable buffer interface or is a string.

Arrays can be both C-style and Fortran-style contiguous simultaneously. This is clear for 1-dimensional arrays, but can also be true for higher dimensional arrays.

Even for contiguous arrays a stride for a given dimension `arr.strides[dim]` may be arbitrary if `arr.shape[dim] == 1` or the array has no elements. It does not generally hold that `self.strides[-1] == self.itemsize` for C-style contiguous arrays or `self.strides[0] == self.itemsize` for Fortran-style contiguous arrays is true.
## Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_CONTIGUOUS</td>
<td>This data is in a single, C-style contiguous segment.</td>
</tr>
<tr>
<td>F_CONTIGUOUS</td>
<td>This data is in a single, Fortran-style contiguous segment.</td>
</tr>
<tr>
<td>OWN_DATA</td>
<td>The array owns the memory it uses or borrows it from another object.</td>
</tr>
<tr>
<td>WRITEABLE</td>
<td>The data area can be written to. Setting this to False locks the data, making it read-only. A view (slice, etc.) inherits WRITEABLE from its base array at creation time, but a view of a writeable array may be subsequently locked while the base array remains writeable. (The opposite is not true, in that a view of a locked array may not be made writeable. However, currently, locking a base object does not lock any views that already reference it, so under that circumstance it is possible to alter the contents of a locked array via a previously created writeable view onto it.) Attempting to change a non-writeable array raises a RuntimeError exception.</td>
</tr>
<tr>
<td>ALIGNED</td>
<td>The data and all elements are aligned appropriately for the hardware.</td>
</tr>
<tr>
<td>UPDATEIFCOPY</td>
<td>This array is a copy of some other array. When this array is deallocated, the base array will be updated with the contents of this array.</td>
</tr>
<tr>
<td>FNC</td>
<td>F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FORC</td>
<td>F_CONTIGUOUS or C_CONTIGUOUS (one-segment test).</td>
</tr>
<tr>
<td>BEHAVED</td>
<td>ALIGNED and WRITEABLE.</td>
</tr>
<tr>
<td>CARRAY</td>
<td>BEHAVED and C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FARRAY</td>
<td>BEHAVED and F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
</tbody>
</table>

**ndarray.flat**

A 1-D iterator over the array.

This is a `numpy.flatiter` instance, which acts similarly to, but is not a subclass of, Python’s built-in iterator object.

**See also:**

- `flatten`
  - Return a copy of the array collapsed into one dimension.

**flatiter**

### Examples

```python
>>> x = np.arange(1, 7).reshape(2, 3)
>>> x
array([[1, 2, 3],
       [4, 5, 6]]
>>> x.flat[3]
4
>>> x.T
array([[1, 4],
       [2, 5],
       [3, 6]])
```
An assignment example:

```python
>>> x.flat = 3; x
array([[3, 3, 3],
       [3, 3, 3]])
>>> x.flat[[1, 4]] = 1; x
array([[3, 1, 3],
       [3, 1, 3]])
```

**ndarray.imag**  
The imaginary part of the array.

**Examples**

```python
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.imag
array([ 0. , 0.70710678])
>>> x.imag.dtype
dtype('float64')
```

**ndarray.real**  
The real part of the array.

See also:

**numpy.real**  
equivalent function

**Examples**

```python
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.real
array([ 1. , 0.70710678])
>>> x.real.dtype
dtype('float64')
```

**ndarray.size**  
The number of elements in the array.

Equivalent to `np.prod(a.shape)`, i.e., the product of the array’s dimensions.

**Examples**

```python
>>> x = np.zeros((3, 5, 2), dtype=np.complex128)
>>> x.size
30
>>> np.prod(x.shape)
30
```

**ndarray.itemsize**  
The length of one array element in bytes.

---

1.1. The N-dimensional array (ndarray)
Examples

```python
>>> x = np.array([1, 2, 3], dtype=np.float64)
>>> x.itemsize
8
>>> x = np.array([1, 2, 3], dtype=np.complex128)
>>> x.itemsize
16
```

defnarray.nbytes
Total bytes consumed by the elements of the array.

Notes
Does not include memory consumed by non-element attributes of the array object.

Examples

```python
>>> x = np.zeros((3, 5, 2), dtype=np.complex128)
>>> x.nbytes
480
>>> np.prod(x.shape) * x.itemsize
480
```

defnarray.ndim
Number of array dimensions.

Examples

```python
>>> x = np.array([1, 2, 3])
>>> x.ndim
1
>>> y = np.zeros((2, 3, 4))
>>> y.ndim
3
```

defnarray.shape
Tuple of array dimensions.

Notes
May be used to “reshape” the array, as long as this would not require a change in the total number of elements.

Examples

```python
>>> x = np.array([1, 2, 3, 4])
>>> x.shape
(4,)
>>> y = np.zeros((2, 3, 4))
>>> y.shape
(2, 3, 4)
>>> y.shape = (3, 6)
>>> y
array([[ 0., 0., 0., 0., 0., 0.],
[ 0., 0., 0., 0., 0., 0.],
[ 0., 0., 0., 0., 0., 0.]])
>>> y.shape = (3, 6)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
```
**ndarray.strides**

Tuple of bytes to step in each dimension when traversing an array.

The byte offset of element \((i[0], i[1], \ldots, i[n])\) in an array \(a\) is:

\[
\text{offset} = \sum\text{np.array}(i) \times a.\text{strides}
\]

A more detailed explanation of strides can be found in the “ndarray.rst” file in the NumPy reference guide.

See also:

numpy.lib.stride_tricks.as_strided

**Notes**

Imagine an array of 32-bit integers (each 4 bytes):

\[
x = \text{np.array}([[0, 1, 2, 3, 4],
                    [5, 6, 7, 8, 9]], \text{dtype=np.int32})
\]

This array is stored in memory as 40 bytes, one after the other (known as a contiguous block of memory). The strides of an array tell us how many bytes we have to skip in memory to move to the next position along a certain axis. For example, we have to skip 4 bytes (1 value) to move to the next column, but 20 bytes (5 values) to get to the same position in the next row. As such, the strides for the array \(x\) will be \((20, 4)\).

**Examples**

```python
>>> y = np.reshape(np.arange(2*3*4), (2,3,4))
>>> y
array([[[ 0, 1, 2, 3],
        [ 4, 5, 6, 7],
        [ 8, 9, 10, 11]],
       [[12, 13, 14, 15],
        [16, 17, 18, 19],
        [20, 21, 22, 23]])
```

```python
>>> y.strides
(48, 16, 4)
```

```python
>>> y[1,1,1]
17
```

```python
>>> offset = sum(y.strides * np.array((1,1,1)))
>>> offset / y.itemsize
17
```

```python
>>> x = np.reshape(np.arange(5*6*7*8), (5,6,7,8)).transpose(2,3,1,0)
>>> x.strides
(32, 4, 224, 1344)
```

```python
>>> i = np.array([3,5,2,2])
>>> offset = sum(i * x.strides)
>>> x[i,3,5,2,2]
813
>>> offset / x.itemsize
813
```

**ndarray.ctypes**

An object to simplify the interaction of the array with the ctypes module.
This attribute creates an object that makes it easier to use arrays when calling shared libraries with the ctypes module. The returned object has, among others, data, shape, and strides attributes (see Notes below) which themselves return ctypes objects that can be used as arguments to a shared library.

**Parameters**

None

**Returns**

c : Python object

Possessing attributes data, shape, strides, etc.

**See also:**

cpython.ctypeslib

**Notes**

Below are the public attributes of this object which were documented in “Guide to NumPy” (we have omitted undocumented public attributes, as well as documented private attributes):

- **data**: A pointer to the memory area of the array as a Python integer. This memory area may contain data that is not aligned, or not in correct byte-order. The memory area may not even be writeable. The array flags and data-type of this array should be respected when passing this attribute to arbitrary C-code to avoid trouble that can include Python crashing. User Beware! The value of this attribute is exactly the same as self._array_interface_['data'][0].

- **shape (c_intp*self.ndim)**: A ctypes array of length self.ndim where the basetype is the C-integer corresponding to dtype('p') on this platform. This base-type could be c_int, c_long, or c_longlong depending on the platform. The c_intp type is defined accordingly in numpy.ctypeslib. The ctypes array contains the shape of the underlying array.

- **strides (c_intp*self.ndim)**: A ctypes array of length self.ndim where the basetype is the same as for the shape attribute. This ctypes array contains the strides information from the underlying array. This strides information is important for showing how many bytes must be jumped to get to the next element in the array.

- **data_as(obj)**: Return the data pointer cast to a particular c-types object. For example, calling self._as_parameter_ is equivalent to self.data_as(ctypes.c_void_p). Perhaps you want to use the data as a pointer to a ctypes array of floating-point data: self.data_as(ctypes.POINTER(ctypes.c_double)).

- **shape_as(obj)**: Return the shape tuple as an array of some other c-types type. For example: self.shape_as(ctypes.c_short).

- **strides_as(obj)**: Return the strides tuple as an array of some other c-types type. For example: self.strides_as(ctypes.c_longlong).

Be careful using the ctypes attribute – especially on temporary arrays or arrays constructed on the fly. For example, calling (a+b).ctypes.data_as(ctypes.c_void_p) returns a pointer to memory that is invalid because the array created as (a+b) is deallocated before the next Python statement. You can avoid this problem using either c=a+b or ct=(a+b).ctypes. In the latter case, ct will hold a reference to the array until ct is deleted or re-assigned.

If the ctypes module is not available, then the ctypes attribute of array objects still returns something useful, but ctypes objects are not returned and errors may be raised instead. In particular, the object will still have the as parameter attribute which will return an integer equal to the data attribute.

**Examples**

```python
>>> import ctypes
>>> x
```
array([[0, 1],
       [2, 3]])
>>> x.ctypes.data
30439712
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_long))
<ctypes.LP_c_long object at 0x01F01300>
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_long)).contents
c_long(0)
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_longlong)).contents
c_longlong(4294967296L)
>>> x.ctypes.shape
<numpy.core._internal.c_long_Array_2 object at 0x01FFD580>
>>> x.ctypes.shape_as(ctypes.c_long)
<numpy.core._internal.c_long_Array_2 object at 0x01FCE620>
>>> x.ctypes.strides
<numpy.core._internal.c_long_Array_2 object at 0x01FCE620>
>>> x.ctypes.strides_as(ctypes.c_longlong)
<numpy.core._internal.c_longlong_Array_2 object at 0x01F01300>

darray.base
Base object if memory is from some other object.

Examples
The base of an array that owns its memory is None:
>>> x = np.array([1, 2, 3, 4])
>>> x.base is None
True

Slicing creates a view, whose memory is shared with x:
>>> y = x[2:]
>>> y.base is x
True

Methods

- all([axis, out]) Returns True if all elements evaluate to True.
- any([axis, out]) Returns True if any of the elements of a evaluate to True.
- argmax([axis, out]) Return indices of the maximum values along the given axis.
- argmin([axis, out]) Return indices of the minimum values along the given axis of a.
- argpartition(kth[, axis, kind, order]) Returns the indices that would partition this array.
- argsort([axis, kind, order]) Returns the indices that would sort this array.
- astype([dtype[, order, casting, subok, copy]]) Copy of the array, cast to a specified type.
- byteswap(inplace) Swap the bytes of the array elements Toggle between low-endian and big-endian data representation.
- clip(a_min, a_max[, out]) Return an array whose values are limited to [a_min, a_max].
- compress(condition[, axis, out]) Return selected slices of this array along given axis.
- conj() Complex-conjugate all elements.
- conjugate() Return the complex conjugate, element-wise.
- copy([order]) Return a copy of the array.
- cumulative product([axis, dtype, out]) Return the cumulative product of the elements along the given axis.
- cumsum([axis, dtype, out]) Return the cumulative sum of the elements along the given axis.
- diagonal([offset, axis1, axis2]) Return specified diagonals.
- dot(b[, out]) Dot product of two arrays.
### Table 1.3 – continued from previous page

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>dump(file)</code></td>
<td>Dump a pickle of the array to the specified file.</td>
</tr>
<tr>
<td><code>dumps()</code></td>
<td>Returns the pickle of the array as a string.</td>
</tr>
<tr>
<td><code>fill(value)</code></td>
<td>Fill the array with a scalar value.</td>
</tr>
<tr>
<td><code>flatten(order)</code></td>
<td>Return a copy of the array collapsed into one dimension.</td>
</tr>
<tr>
<td><code>getfield(dtype[, offset])</code></td>
<td>Returns a field of the given array as a certain type.</td>
</tr>
<tr>
<td><code>item(*args)</code></td>
<td>Copy an element of an array to a standard Python scalar and return it.</td>
</tr>
<tr>
<td><code>itemset(*args)</code></td>
<td>Insert scalar into an array (scalar is cast to array’s dtype, if possible)</td>
</tr>
<tr>
<td><code>max([axis, out])</code></td>
<td>Return the maximum along a given axis.</td>
</tr>
<tr>
<td><code>mean([axis, dtype, out])</code></td>
<td>Returns the average of the array elements along given axis.</td>
</tr>
<tr>
<td><code>min([axis, out])</code></td>
<td>Return the minimum along a given axis.</td>
</tr>
<tr>
<td><code>newbyteorder([new_order])</code></td>
<td>Return the array with the same data viewed with a different byte order.</td>
</tr>
<tr>
<td><code>nonzero()</code></td>
<td>Return the indices of the elements that are non-zero.</td>
</tr>
<tr>
<td><code>partition(kth[, axis, kind, order])</code></td>
<td>Rearranges the elements in the array in such a way that value of the element in kth position is in its sorted position.</td>
</tr>
<tr>
<td><code>prod([axis, dtype, out])</code></td>
<td>Return the product of the array elements over the given axis.</td>
</tr>
<tr>
<td><code>ptp([axis, out])</code></td>
<td>Peak to peak (maximum - minimum) value along a given axis.</td>
</tr>
<tr>
<td><code>put(indices, values[, mode])</code></td>
<td>Set <code>a.flat[n] = values[n]</code> for all <code>n</code> in <code>indices</code>.</td>
</tr>
<tr>
<td><code>ravel(order)</code></td>
<td>Return a flattened array.</td>
</tr>
<tr>
<td><code>repeat(repeats[, axis])</code></td>
<td>Repeat elements of an array.</td>
</tr>
<tr>
<td><code>reshape(shape[, order])</code></td>
<td>Returns an array containing the same data with a new shape.</td>
</tr>
<tr>
<td><code>resize(new_shape[, refcheck])</code></td>
<td>Change shape and size of array in-place.</td>
</tr>
<tr>
<td><code>round([decimals, out])</code></td>
<td>Return a with each element rounded to the given number of decimals.</td>
</tr>
<tr>
<td><code>searchsorted(v[, side, sorter])</code></td>
<td>Find indices where elements of v should be inserted in a to maintain order.</td>
</tr>
<tr>
<td><code>setfield(val, dtype[, offset])</code></td>
<td>Put a value into a specified place in a field defined by a data-type.</td>
</tr>
<tr>
<td><code>setflags([write, align, uic])</code></td>
<td>Set array flags WRITEABLE, ALIGNED, and UPDATEIFCOPY, respectively.</td>
</tr>
<tr>
<td><code>squeeze(axis)</code></td>
<td>Remove single-dimensional entries from the shape of a.</td>
</tr>
<tr>
<td><code>std([axis, dtype, out, ddof])</code></td>
<td>Returns the standard deviation of the array elements along given axis.</td>
</tr>
<tr>
<td><code>sum([axis, dtype, out])</code></td>
<td>Return the sum of the array elements over the given axis.</td>
</tr>
<tr>
<td><code>swapaxes(axis1, axis2)</code></td>
<td>Return a view of the array with <code>axis1</code> and <code>axis2</code> interchanged.</td>
</tr>
<tr>
<td><code>take(indices[, axis, out, mode])</code></td>
<td>Return an array formed from the elements of <code>a</code> at the given indices.</td>
</tr>
<tr>
<td><code>tobytes(order)</code></td>
<td>Construct Python bytes containing the raw data bytes in the array.</td>
</tr>
<tr>
<td><code>tofile(fid[, sep, format])</code></td>
<td>Write array to a file as text or binary (default).</td>
</tr>
<tr>
<td><code>tolist()</code></td>
<td>Return the array as a (possibly nested) list.</td>
</tr>
<tr>
<td><code>tostring(order)</code></td>
<td>Construct Python bytes containing the raw data bytes in the array.</td>
</tr>
<tr>
<td><code>trace(offset, axis1, axis2, out)</code></td>
<td>Return the sum along diagonals of the array.</td>
</tr>
<tr>
<td><code>transpose(*axes)</code></td>
<td>Returns a view of the array with axes transposed.</td>
</tr>
<tr>
<td><code>var([axis, dtype, out, ddof])</code></td>
<td>Returns the variance of the array elements, along given axis.</td>
</tr>
<tr>
<td><code>view([dtype, type])</code></td>
<td>New view of array with the same data.</td>
</tr>
</tbody>
</table>

**ndarray.all**  
```python
ndarray.all (axis=None, out=None)
```

Returns True if all elements evaluate to True.

Refer to `numpy.all` for full documentation.

See also:

**ndarray.any**  
```python
ndarray.any (axis=None, out=None)
```

Returns True if any of the elements of `a` evaluate to True.

Refer to `numpy.any` for full documentation.
See also:

```
numpy.any
   equivalent function
```

```
ndarray.argmax(axis=None, out=None)
   Return indices of the maximum values along the given axis.
   Refer to numpy.argmax for full documentation.

See also:
```
```
numpy.argmax
   equivalent function
```

```
ndarray.argmin(axis=None, out=None)
   Return indices of the minimum values along the given axis of a.
   Refer to numpy.argmin for detailed documentation.

See also:
```
```
numpy.argmin
   equivalent function
```

```
ndarray.argpartition(kth, axis=-1, kind='introselect', order=None)
   Returns the indices that would partition this array.
   Refer to numpy.argpartition for full documentation.
   New in version 1.8.0.

See also:
```
```
numpy.argpartition
   equivalent function
```

```
ndarray.argsort(axis=-1, kind='quicksort', order=None)
   Returns the indices that would sort this array.
   Refer to numpy.argsort for full documentation.

See also:
```
```
numpy.argsort
   equivalent function
```

```
ndarray.astype(dtype, order='K', casting='unsafe', subok=True, copy=True)
   Copy of the array, cast to a specified type.

Parameters

dtype : str or dtype
   Typecode or data-type to which the array is cast.

order : {'C', 'F', 'A', 'K'}, optional
   Controls the memory layout order of the result. ‘C’ means C order, ‘F’ means Fortran order, ‘A’ means ‘F’ order if all the arrays are Fortran contiguous, ‘C’ order otherwise,
```

1.1. The N-dimensional array (ndarray)
and ‘K’ means as close to the order the array elements appear in memory as possible. Default is ‘K’.

**casting**: {'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional

Controls what kind of data casting may occur. Defaults to ‘unsafe’ for backwards compatibility.
- ‘no’ means the data types should not be cast at all.
- ‘equiv’ means only byte-order changes are allowed.
- ‘safe’ means only casts which can preserve values are allowed.
- ‘same_kind’ means only safe casts or casts within a kind, like float64 to float32, are allowed.
- ‘unsafe’ means any data conversions may be done.

**subok**: bool, optional

If True, then sub-classes will be passed-through (default), otherwise the returned array will be forced to be a base-class array.

**copy**: bool, optional

By default, astype always returns a newly allocated array. If this is set to false, and the `dtype`, `order`, and `subok` requirements are satisfied, the input array is returned instead of a copy.

**Returns**

- `arr_t`: ndarray

  Unless `copy` is False and the other conditions for returning the input array are satisfied (see description for `copy` input parameter), `arr_t` is a new array of the same shape as the input array, with dtype, order given by `dtype`, `order`.

**Raises**

- `ComplexWarning`

  When casting from complex to float or int. To avoid this, one should use `a.real.astype(t)`.

**Notes**

Starting in NumPy 1.9, astype method now returns an error if the string dtype to cast to is not long enough in ‘safe’ casting mode to hold the max value of integer/float array that is being casted. Previously the casting was allowed even if the result was truncated.

**Examples**

```python
>>> x = np.array([1, 2, 2.5])
>>> x
array([ 1., 2., 2.5])

>>> x.astype(int)
array([1, 2, 2])
```

```
ndarray.byteswap(inplace)
```

Swap the bytes of the array elements

Toggle between low-endian and big-endian data representation by returning a byteswapped array, optionally swapped in-place.
Parameters

inplace : bool, optional

If True, swap bytes in-place, default is False.

Returns

out : ndarray

The byteswapped array. If inplace is True, this is a view to self.

Examples

>>> A = np.array([1, 256, 8755], dtype=np.int16)
>>> map(hex, A)
['0x1', '0x100', '0x2233']
>>> A.byteswap(True)
array([  256,     1, 13090], dtype=int16)
>>> map(hex, A)
['0x100', '0x1', '0x3322']

Arrays of strings are not swapped

>>> A = np.array(['ceg', 'fac'])
>>> A.byteswap()
array(['ceg', 'fac'],
      dtype='|S3')

ndarray.choose(choices, out=None, mode='raise')
Use an index array to construct a new array from a set of choices.

Refer to numpy.choose for full documentation.

See also:

numpy.choose

   equivalent function

ndarray.clip(a_min, a_max, out=None)
Return an array whose values are limited to [a_min, a_max].

Refer to numpy.clip for full documentation.

See also:

numpy.clip

   equivalent function

ndarray.compress(condition, axis=None, out=None)
Return selected slices of this array along given axis.

Refer to numpy.compress for full documentation.

See also:

numpy.compress

   equivalent function

ndarray.conj()
Complex-conjugate all elements.

Refer to numpy.conjugate for full documentation.

1.1. The N-dimensional array (ndarray)
See also:

\texttt{numpy.conjugate}

equivalent function

\texttt{ndarray.conjugate()}

Return the complex conjugate, element-wise.

Refer to \texttt{numpy.conjugate} for full documentation.

See also:

\texttt{numpy.conjugate}

equivalent function

\texttt{ndarray.copy(order='C')}

Return a copy of the array.

\textbf{Parameters}

\texttt{order : \{'C', 'F', 'A', 'K'}, optional

Controls the memory layout of the copy. ‘C’ means C-order, ‘F’ means F-order, ‘A’
means ‘F’ if a is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of a as
closely as possible. (Note that this function and :func:numpy.copy are very similar, but
have different default values for their order= arguments.)

See also:

\texttt{numpy.copy, numpy.copyto}

\textbf{Examples}

\begin{verbatim}
>>> x = np.array([[1, 2, 3], [4, 5, 6]], order='F')
>>> y = x.copy()
>>> x.fill(0)

>>> x
array([[0, 0, 0],
       [0, 0, 0]])

>>> y
array([[1, 2, 3],
       [4, 5, 6]])

>>> y.flags[‘C_CONTIGUOUS’]
True
\end{verbatim}

\texttt{ndarray.cumprod(axis=None, dtype=None, out=None)}

Return the cumulative product of the elements along the given axis.

Refer to \texttt{numpy.cumprod} for full documentation.

See also:

\texttt{numpy.cumprod}

equivalent function
ndarray.cumsum (axis=None, dtype=None, out=None)
Return the cumulative sum of the elements along the given axis.

Refer to numpy.cumsum for full documentation.

See also:

numpy.cumsum
   equivalent function

ndarray.diagonal (offset=0, axis1=0, axis2=1)
Return specified diagonals. In NumPy 1.9 the returned array is a read-only view instead of a copy as in previous NumPy versions. In NumPy 1.10 the read-only restriction will be removed.

Refer to numpy.diagonal for full documentation.

See also:

numpy.diagonal
   equivalent function

ndarray.dot (b, out=None)
Dot product of two arrays.

Refer to numpy.dot for full documentation.

See also:

numpy.dot
   equivalent function

Examples
>>> a = np.eye(2)
>>> b = np.ones((2, 2)) * 2
>>> a.dot(b)
array([[ 2.,  2.],
       [ 2.,  2.]])

This array method can be conveniently chained:

>>> a.dot(b).dot(b)
array([[ 8.,  8.],
       [ 8.,  8.]])

ndarray.dump (file)
Dump a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

Parameters
file : str
   A string naming the dump file.

ndarray.dumps ()
Returns the pickle of the array as a string. pickle.loads or numpy.loads will convert the string back to an array.

Parameters
None
ndarray.fill(value)
    Fill the array with a scalar value.

    Parameters
    value : scalar
        All elements of a will be assigned this value.

    Examples
    >>> a = np.array([1, 2])
    >>> a.fill(0)
    array([0, 0])
    >>> a = np.empty(2)
    >>> a.fill(1)
    array([ 1., 1.])

ndarray.flatten(order='C')
    Return a copy of the array collapsed into one dimension.

    Parameters
    order : {'C', 'F', 'A'}, optional
        Whether to flatten in C (row-major), Fortran (column-major) order, or preserve the
        C/Fortran ordering from a. The default is 'C'.

    Returns
    y : ndarray
        A copy of the input array, flattened to one dimension.

    See also:
    ravel
        Return a flattened array.

    flat
        A 1-D flat iterator over the array.

    Examples
    >>> a = np.array([[1,2], [3,4]])
    >>> a.flatten()
    array([1, 2, 3, 4])
    >>> a.flatten('F')
    array([1, 3, 2, 4])

ndarray.getfield(dtype, offset=0)
    Returns a field of the given array as a certain type.

    A field is a view of the array data with a given data-type. The values in the view are determined by the
given type and the offset into the current array in bytes. The offset needs to be such that the view dtype fits
in the array dtype; for example an array of dtype complex128 has 16-byte elements. If taking a view with
a 32-bit integer (4 bytes), the offset needs to be between 0 and 12 bytes.

    Parameters
    dtype : str or dtype
        The data type of the view. The dtype size of the view can not be larger than that of the
        array itself.
**offset**: int

Number of bytes to skip before beginning the element view.

**Examples**

```python
>>> x = np.diag([1.+1.j]*2)
>>> x[1, 1] = 2 + 4.j
>>> x
array([[ 1.+1.j, 0.+0.j],
       [ 0.+0.j, 2.+4.j]])
>>> x.getfield(np.float64)
array([[ 1., 0.],
       [ 0., 2.]])
```

By choosing an offset of 8 bytes we can select the complex part of the array for our view:

```python
>>> x.getfield(np.float64, offset=8)
array([[ 1., 0.],
       [ 0., 4.]])
```

**ndarray.item(***args**)

Copy an element of an array to a standard Python scalar and return it.

**Parameters**

*args: Arguments (variable number and type)

- none: in this case, the method only works for arrays with one element (`a.size == 1`), which element is copied into a standard Python scalar object and returned.
- int_type: this argument is interpreted as a flat index into the array, specifying which element to copy and return.
- tuple of int_types: functions as does a single int_type argument, except that the argument is interpreted as an nd-index into the array.

**Returns**

z: Standard Python scalar object

A copy of the specified element of the array as a suitable Python scalar

**Notes**

When the data type of `a` is longdouble or clongdouble, item() returns a scalar array object because there is no available Python scalar that would not lose information. Void arrays return a buffer object for item(), unless fields are defined, in which case a tuple is returned.

**item** is very similar to `a[args]`, except, instead of an array scalar, a standard Python scalar is returned. This can be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using Python’s optimized math.

**Examples**

```python
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[3, 1, 7],
       [2, 8, 3],
       [8, 5, 3]])
>>> x.item(3)
2
>>> x.item(7)
5
```
```python
>>> x.item((0, 1))
1
>>> x.item((2, 2))
3

ndarray.itemset(*args)
Insert scalar into an array (scalar is cast to array’s dtype, if possible)
There must be at least 1 argument, and define the last argument as item. Then, a.itemset(*args) is
equivalent to but faster than a[args] = item. The item should be a scalar value and args must select
a single item in the array a.

Parameters
*args : Arguments
    If one argument: a scalar, only used in case a is of size 1. If two arguments: the last
    argument is the value to be set and must be a scalar, the first argument specifies a single
    array element location. It is either an int or a tuple.

Notes
Compared to indexing syntax, itemset provides some speed increase for placing a scalar into a particular
location in an ndarray, if you must do this. However, generally this is discouraged: among other
problems, it complicates the appearance of the code. Also, when using itemset and item inside a
loop, be sure to assign the methods to a local variable to avoid the attribute look-up at each loop iteration.

Examples
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[3, 1, 7],
       [2, 8, 3],
       [8, 5, 3]])
>>> x.itemset(4, 0)
>>> x.itemset((2, 2), 9)
>>> x
array([[3, 1, 7],
       [2, 0, 3],
       [8, 5, 9]])
```

ndarray.max(axis=None, out=None)
Return the maximum along a given axis.
Refer to numpy.amax for full documentation.

See also:

- **numpy.amax**
  equivalent function

ndarray.mean(axis=None, dtype=None, out=None)
Returns the average of the array elements along given axis.
Refer to numpy.mean for full documentation.

See also:

- **numpy.mean**
  equivalent function
ndarray.min(axis=None, out=None)

Return the minimum along a given axis.

Refer to numpy.amin for full documentation.

See also:

numpy.amin
equivalent function

ndarray.newbyteorder(new_order='S')

Return the array with the same data viewed with a different byte order.

Equivalent to:

arr.view(arr.dtype.newbyteorder(new_order))

Changes are also made in all fields and sub-arrays of the array data type.

Parameters

new_order : string, optional

Byte order to force; a value from the byte order specifications above. new_order codes can be any of:

* 'S' - swap dtype from current to opposite endian
* {'<', 'L'} - little endian
* {'>', 'B'} - big endian
* {'=', 'N'} - native order
* {'|', 'I'} - ignore (no change to byte order)

The default value ('S') results in swapping the current byte order. The code does a case-insensitive check on the first letter of new_order for the alternatives above. For example, any of 'B' or 'b' or 'biggish' are valid to specify big-endian.

Returns

new_arr : array

New array object with the dtype reflecting given change to the byte order.

ndarray.nonzero()

Return the indices of the elements that are non-zero.

Refer to numpy.nonzero for full documentation.

See also:

numpy.nonzero
equivalent function

ndarray.partition(kth, axis=-1, kind='introselect', order=None)

Rearranges the elements in the array in such a way that value of the element in kth position is in the position it would be in a sorted array. All elements smaller than the kth element are moved before this element and all equal or greater are moved behind it. The ordering of the elements in the two partitions is undefined.

New in version 1.8.0.

Parameters

kth : int or sequence of ints
Element index to partition by. The kth element value will be in its final sorted position and all smaller elements will be moved before it and all equal or greater elements behind it. The order all elements in the partitions is undefined. If provided with a sequence of kth it will partition all elements indexed by kth of them into their sorted position at once.

**axis** : int, optional
Axis along which to sort. Default is -1, which means sort along the last axis.

**kind** : {'introselect'}, optional
Selection algorithm. Default is 'introselect'.

**order** : list, optional
When a is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

**See also:**

numpy.partition
Return a partitioned copy of an array.

argpartition
Indirect partition.

sort
Full sort.

**Notes**
See np.partition for notes on the different algorithms.

**Examples**

```python
>>> a = np.array([3, 4, 2, 1])
>>> a.partition(a, 3)
>>> a
array([2, 1, 3, 4])

>>> a.partition((1, 3))
array([1, 2, 3, 4])
```

**ndarray.prod** *(axis=None, dtype=None, out=None)*
Return the product of the array elements over the given axis

Refer to numpy.prod for full documentation.

**See also:**

numpy.prod
equivalent function

**ndarray.ptp** *(axis=None, out=None)*
Peak to peak (maximum - minimum) value along a given axis.

Refer to numpy.ptp for full documentation.

**See also:**

numpy.ptp
equivalent function
ndarray.put(indices, values, mode='raise')
Set a.flat[n] = values[n] for all n in indices.
Refer to numpy.put for full documentation.
See also:

numpy.put
equivalent function

ndarray.ravel([order])
Return a flattened array.
Refer to numpy.ravel for full documentation.
See also:

numpy.ravel
equivalent function

ndarray.flat
a flat iterator on the array.

ndarray.repeat(repeats, axis=None)
Repeat elements of an array.
Refer to numpy.repeat for full documentation.
See also:

numpy.repeat
equivalent function

ndarray.reshape(shape, order='C')
Returns an array containing the same data with a new shape.
Refer to numpy.reshape for full documentation.
See also:

numpy.reshape
equivalent function

ndarray.resize(new_shape, refcheck=True)
Change shape and size of array in-place.

Parameters
new_shape : tuple of ints, or n ints
Shape of resized array.
refcheck : bool, optional
If False, reference count will not be checked. Default is True.

Returns
None

Raises
ValueError

1.1. The N-dimensional array (ndarray)
If `a` does not own its own data or references or views to it exist, and the data memory must be changed.

**SystemError**

If the `order` keyword argument is specified. This behaviour is a bug in NumPy.

See also:

`resize`

Return a new array with the specified shape.

Notes

This reallocates space for the data area if necessary.

Only contiguous arrays (data elements consecutive in memory) can be resized.

The purpose of the reference count check is to make sure you do not use this array as a buffer for another Python object and then reallocate the memory. However, reference counts can increase in other ways so if you are sure that you have not shared the memory for this array with another Python object, then you may safely set `refcheck` to False.

Examples

Shrinking an array: array is flattened (in the order that the data are stored in memory), resized, and reshaped:

```python
>>> a = np.array([[0, 1], [2, 3]], order='C')
>>> a.resize((2, 1))
array([[0],
       [1]])
```

```python
>>> a = np.array([[0, 1], [2, 3]], order='F')
>>> a.resize((2, 1))
array([[0],
       [2]])
```

Enlarging an array: as above, but missing entries are filled with zeros:

```python
>>> b = np.array([[0, 1], [2, 3]])
>>> b.resize(2, 3)  # new_shape parameter doesn’t have to be a tuple
array([[0, 1, 2],
       [3, 0, 0]])
```

Referencing an array prevents resizing...

```python
>>> c = a
>>> a.resize((1, 1))
Traceback (most recent call last):
 ... ValueError: cannot resize an array that has been referenced ...
```

Unless `refcheck` is False:
>>> a.resize((1, 1), refcheck=False)
>>> a
array([[0]])

ndarray.round (decimals=0, out=None)
Return a with each element rounded to the given number of decimals.
Refer to numpy.around for full documentation.
See also:

numpy.around
equivalent function

ndarray.searchsorted (v, side='left', sorter=None)
Find indices where elements of v should be inserted in a to maintain order.
For full documentation, see numpy.searchsorted
See also:

numpy.searchsorted
equivalent function

ndarray.setfield (val, dtype, offset=0)
Put a value into a specified place in a field defined by a data-type.
Place val into a’s field defined by dtype and beginning offset bytes into the field.

Parameters
val : object
Value to be placed in field.
dtype : dtype object
Data-type of the field in which to place val.
offset : int, optional
The number of bytes into the field at which to place val.

Returns
None
See also:

getfield

Examples
>>> x = np.eye(3)
>>> x.getfield(np.float64)
array([[ 1., 0., 0.],
[ 0., 1., 0.],
[ 0., 0., 1.]])
>>> x.setfield(3, np.int32)
>>> x.getfield(np.int32)
array([[3, 3, 3],
[3, 3, 3],
[3, 3, 3]],
[3, 3, 3],
[3, 3, 3],
[3, 3, 3]])
```python
>>> x
array([[1.00000000e+000, 1.48219694e-323, 1.48219694e-323],
       [1.48219694e-323, 1.00000000e+000, 1.48219694e-323],
       [1.48219694e-323, 1.48219694e-323, 1.00000000e+000]])
>>> x.setfield(np.eye(3), np.int32)
>>> x
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
```

typically:

```python
ndarray.setflags(write=None, align=None, uic=None)
```

Set array flags WRITEABLE, ALIGNED, and UPDATEIFCOPY, respectively.

These Boolean-valued flags affect how numpy interprets the memory area used by a (see Notes below). The ALIGNED flag can only be set to True if the data is actually aligned according to the type. The UPDATEIFCOPY flag can never be set to True. The flag WRITEABLE can only be set to True if the array owns its own memory, or the ultimate owner of the memory exposes a writeable buffer interface, or is a string. (The exception for string is made so that unpickling can be done without copying memory.)

**Parameters**

- **write**: bool, optional
  Describes whether or not a can be written to.

- **align**: bool, optional
  Describes whether or not a is aligned properly for its type.

- **uic**: bool, optional
  Describes whether or not a is a copy of another “base” array.

**Notes**

Array flags provide information about how the memory area used for the array is to be interpreted. There are 6 Boolean flags in use, only three of which can be changed by the user: UPDATEIFCOPY, WRITEABLE, and ALIGNED.

WRITEABLE (W) the data area can be written to;

ALIGNED (A) the data and strides are aligned appropriately for the hardware (as determined by the compiler);

UPDATEIFCOPY (U) this array is a copy of some other array (referenced by .base). When this array is deallocated, the base array will be updated with the contents of this array.

All flags can be accessed using their first (upper case) letter as well as the full name.

**Examples**

```python
>>> y
array([[3, 1, 7],
       [2, 0, 0],
       [8, 5, 9]])
>>> y.flags
C_CONTIGUOUS : True
F_CONTIGUOUS : False
OWNDATA : True
WRITEABLE : False
ALIGNED : True
UPDATEIFCOPY : False
```
>>> y.setflags(write=0, align=0)

```{
C_CONTIGUOUS : True
F_CONTIGUOUS : False
OWNDATA : True
WRITEABLE : False
ALIGNED : False
UPDATEIFCOPY : False
```  
>>> y.setflags(uic=1)

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: cannot set UPDATEIFCOPY flag to True
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: cannot set UPDATEIFCOPY flag to True
```

ndarray.sort(axis=-1, kind='quicksort', order=None)

Sort an array, in-place.

**Parameters**

- **axis**: int, optional
  - Axis along which to sort. Default is -1, which means sort along the last axis.
- **kind**: {'quicksort', 'mergesort', 'heapsort'}, optional
  - Sorting algorithm. Default is 'quicksort'.
- **order**: list, optional
  - When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

**See also:**

- **numpy.sort**: Return a sorted copy of an array.
- **argsort**: Indirect sort.
- **lexsort**: Indirect stable sort on multiple keys.
- **searchsorted**: Find elements in sorted array.
- **partition**: Partial sort.

**Notes**

See `sort` for notes on the different sorting algorithms.

**Examples**

```{
>>> a = np.array([[1, 4], [3, 1]])
>>> a.sort(axis=1)
>>> a
array([[1, 4],
       [1, 3]])
>>> a.sort(axis=0)
```
Use the `order` keyword to specify a field to use when sorting a structured array:

```python
>>> a = np.array([('a', 2), ('c', 1)], dtype=[('x', 'S1'), ('y', int)])
>>> a.sort(order='y')
>>> a
array([('c', 1), ('a', 2)],
      dtype=[('x', '|S1'), ('y', '<i4')])
```

```python
ndarray.squeeze(axis=None)
```

Remove single-dimensional entries from the shape of `a`.

Refer to `numpy.squeeze` for full documentation.

See also:

- `numpy.squeeze`
equivalent function

```python
ndarray.std(axis=None, dtype=None, out=None, ddof=0)
```

Returns the standard deviation of the array elements along given axis.

Refer to `numpy.std` for full documentation.

See also:

- `numpy.std`
equivalent function

```python
ndarray.sum(axis=None, dtype=None, out=None)
```

Return the sum of the array elements over the given axis.

Refer to `numpy.sum` for full documentation.

See also:

- `numpy.sum`
equivalent function

```python
ndarray.swapaxes(axis1, axis2)
```

Return a view of the array with `axis1` and `axis2` interchanged.

Refer to `numpy.swapaxes` for full documentation.

See also:

- `numpy.swapaxes`
equivalent function

```python
ndarray.take(indices, axis=None, out=None, mode='raise')
```

Return an array formed from the elements of `a` at the given indices.

Refer to `numpy.take` for full documentation.

See also:
**numpy.take**

Equivalent function

**ndarray.tobytes(order='C')**

Construct Python bytes containing the raw data bytes in the array.

Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object can be produced in either ‘C’ or ‘Fortran’, or ‘Any’ order (the default is ‘C’-order). ‘Any’ order means C-order unless the F_CONTIGUOUS flag in the array is set, in which case it means ‘Fortran’ order.

New in version 1.9.0.

**Parameters**

- **order:** {'C', 'F', None}, optional
  
  Order of the data for multidimensional arrays: C, Fortran, or the same as for the original array.

**Returns**

- **s:** bytes
  
  Python bytes exhibiting a copy of a’s raw data.

**Examples**

```python
>>> x = np.array([[0, 1], [2, 3]])
>>> x.tobytes()
b'\x00\x00\x00\x00\x01\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x0
**ndarray.tolist()**

Return the array as a (possibly nested) list.

Return a copy of the array data as a (nested) Python list. Data items are converted to the nearest compatible Python type.

**Parameters**
none

**Returns**

y : list
The possibly nested list of array elements.

**Notes**

The array may be recreated, $a = \text{np.array}(a\text{.tolist}())$.

**Examples**

```python
>>> a = np.array([[1, 2]])
>>> a.tolist()
[[1, 2]]
>>> a = np.array([[1, 2], [3, 4]])
>>> list(a)
[array([1, 2]), array([3, 4])]
>>> a.tolist()
[[1, 2], [3, 4]]
```

**ndarray.tostring(order='C')**

Construct Python bytes containing the raw data bytes in the array.

Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object can be produced in either ‘C’ or ‘Fortran’, or ‘Any’ order (the default is ‘C’-order). ‘Any’ order means C-order unless the F_CONTIGUOUS flag in the array is set, in which case it means ‘Fortran’ order.

This function is a compatibility alias for tobytes. Despite its name it returns bytes not strings.

**Parameters**

order : {'C', 'F', None}, optional
Order of the data for multidimensional arrays: C, Fortran, or the same as for the original array.

**Returns**

s : bytes
Python bytes exhibiting a copy of $a$’s raw data.

**Examples**

```python
>>> x = np.array([[0, 1], [2, 3]])
>>> x.tobytes()  # default is 'C' order.
b'\x00\x00\x00\x00\x00\x01\x00\x00\x02\x00\x03\x00\x00\x00\x00'
>>> x.tobytes('C') == x.tobytes()
True
>>> x.tobytes('F')
b'\x00\x00\x00\x00\x00\x01\x00\x00\x01\x00\x03\x00\x00\x00\x00'
```

**ndarray.trace(offset=0, axis1=0, axis2=1, dtype=None, out=None)**

Return the sum along diagonals of the array.

Refer to numpy.trace for full documentation.
ndarray.transpose(*axes)

Returns a view of the array with axes transposed.

For a 1-D array, this has no effect. (To change between column and row vectors, first cast the 1-D array into a matrix object.) For a 2-D array, this is the usual matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided and a.shape = (i[0], i[1], ... i[n-2], i[n-1]), then a.transpose().shape = (i[n-1], i[n-2], ... i[1], i[0]).

Parameters
axes : None, tuple of ints, or n ints
  • None or no argument: reverses the order of the axes.
  • tuple of ints: i in the j-th place in the tuple means a’s i-th axis becomes a.transpose()’s j-th axis.
  • n ints: same as an n-tuple of the same ints (this form is intended simply as a “convenience” alternative to the tuple form)

Returns
out : ndarray
  View of a, with axes suitably permuted.

See also:
ndarray.T
Array property returning the array transposed.

Examples
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])

ndarray.var (axis=None, dtype=None, out=None, ddof=0)

Returns the variance of the array elements, along given axis.

Refer to numpy.var for full documentation.

See also:
numpy.var
  equivalent function
ndarray.view(dtype=None, type=None)

New view of array with the same data.

**Parameters**

dtype : data-type or ndarray sub-class, optional

Data-type descriptor of the returned view, e.g., float32 or int16. The default, None, results in the view having the same data-type as A. This argument can also be specified as an ndarray sub-class, which then specifies the type of the returned object (this is equivalent to setting the type parameter).

type : Python type, optional

Type of the returned view, e.g., ndarray or matrix. Again, the default None results in type preservation.

**Notes**

a.view() is used two different ways:

a.view(some_dtype) or a.view(dtype=some_dtype) constructs a view of the array’s memory with a different data-type. This can cause a reinterpretation of the bytes of memory.

a.view(ndarray_subclass) or a.view(type=ndarray_subclass) just returns an instance of ndarray_subclass that looks at the same array (same shape, dtype, etc.) This does not cause a reinterpretation of the memory.

For a.view(some_dtype), if some_dtype has a different number of bytes per entry than the previous dtype (for example, converting a regular array to a structured array), then the behavior of the view cannot be predicted just from the superficial appearance of a (shown by print(a)). It also depends on exactly how a is stored in memory. Therefore if a is C-ordered versus fortran-ordered, versus defined as a slice or transpose, etc., the view may give different results.

**Examples**

```python
>>> x = np.array([(1, 2), (3, 4)], dtype=[('a', np.int8), ('b', np.int8)])
```

Viewing array data using a different type and dtype:

```python
>>> y = x.view(dtype=np.int16, type=np.matrix)
```

```python
matrix([[513]], dtype=int16)
```

```python
>>> print type(y)
<class 'numpy.matrixlib.defmatrix.matrix'>
```

Creating a view on a structured array so it can be used in calculations

```python
>>> x = np.array([(1, 2), (3, 4)], dtype=[('a', np.int8), ('b', np.int8)])
```

```python
>>> xv = x.view(dtype=np.int8).reshape(-1,2)
```

```python
array([[1, 2],
       [3, 4]], dtype=int8)
```

```python
>>> xv.mean(0)
array([ 2., 3.])
```

Making changes to the view changes the underlying array

```python
>>> xv[0,1] = 20
>>> print x
[(1, 20) (3, 4)]
```
Using a view to convert an array to a record array:

```python
>>> z = x.view(np.recarray)
>>> z.a
array([1], dtype=int8)
```

Views share data:

```python
>>> x[0] = (9, 10)
>>> z[0]
(9, 10)
```

Views that change the dtype size (bytes per entry) should normally be avoided on arrays defined by slices, transposes, fortran-ordering, etc.:

```python
>>> x = np.array([[1, 2, 3], [4, 5, 6]], dtype=np.int16)
>>> y = x[:, 0:2]
>>> y
array([[1, 2],
       [4, 5]], dtype=int16)
>>> y.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: new type not compatible with array.
>>> z = y.copy()
>>> z.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: new type not compatible with array.
```

1.1.2 Indexing arrays

Arrays can be indexed using an extended Python slicing syntax, `array[selection]`. Similar syntax is also used for accessing fields in a `record array`.

See also: 

Array Indexing.

1.1.3 Internal memory layout of an ndarray

An instance of class `ndarray` consists of a contiguous one-dimensional segment of computer memory (owned by the array, or by some other object), combined with an indexing scheme that maps N integers into the location of an item in the block. The ranges in which the indices can vary is specified by the `shape` of the array. How many bytes each item takes and how the bytes are interpreted is defined by the `data-type object` associated with the array.

A segment of memory is inherently 1-dimensional, and there are many different schemes for arranging the items of an N-dimensional array in a 1-dimensional block. Numpy is flexible, and `ndarray` objects can accommodate any `strided indexing scheme`. In a strided scheme, the N-dimensional index \((n_0, n_1, ..., n_{N-1})\) corresponds to the offset (in bytes):

\[
n_{\text{offset}} = \sum_{k=0}^{N-1} s_k n_k
\]
from the beginning of the memory block associated with the array. Here, $s_k$ are integers which specify the strides of the array. The column-major order (used, for example, in the Fortran language and in Matlab) and row-major order (used in C) schemes are just specific kinds of strided scheme, and correspond to memory that can be addressed by the strides:

$$s_k^{\text{column}} = \prod_{j=0}^{k-1} d_j,$$

$$s_k^{\text{row}} = \prod_{j=k+1}^{N-1} d_j,$$

where $d_j = \text{self.itemsize} \times \text{self.shape}[j]$.

Both the C and Fortran orders are contiguous, i.e., single-segment, memory layouts, in which every part of the memory block can be accessed by some combination of the indices.

While a C-style and Fortran-style contiguous array, which has the corresponding flags set, can be addressed with the above strides, the actual strides may be different. This can happen in two cases:

1. If `self.shape[k] == 1` then for any legal index `index[k] == 0`. This means that in the formula for the offset $n_k = 0$ and thus $s_k n_k = 0$ and the value of $s_k = self.strides[k]$ is arbitrary.

2. If an array has no elements (`self.size == 0`) there is no legal index and the strides are never used. Any array with no elements may be considered C-style and Fortran-style contiguous.

Point 1. means that `self` and `self.squeeze()` always have the same contiguity and aligned flags value. This also means that even a high dimensional array could be C-style and Fortran-style contiguous at the same time.

An array is considered aligned if the memory offsets for all elements and the base offset itself is a multiple of `self.itemsize`.

**Note:** Points (1) and (2) are not yet applied by default. Beginning with Numpy 1.8.0, they are applied consistently only if the environment variable `NPY_RELAXED_STRIDES_CHECKING=1` was defined when NumPy was built. Eventually this will become the default.

You can check whether this option was enabled when your NumPy was built by looking at the value of `np.ones((10,1), order='C').flags.f_contiguous`. If this is `True`, then your NumPy has relaxed strides checking enabled.

**Warning:** It does not generally hold that `self.strides[-1] == self.itemsize` for C-style contiguous arrays or `self.strides[0] == self.itemsize` for Fortran-style contiguous arrays is true.

Data in new ndarrays is in the row-major (C) order, unless otherwise specified, but, for example, basic array slicing often produces views in a different scheme.

**Note:** Several algorithms in NumPy work on arbitrarily strided arrays. However, some algorithms require single-segment arrays. When an irregularly strided array is passed in to such algorithms, a copy is automatically made.

### 1.1.4 Array attributes

Array attributes reflect information that is intrinsic to the array itself. Generally, accessing an array through its attributes allows you to get and sometimes set intrinsic properties of the array without creating a new array. The exposed attributes are the core parts of an array and only some of them can be reset meaningfully without creating a new array. Information on each attribute is given below.

**Memory layout**

The following attributes contain information about the memory layout of the array:
ndarray.flags
Information about the memory layout of the array.

Notes

The flags object can be accessed dictionary-like (as in a.flags[‘WRITEABLE’]), or by using lowercased attribute names (as in a.flags.writeable). Short flag names are only supported in dictionary access.

Only the UPDATEIFCOPY, WRITEABLE, and ALIGNED flags can be changed by the user, via direct assignment to the attribute or dictionary entry, or by calling ndarray.setflags.

The array flags cannot be set arbitrarily:

- UPDATEIFCOPY can only be set False.
- ALIGNED can only be set True if the data is truly aligned.
- WRITEABLE can only be set True if the array owns its own memory or the ultimate owner of the memory exposes a writeable buffer interface or is a string.

Arrays can be both C-style and Fortran-style contiguous simultaneously. This is clear for 1-dimensional arrays, but can also be true for higher dimensional arrays.

Even for contiguous arrays a stride for a given dimension arr.strides[dim] may be arbitrary if arr.shape[dim] == 1 or the array has no elements. It does not generally hold that self.strides[-1] == self.itemsize for C-style contiguous arrays or self.strides[0] == self.itemsize for Fortran-style contiguous arrays is true.
Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_CONTIGUOUS</td>
<td>data is in a single, C-style contiguous segment.</td>
</tr>
<tr>
<td>F_CONTIGUOUS</td>
<td>data is in a single, Fortran-style contiguous segment.</td>
</tr>
<tr>
<td>OWNDATA</td>
<td>The array owns the memory it uses or borrows it from another object.</td>
</tr>
<tr>
<td>WRITEABLE</td>
<td>The data area can be written to. Setting this to False locks the data, making it read-only. A view (slice, etc.) inherits WRITEABLE from its base array at creation time, but a view of a writable array may be subsequently locked while the base array remains writeable. (The opposite is not true, in that a view of a locked array may not be made writeable. However, currently, locking a base object does not lock any views that already reference it, so under that circumstance it is possible to alter the contents of a locked array via a previously created writeable view onto it.) Attempting to change a non-writeable array raises a RuntimeError exception.</td>
</tr>
<tr>
<td>ALIGNED</td>
<td>The data and all elements are aligned appropriately for the hardware.</td>
</tr>
<tr>
<td>UPDATEIFCOPY</td>
<td>This array is a copy of some other array. When this array is deallocated, the base array will be updated with the contents of this array.</td>
</tr>
<tr>
<td>FNC</td>
<td>F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FORC</td>
<td>F_CONTIGUOUS or C_CONTIGUOUS (one-segment test).</td>
</tr>
<tr>
<td>BEHAVED</td>
<td>ALIGNED and WRITEABLE.</td>
</tr>
<tr>
<td>CARRAY</td>
<td>BEHAVED and C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FARRAY</td>
<td>BEHAVED and F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
</tbody>
</table>

`ndarray.shape`

Tuple of array dimensions.

Notes

May be used to “reshape” the array, as long as this would not require a change in the total number of elements.

Examples

```python
>>> x = np.array([1, 2, 3, 4])
>>> x.shape
(4,)
>>> y = np.zeros((2, 3, 4))
>>> y.shape
(2, 3, 4)
>>> y.shape = (3, 8)
```

Traceback (most recent call last):
  File "<stdin>"", line 1, in <module>
ValueError: total size of new array must be unchanged

Traceback (most recent call last):
  File "<stdin>"", line 1, in <module>
ValueError: total size of new array must be unchanged
ndarray.

**ndarray.strides**

Tuple of bytes to step in each dimension when traversing an array.

The byte offset of element \((i[0], i[1], \ldots, i[n])\) in an array \(a\) is:

\[
\text{offset} = \sum (\text{np.array}(i) \times a\text{.strides})
\]

A more detailed explanation of strides can be found in the “ndarray.rst” file in the NumPy reference guide.

**See also:**

numpy.lib.stride_tricks.as_strided

**Notes**

Imagine an array of 32-bit integers (each 4 bytes):

\[
\begin{align*}
x &= \text{np.array}([[0, 1, 2, 3, 4],
                    [5, 6, 7, 8, 9]], \text{dtype=np.int32})
\end{align*}
\]

This array is stored in memory as 40 bytes, one after the other (known as a contiguous block of memory). The strides of an array tell us how many bytes we have to skip in memory to move to the next position along a certain axis. For example, we have to skip 4 bytes (1 value) to move to the next column, but 20 bytes (5 values) to get to the same position in the next row. As such, the strides for the array \(x\) will be \((20, 4)\).

**Examples**

```python
>>> y = np.reshape(np.arange(2*3*4), (2,3,4))
>>> y
array([[[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]],
       [[12, 13, 14, 15],
        [16, 17, 18, 19],
        [20, 21, 22, 23]]])
>>> y.strides
(48, 16, 4)
>>> y[1,1,1]
17
>>> offset = sum(y.strides * np.array((1,1,1)))
>>> offset / y.itemsize
17
```

```python
>>> x = np.reshape(np.arange(5*6*7*8), (5,6,7,8)).transpose(2,3,1,0)
>>> x.strides
(32, 4, 224, 1344)
>>> i = np.array([3,5,2,2])
>>> offset = sum(i * x.strides)
>>> x[3,5,2,2]
813
>>> offset / x.itemsize
813
```

**ndarray.ndim**

Number of array dimensions.

**Examples**

```python
>>> x = np.array([1, 2, 3])
>>> x.ndim
1
```
>>> y = np.zeros((2, 3, 4))
>>> y.ndim
3

`ndarray.data`
Python buffer object pointing to the start of the array’s data.

`ndarray.size`
Number of elements in the array.
Equivalent to `np.prod(a.shape)`, i.e., the product of the array’s dimensions.

**Examples**

```python
>>> x = np.zeros((3, 5, 2), dtype=np.complex128)
>>> x.size
30
>>> np.prod(x.shape)
30
```

`ndarray.itemsize`
Length of one array element in bytes.

**Examples**

```python
>>> x = np.array([1, 2, 3], dtype=np.float64)
>>> x.itemsize
8
>>> x = np.array([1, 2, 3], dtype=np.complex128)
>>> x.itemsize
16
```

`ndarray.nbytes`
Total bytes consumed by the elements of the array.

**Notes**
Does not include memory consumed by non-element attributes of the array object.

**Examples**

```python
>>> x = np.zeros((3, 5, 2), dtype=np.complex128)
>>> x.nbytes
480
>>> np.prod(x.shape) * x.itemsize
480
```

`ndarray.base`
Base object if memory is from some other object.

**Examples**

The base of an array that owns its memory is None:

```python
>>> x = np.array([1, 2, 3, 4])
>>> x.base is None
True
```

Slicing creates a view, whose memory is shared with x:
```python
>>> y = x[2:]
>>> y.base is x
True
```

**Data type**

See also:

*Data type objects*

The data type object associated with the array can be found in the `dtype` attribute:

```python
ndarray.dtype
```

Data-type of the array’s elements.

**Parameters**

None

**Returns**

- `d` : numpy dtype object

See also:

numpy.dtype

**Examples**

```python
>>> x
array([[0, 1],
       [2, 3]])
>>> x.dtype
dtype('int32')
>>> type(x.dtype)
<type 'numpy.dtype'>
```

**Other attributes**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>ndarray.T</code></td>
<td>Same as self.transpose(), except that self is returned if self.ndim &lt; 2.</td>
</tr>
<tr>
<td><code>ndarray.real</code></td>
<td>The real part of the array.</td>
</tr>
<tr>
<td><code>ndarray.imag</code></td>
<td>The imaginary part of the array.</td>
</tr>
<tr>
<td><code>ndarray.flat</code></td>
<td>A 1-D iterator over the array.</td>
</tr>
<tr>
<td><code>ndarray.ctypes</code></td>
<td>An object to simplify the interaction of the array with the ctypes module.</td>
</tr>
<tr>
<td><code>__array_priority__</code></td>
<td></td>
</tr>
</tbody>
</table>

```python
ndarray.T
```

Same as self.transpose(), except that self is returned if self.ndim < 2.

**Examples**

```python
>>> x = np.array([[1., 2.], [3., 4.]])
>>> x
array([[ 1.,  2.],
       [ 3.,  4.]])
```

1.1. The N-dimensional array (`ndarray`)
```python
>>> x.T
array([[ 1.,  3.],
       [ 2.,  4.]])
>>> x = np.array([1., 2., 3., 4.])
>>> x
array([ 1.,  2.,  3.,  4.])
>>> x.T
array([ 1.,  2.,  3.,  4.])
```

`ndarray.real`

The real part of the array.

See also:

- `numpy.real`
  equivalent function

**Examples**

```python
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.real
array([ 1. ,  0.70710678])
>>> x.real.dtype
dtype('float64')
```

`ndarray.imag`

The imaginary part of the array.

**Examples**

```python
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.imag
array([ 0. ,  0.70710678])
>>> x.imag.dtype
dtype('float64')
```

`ndarray.flat`

A 1-D iterator over the array.

This is a `numpy.flatiter` instance, which acts similarly to, but is not a subclass of, Python’s built-in iterator object.

See also:

- `flatten`
  Return a copy of the array collapsed into one dimension.

**Examples**

```python
>>> x = np.arange(1, 7).reshape(2, 3)
>>> x
array([[1, 2, 3],
       [4, 5, 6]])
>>> x.flat[3]
4
>>> x.T
array([[1, 4],
       [2, 5],
       [3, 6]])
```
An assignment example:

```python
>>> x.flat = 3; x
array([[3, 3, 3],
       [3, 3, 3]])
```

Note: The `x.flat[1,4] = 1; x` line is commented out in the book, but it should be included.

**ndarray.ctypes**

An object to simplify the interaction of the array with the ctypes module.

This attribute creates an object that makes it easier to use arrays when calling shared libraries with the ctypes module. The returned object has, among others, data, shape, and strides attributes (see Notes below) which themselves return ctypes objects that can be used as arguments to a shared library.

**Parameters**

None

**Returns**

- `c`: Python object

  Possessing attributes data, shape, strides, etc.

**See also**

- `numpy.ctypeslib`

**Notes**

Below are the public attributes of this object which were documented in “Guide to NumPy” (we have omitted undocumented public attributes, as well as documented private attributes):

- **data**: A pointer to the memory area of the array as a Python integer. This memory area may contain data that is not aligned, or not in correct byte-order. The memory area may not even be writeable. The array flags and data-type of this array should be respected when passing this attribute to arbitrary C-code to avoid trouble that can include Python crashing. User Beware! The value of this attribute is exactly the same as `self._array_interface_['data'][0]`.

- **shape** (`c_intp*`self.ndim): A ctypes array of length self.ndim where the basetype is the C-integer corresponding to dtype('p') on this platform. This base-type could be c_int, c_long, or c_longlong depending on the platform. The c_intp type is defined accordingly in numpy.ctypeslib. The ctypes array contains the shape of the underlying array.

- **strides** (`c_intp*`self.ndim): A ctypes array of length self.ndim where the basetype is the same as for the shape attribute. This ctypes array contains the strides information from the underlying array. This strides information is important for showing how many bytes must be jumped to get to the next element in the array.

- **data_as(obj)**: Return the data pointer cast to a particular c-types object. For example, calling `self._as_parameter_` is equivalent to `self.data_as(ctypes.c_void_p)`. Perhaps you want to use the data as a pointer to a ctypes array of floating-point data: `self.data_as(ctypes.POINTER(ctypes.c_double))`. 

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- **shape_as(obj)**: Return the shape tuple as an array of some other c-types type. For example:
  ```python
  self.shape_as(ctypes.c_short).
  ```

- **strides_as(obj)**: Return the strides tuple as an array of some other c-types type. For example:
  ```python
  self.strides_as(ctypes.c_longlong).
  ```

Be careful using the ctypes attribute - especially on temporary arrays or arrays constructed on the fly. For example, calling `(a+b).ctypes.data_as(ctypes.c_void_p)` returns a pointer to memory that is invalid because the array created as `(a+b)` is deallocated before the next Python statement. You can avoid this problem using either `c=a+b` or `ct=(a+b).ctypes`. In the latter case, `ct` will hold a reference to the array until `ct` is deleted or re-assigned.

If the ctypes module is not available, then the ctypes attribute of array objects still returns something useful, but ctypes objects are not returned and errors may be raised instead. In particular, the object will still have the `as` parameter attribute which will return an integer equal to the data attribute.

### Examples

```python
>>> import ctypes
>>> x
array([[0, 1],
       [2, 3]])
>>> x.ctypes.data
30439712
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_long))
<ctypes.LP_c_long object at 0x01F01300>
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_long)).contents
c_long(0)
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_longlong)).contents
c_longlong(4294967296L)
>>> x.ctypes.shape
<numpy.core._internal.c_long_Array_2 object at 0x01FFD580>
>>> x.ctypes.shape_as(ctypes.c_long)
<numpy.core._internal.c_long_Array_2 object at 0x01FCE620>
>>> x.ctypes.strides
<numpy.core._internal.c_long_Array_2 object at 0x01FCE620>
>>> x.ctypes.strides_as(ctypes.c_longlong)
<numpy.core._internal.c_longlong_Array_2 object at 0x01F01300>
```

### Array interface

See also:

*The Array Interface.*

<table>
<thead>
<tr>
<th><strong>array_interface</strong></th>
<th>Python-side of the array interface</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>array_struct</strong></td>
<td>C-side of the array interface</td>
</tr>
</tbody>
</table>

#### ctypes foreign function interface

- **ndarray.ctypes**
  An object to simplify the interaction of the array with the ctypes module.

- **ndarray.ctypes**
  An object to simplify the interaction of the array with the ctypes module.

This attribute creates an object that makes it easier to use arrays when calling shared libraries with the ctypes
module. The returned object has, among others, data, shape, and strides attributes (see Notes below) which themselves return ctypes objects that can be used as arguments to a shared library.

Parameters
None

Returns
c : Python object

Possessing attributes data, shape, strides, etc.

See also:
numpy.ctypeslib

Notes
Below are the public attributes of this object which were documented in “Guide to NumPy” (we have omitted undocumented public attributes, as well as documented private attributes):

•data: A pointer to the memory area of the array as a Python integer. This memory area may contain data that is not aligned, or not in correct byte-order. The memory area may not even be writeable. The array flags and data-type of this array should be respected when passing this attribute to arbitrary C-code to avoid trouble that can include Python crashing. User Beware! The value of this attribute is exactly the same as self._array_interface_['data'][0].

•shape (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the C-integer corresponding to dtype(‘p’) on this platform. This base-type could be c_int, c_long, or c_longlong depending on the platform. The c_intp type is defined accordingly in numpy.ctypeslib. The ctypes array contains the shape of the underlying array.

•strides (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the same as for the shape attribute. This ctypes array contains the strides information from the underlying array. This strides information is important for showing how many bytes must be jumped to get to the next element in the array.

•data_as(obj): Return the data pointer cast to a particular c-types object. For example, calling self._as_parameter_ is equivalent to self.data_as(ctypes.c_void_p). Perhaps you want to use the data as a pointer to a ctypes array of floating-point data: self.data_as(ctypes.POINTER(ctypes.c_double)).

•shape_as(obj): Return the shape tuple as an array of some other c-types type. For example: self.shape_as(ctypes.c_short).

•strides_as(obj): Return the strides tuple as an array of some other c-types type. For example: self.strides_as(ctypes.c_longlong).

Be careful using the ctypes attribute - especially on temporary arrays or arrays constructed on the fly. For example, calling (a+b).ctypes.data_as(ctypes.c_void_p) returns a pointer to memory that is invalid because the array created as (a+b) is deallocated before the next Python statement. You can avoid this problem using either c=a+b or ct=(a+b).ctypes. In the latter case, ct will hold a reference to the array until ct is deleted or re-assigned.

If the ctypes module is not available, then the ctypes attribute of array objects still returns something useful, but ctypes objects are not returned and errors may be raised instead. In particular, the object will still have the as parameter attribute which will return an integer equal to the data attribute.

Examples

>>> import ctypes
>>> x
array([[0, 1],
       [2, 3]])
Array methods

An `ndarray` object has many methods which operate on or with the array in some fashion, typically returning an array result. These methods are briefly explained below. (Each method’s docstring has a more complete description.)

For the following methods there are also corresponding functions in `numpy`: `all`, `any`, `argmax`, `argmin`, `argpartition`, `argsort`, `choose`, `clip`, `compress`, `copy`, `cumprod`, `cumsum`, `diagonal`, `imag`, `max`, `mean`, `min`, `nonzero`, `partition`, `prod`, `ptp`, `put`, `ravel`, `real`, `repeat`, `reshape`, `round`, `searchsorted`, `sort`, `squeeze`, `std`, `sum`, `swapaxes`, `take`, `trace`, `transpose`, `var`.

Array conversion

### ndarray.item(*args)
Copy an element of an array to a standard Python scalar and return it.

**Parameters**

*args : Arguments (variable number and type)

* none: in this case, the method only works for arrays with one element (`a.size == 1`), which
element is copied into a standard Python scalar object and returned.

- int_type: this argument is interpreted as a flat index into the array, specifying which element
to copy and return.
- tuple of int_types: functions as does a single int_type argument, except that the argument is
interpreted as an nd-index into the array.

Returns

z : Standard Python scalar object

A copy of the specified element of the array as a suitable Python scalar

Notes

When the data type of a is longdouble or clongdouble, item() returns a scalar array object because there is no
available Python scalar that would not lose information. Void arrays return a buffer object for item(), unless
fields are defined, in which case a tuple is returned.

item is very similar to a[args], except, instead of an array scalar, a standard Python scalar is returned. This can
be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using
Python's optimized math.

Examples

```python
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[3, 1, 7],
       [2, 8, 3],
       [8, 5, 3]])
>>> x.item(3)
2
>>> x.item(7)
5
>>> x.item((0, 1))
1
>>> x.item((2, 2))
3
```

ndarray.tolist()

Return the array as a (possibly nested) list.

Return a copy of the array data as a (nested) Python list. Data items are converted to the nearest compatible
Python type.

Parameters

none

Returns

y : list

The possibly nested list of array elements.

Notes

The array may be recreated, a = np.array(a.tolist()).

Examples

```python
>>> a = np.array([1, 2])
>>> a.tolist()
[1, 2]
```
```python
>>> a = np.array([[1, 2], [3, 4]])
>>> list(a)
[array([1, 2]), array([3, 4])]
>>> a.tolist()
[[1, 2], [3, 4]]
```

**ndarray.itemset(*args)**

Insert scalar into an array (scalar is cast to array's dtype, if possible)

There must be at least 1 argument, and define the last argument as `item`. Then, `a.itemset(*args)` is equivalent to but faster than `a[args] = item`. The item should be a scalar value and `args` must select a single item in the array `a`.

**Parameters**

* `*args`: Arguments

  If one argument: a scalar, only used in case `a` is of size 1. If two arguments: the last argument is the value to be set and must be a scalar, the first argument specifies a single array element location. It is either an int or a tuple.

**Notes**

Compared to indexing syntax, `itemset` provides some speed increase for placing a scalar into a particular location in an `ndarray`, if you must do this. However, generally this is discouraged: among other problems, it complicates the appearance of the code. Also, when using `itemset` (and `item`) inside a loop, be sure to assign the methods to a local variable to avoid the attribute look-up at each loop iteration.

**Examples**

```python
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[3, 1, 7],
       [2, 8, 3],
       [8, 5, 3]])
>>> x.itemset(4, 0)
>>> x.itemset((2, 2), 9)
>>> x
array([[3, 1, 7],
       [2, 0, 3],
       [8, 5, 9]])
```

**ndarray.tostring(order='C')**

Construct Python bytes containing the raw data bytes in the array.

Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object can be produced in either ‘C’ or ‘Fortran’, or ‘Any’ order (the default is ‘C’-order). ‘Any’ order means C-order unless the F_CONTIGUOUS flag in the array is set, in which case it means ‘Fortran’ order.

This function is a compatibility alias for tobytes. Despite its name it returns bytes not strings.

**Parameters**

* `order`: {'C', 'F', None}, optional

  Order of the data for multidimensional arrays: C, Fortran, or the same as for the original array.

**Returns**

* `s`: bytes

  Python bytes exhibiting a copy of `a`'s raw data.
NumPy Reference, Release 1.9.2

Examples
>>> x = np.array([[0, 1], [2, 3]])
>>> x.tobytes()
b’\x00\x00\x00\x00\x01\x00\x00\x00\x02\x00\x00\x00\x03\x00\x00\x00’
>>> x.tobytes(’C’) == x.tobytes()
True
>>> x.tobytes(’F’)
b’\x00\x00\x00\x00\x02\x00\x00\x00\x01\x00\x00\x00\x03\x00\x00\x00’

ndarray.tobytes(order=’C’)
Construct Python bytes containing the raw data bytes in the array.
Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object can be produced
in either ‘C’ or ‘Fortran’, or ‘Any’ order (the default is ‘C’-order). ‘Any’ order means C-order unless the
F_CONTIGUOUS flag in the array is set, in which case it means ‘Fortran’ order.
New in version 1.9.0.
Parameters
order : {‘C’, ‘F’, None}, optional
Order of the data for multidimensional arrays: C, Fortran, or the same as for the original
array.
Returns
s : bytes
Python bytes exhibiting a copy of a‘s raw data.
Examples
>>> x = np.array([[0, 1], [2, 3]])
>>> x.tobytes()
b’\x00\x00\x00\x00\x01\x00\x00\x00\x02\x00\x00\x00\x03\x00\x00\x00’
>>> x.tobytes(’C’) == x.tobytes()
True
>>> x.tobytes(’F’)
b’\x00\x00\x00\x00\x02\x00\x00\x00\x01\x00\x00\x00\x03\x00\x00\x00’

ndarray.tofile(fid, sep=”“, format=”%s”)
Write array to a file as text or binary (default).
Data is always written in ‘C’ order, independent of the order of a. The data produced by this method can be
recovered using the function fromfile().
Parameters
fid : file or str
An open file object, or a string containing a filename.
sep : str
Separator between array items for text output. If “” (empty), a binary file is written,
equivalent to file.write(a.tobytes()).
format : str
Format string for text file output. Each entry in the array is formatted to text by first
converting it to the closest Python type, and then using “format” % item.

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Notes

This is a convenience function for quick storage of array data. Information on endianness and precision is lost, so this method is not a good choice for files intended to archive data or transport data between machines with different endianness. Some of these problems can be overcome by outputting the data as text files, at the expense of speed and file size.

```
ndarray.dump(file)
```

Dumps a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

**Parameters**

- `file`: str
  - A string naming the dump file.

```
ndarray.dumps()
```

Returns the pickle of the array as a string. pickle.loads or numpy.loads will convert the string back to an array.

**Parameters**

- None

```
ndarray.astype(dtype, order='K', casting='unsafe', subok=True, copy=True)
```

Copy of the array, cast to a specified type.

**Parameters**

- `dtype`: str or dtype
  - Typecode or data-type to which the array is cast.

- `order`: {'C', 'F', 'A', 'K'}, optional
  - Controls the memory layout order of the result. ‘C’ means C order, ‘F’ means Fortran order, ‘A’ means ‘F’ order if all the arrays are Fortran contiguous, ‘C’ order otherwise, and ‘K’ means as close to the order the array elements appear in memory as possible. Default is ‘K’.

- `casting`: {'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional
  - Controls what kind of data casting may occur. Defaults to ‘unsafe’ for backwards compatibility.
  
  - ‘no’ means the data types should not be cast at all.
  
  - ‘equiv’ means only byte-order changes are allowed.
  
  - ‘safe’ means only casts which can preserve values are allowed.
  
  - ‘same_kind’ means only safe casts or casts within a kind, like float64 to float32, are allowed.
  
  - ‘unsafe’ means any data conversions may be done.

- `subok`: bool, optional
  - If True, then sub-classes will be passed-through (default), otherwise the returned array will be forced to be a base-class array.

- `copy`: bool, optional
  - By default, astype always returns a newly allocated array. If this is set to false, and the `dtype`, `order`, and `subok` requirements are satisfied, the input array is returned instead of a copy.

**Returns**

- `arr_t`: ndarray
Unless `copy` is False and the other conditions for returning the input array are satisfied (see description for `copy` input parameter), `arr_t` is a new array of the same shape as the input array, with dtype, order given by `dtype, order`.

**Raises**

*ComplexWarning*

When casting from complex to float or int. To avoid this, one should use `a.real.astype(t)`.

**Notes**

Starting in NumPy 1.9, astype method now returns an error if the string dtype to cast to is not long enough in 'safe' casting mode to hold the max value of integer/float array that is being casted. Previously the casting was allowed even if the result was truncated.

**Examples**

```python
>>> x = np.array([1, 2, 2.5])
>>> x
array([ 1. , 2. , 2.5])
>>> x.astype(int)
array([1, 2, 2])
```

### ndarray.byteswap(inplace)

Swap the bytes of the array elements

**Parameters**

- `inplace` : bool, optional
  
  If `True`, swap bytes in-place, default is `False`.

**Returns**

- `out` : ndarray

  The byteswapped array. If `inplace` is `True`, this is a view to self.

**Examples**

```python
>>> A = np.array([1, 256, 8755], dtype=np.int16)
>>> map(hex, A)
['0x1', '0x100', '0x2233']
>>> A.byteswap(True)
array([ 256, 1, 13090], dtype=int16)
>>> map(hex, A)
['0x100', '0x1', '0x3322']
```

Arrays of strings are not swapped

```python
>>> A = np.array(['ceg', 'fac'])
>>> A.byteswap()
array(['ceg', 'fac'],
      dtype='|S3')
```

**ndarray.copy(order='C')**

Return a copy of the array.
**Parameters**

- **order**: {'C', 'F', 'A', 'K'}, optional
  
  Controls the memory layout of the copy. ‘C’ means C-order, ‘F’ means F-order, ‘A’ means ‘F’ if a is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of a as closely as possible. (Note that this function and :func:`numpy.copy` are very similar, but have different default values for their order= arguments.)

**See also:**

- `numpy.copy`, `numpy.copyto`

**Examples**

```python
>>> x = np.array([[1, 2, 3], [4, 5, 6]], order='F')
>>> y = x.copy()
>>> x.fill(0)

>>> x
array([[0, 0, 0],
       [0, 0, 0]])

>>> y
array([[1, 2, 3],
       [4, 5, 6]])

>>> y.flags['C_CONTIGUOUS']
True
```

`ndarray.view(dtype=None, type=None)`

New view of array with the same data.

**Parameters**

- **dtype**: data-type or ndarray sub-class, optional
  
  Data-type descriptor of the returned view, e.g., float32 or int16. The default, None, results in the view having the same data-type as a. This argument can also be specified as an ndarray sub-class, which then specifies the type of the returned object (this is equivalent to setting the type parameter).

- **type**: Python type, optional
  
  Type of the returned view, e.g., ndarray or matrix. Again, the default None results in type preservation.

**Notes**

`a.view()` is used two different ways:

- `a.view(some_dtype)` or `a.view(dtype=some_dtype)` constructs a view of the array’s memory with a different data-type. This can cause a reinterpretation of the bytes of memory.

- `a.view(ndarray_subclass)` or `a.view(type=ndarray_subclass)` just returns an instance of `ndarray_subclass` that looks at the same array (same shape, dtype, etc.) This does not cause a reinterpretation of the memory.

For `a.view(some_dtype)`, if `some_dtype` has a different number of bytes per entry than the previous dtype (for example, converting a regular array to a structured array), then the behavior of the view cannot be predicted just from the superficial appearance of a (shown by `print(a)`). It also depends on exactly how a
is stored in memory. Therefore if a is C-ordered versus fortran-ordered, versus defined as a slice or transpose, etc., the view may give different results.

**Examples**

```python
>>> x = np.array([[1, 2]], dtype=[('a', np.int8), ('b', np.int8)])
Viewing array data using a different type and dtype:
```n
```python
>>> y = x.view(dtype=np.int16, type=np.matrix)
```n
```python
>>> print type(y)
<class 'numpy.matrixlib.defmatrix.matrix'>

Creating a view on a structured array so it can be used in calculations
```n
```python
>>> x = np.array([[1, 2],[3,4]], dtype=[('a', np.int8), ('b', np.int8)])
```n
```python
>>> xv = x.view(dtype=np.int8).reshape(-1,2)
```n
```python
>>> xv
array([[1, 2],
       [3, 4]], dtype=int8)
>>> xv.mean(0)
array([ 2., 3.])

Making changes to the view changes the underlying array
```n
```python
>>> xv[0,1] = 20
```n
```python
>>> print x
[(1, 20) (3, 4)]

Using a view to convert an array to a record array:
```n
```python
>>> z = x.view(np.recarray)
```n
```python
>>> z.a
array([1], dtype=int8)

Views share data:
```n
```python
>>> x[0] = (9, 10)
```n
```python
>>> z[0]
(9, 10)

Views that change the dtype size (bytes per entry) should normally be avoided on arrays defined by slices, transposes, fortran-ordering, etc.:
```n
```python
>>> x = np.array([[1,2,3],[4,5,6]], dtype=np.int16)
>>> y = x[:, 0:2]
>>> y
array([[1, 2],
       [4, 5]], dtype=int16)
>>> y.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
 File "<stdin>", line 1, in <module>
ValueError: new type not compatible with array.
>>> z = y.copy()
>>> z.view(dtype=[('width', np.int16), ('length', np.int16)])
array([[1, 2],
       [4, 5]], dtype=[('width', '<i2'), ('length', '<i2')])
Traceback (most recent call last):
```
File "<stdin>", line 1, in <module>
ValueError: new type not compatible with array.

ndarray.getfield(dtype, offset=0)

Returns a field of the given array as a certain type.

A field is a view of the array data with a given data-type. The values in the view are determined by the given
type and the offset into the current array in bytes. The offset needs to be such that the view dtype fits in the array
dtype; for example an array of dtype complex128 has 16-byte elements. If taking a view with a 32-bit integer (4
bytes), the offset needs to be between 0 and 12 bytes.

Parameters

dtype : str or dtype

  The data type of the view. The dtype size of the view can not be larger than that of the
array itself.

offset : int

  Number of bytes to skip before beginning the element view.

Examples

>>> x = np.diag([1.+1.j]*2)
>>> x[1, 1] = 2 + 4.j
>>> x
array([[ 1.+1.j, 0.+0.j],
       [ 0.+0.j, 2.+4.j]])
>>> x.getfield(np.float64)
array([[ 1., 0.],
       [ 0., 2.]])

By choosing an offset of 8 bytes we can select the complex part of the array for our view:

>>> x.getfield(np.float64, offset=8)
array([[ 1., 0.],
       [ 0., 4.]])

ndarray.setflags(write=None, align=None, uic=None)

Set array flags WRITEABLE, ALIGNED, and UPDATEIFCOPY, respectively.

These Boolean-valued flags affect how numpy interprets the memory area used by a (see Notes below). The
ALIGNED flag can only be set to True if the data is actually aligned according to the type. The UPDATEIFCOPY
flag can never be set to True. The flag WRITEABLE can only be set to True if the array owns its own
memory, or the ultimate owner of the memory exposes a writeable buffer interface, or is a string. (The exception
for string is made so that unpickling can be done without copying memory.)

Parameters

write : bool, optional

  Describes whether or not a can be written to.

align : bool, optional

  Describes whether or not a is aligned properly for its type.

uic : bool, optional

  Describes whether or not a is a copy of another “base” array.
Notes

Array flags provide information about how the memory area used for the array is to be interpreted. There are 6 Boolean flags in use, only three of which can be changed by the user: UPDATEIFCOPY, WRITEABLE, and ALIGNED.

WRITEABLE (W) the data area can be written to;

ALIGNED (A) the data and strides are aligned appropriately for the hardware (as determined by the compiler);

UPDATEIFCOPY (U) this array is a copy of some other array (referenced by .base). When this array is deallocated, the base array will be updated with the contents of this array.

All flags can be accessed using their first (upper case) letter as well as the full name.

Examples

```python
>>> y
array([[3, 1, 7],
       [2, 0, 0],
       [8, 5, 9]])
>>> y.flags
C_CONTIGUOUS : True
F_CONTIGUOUS : False
OWNDATA : True
WRITEABLE : True
ALIGNED : True
UPDATEIFCOPY : False
>>> y.setflags(write=0, align=0)
>>> y.flags
C_CONTIGUOUS : True
F_CONTIGUOUS : False
OWNDATA : True
WRITEABLE : False
ALIGNED : False
UPDATEIFCOPY : False
>>> y.setflags(uic=1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: cannot set UPDATEIFCOPY flag to True
```

ndarray.fill(value)

Fill the array with a scalar value.

Parameters

value : scalar

All elements of a will be assigned this value.

Examples

```python
>>> a = np.array([1, 2])
>>> a.fill(0)
>>> a
array([0, 0])
>>> a = np.empty(2)
>>> a.fill(1)
```
```python
>>> a
array([ 1., 1.])
```

### Shape manipulation

For reshape, resize, and transpose, the single tuple argument may be replaced with \( n \) integers which will be interpreted as an \( n \)-tuple.

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</tr>
<tr>
<td><code>ndarray.resize(new_shape[, refcheck])</code></td>
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<td><code>ndarray.transpose(*axes)</code></td>
<td>Returns a view of the array with axes transposed.</td>
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<td>Return a view of the array with ( axis1 ) and ( axis2 ) interchanged.</td>
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<td><code>ndarray.flatten([order])</code></td>
<td>Return a copy of the array collapsed into one dimension.</td>
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<td><code>ndarray.ravel([order])</code></td>
<td>Return a flattened array.</td>
</tr>
<tr>
<td><code>ndarray.squeeze([axis])</code></td>
<td>Remove single-dimensional entries from the shape of ( a ).</td>
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</table>

**ndarray.reshape (shape, order='C')**

Returns an array containing the same data with a new shape.

Refer to `numpy.reshape` for full documentation.

**See also:**

`numpy.reshape`

equivalent function

**ndarray.resize (new_shape, refcheck=True)**

Change shape and size of array in-place.

**Parameters**

- **new_shape**: tuple of ints, or \( n \) ints
  Shape of resized array.

- **refcheck**: bool, optional
  If False, reference count will not be checked. Default is True.

**Returns**

None

**Raises**

- **ValueError**
  If \( a \) does not own its own data or references or views to it exist, and the data memory must be changed.

- **SystemError**
  If the \( order \) keyword argument is specified. This behaviour is a bug in NumPy.

**See also:**

`resize`

Return a new array with the specified shape.
Notes

This reallocates space for the data area if necessary.

Only contiguous arrays (data elements consecutive in memory) can be resized.

The purpose of the reference count check is to make sure you do not use this array as a buffer for another Python object and then reallocate the memory. However, reference counts can increase in other ways so if you are sure that you have not shared the memory for this array with another Python object, then you may safely set refcheck to False.

Examples

Shrinking an array: array is flattened (in the order that the data are stored in memory), resized, and reshaped:

```python
>>> a = np.array([[0, 1], [2, 3]], order='C')
>>> a.resize((2, 1))
array([[0],
       [1]])

>>> a = np.array([[0, 1], [2, 3]], order='F')
>>> a.resize((2, 1))
array([[0],
       [2]])
```

Enlarging an array: as above, but missing entries are filled with zeros:

```python
>>> b = np.array([[0, 1], [2, 3]])
>>> b.resize(2, 3) # new_shape parameter doesn't have to be a tuple
>>> b
array([[0, 1, 2],
       [3, 0, 0]])
```

Referencing an array prevents resizing...

```python
>>> c = a
>>> a.resize((1, 1))
Traceback (most recent call last):
  ... ValueError: cannot resize an array that has been referenced ...
Traceback (most recent call last):
  ... ValueError: cannot resize an array that has been referenced ...
```

Unless refcheck is False:

```python
>>> a.resize((1, 1), refcheck=False)
>>> a
array([[0]])
>>> c
array([[0]])
```

`ndarray.transpose(*axes)`

Returns a view of the array with axes transposed.

For a 1-D array, this has no effect. (To change between column and row vectors, first cast the 1-D array into a matrix object.) For a 2-D array, this is the usual matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided and `a.shape = (i[0], i[1],`
... \( i[n-2], i[n-1] \), then \( \text{a.transpose().shape = (i[n-1], i[n-2], \ldots, i[1], i[0])} \).

**Parameters**

- **axes**: None, tuple of ints, or \( n \) ints
  - None or no argument: reverses the order of the axes.
  - tuple of ints: \( i \) in the \( j \)-th place in the tuple means \( a \)'s \( i \)-th axis becomes \( \text{a.transpose()} \)'s \( j \)-th axis.
  - \( n \) ints: same as an \( n \)-tuple of the same ints (this form is intended simply as a “convenience” alternative to the tuple form)

**Returns**

- **out**: ndarray
  View of \( a \), with axes suitably permuted.

See also:

- **\texttt{ndarray.T}**
  Array property returning the array transposed.

**Examples**

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])
```

**ndarray.swapaxes\( (axis1, axis2)\)**

Return a view of the array with \( axis1 \) and \( axis2 \) interchanged.

Refer to **\texttt{numpy.swapaxes}** for full documentation.

See also:

- **\texttt{numpy.swapaxes}**
  equivalent function

**ndarray.flatten\( (order='C')\)**

Return a copy of the array collapsed into one dimension.

**Parameters**

- **order**: \{'C', 'F', 'A'\}, optional
  Whether to flatten in C (row-major), Fortran (column-major) order, or preserve the C/Fortran ordering from \( a \). The default is ‘C’.

**Returns**

- **y**: ndarray
A copy of the input array, flattened to one dimension.

See also:

**ravel**
Return a flattened array.

**flat**
A 1-D flat iterator over the array.

**Examples**

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])
```

```python
ndarray.ravel([order])
```
Return a flattened array.

Refer to `numpy.ravel` for full documentation.

See also:

**numpy.ravel**
equivalent function

```python
ndarray.flat
```
a flat iterator on the array.

```python
ndarray.squeeze(axis=None)
```
Remove single-dimensional entries from the shape of `a`.

Refer to `numpy.squeeze` for full documentation.

See also:

**numpy.squeeze**
equivalent function

**Item selection and manipulation**

For array methods that take an `axis` keyword, it defaults to `None`. If `axis` is `None`, then the array is treated as a 1-D array. Any other value for `axis` represents the dimension along which the operation should proceed.

```python
ndarray.take(indices[, axis, out, mode])
Return an array formed from the elements of `a` at the given indices.
```

```python
ndarray.put(indices, values[, mode])
Set `a.flat[n] = values[n]` for all `n` in indices.
```

```python
ndarray.repeat(repeats[, axis])
Repeat elements of an array.
```

```python
ndarray.choose(choices[, out, mode])
Use an index array to construct a new array from a set of choices.
```

```python
ndarray.sort([axis, kind, order])
Sort an array, in-place.
```

```python
ndarray.argsort([axis, kind, order])
Returns the indices that would sort this array.
```

```python
ndarray.partition(kth[, axis, kind, order])
Rearranges the elements in the array in such a way that value of the element in kth position is in the position it would be in a sorted array.
```

```python
ndarray.argpartition(kth[, axis, kind, order])
Returns the indices that would partition this array.
```

```python
ndarray.searchsorted(v[, side, sorter])
Find indices where elements of `v` should be inserted in `a` to maintain order.
```

```python
ndarray.nonzero()
Return the indices of the elements that are non-zero.
```

```python
ndarray.compress(condition[, axis, out])
Return selected slices of this array along given axis.
```
ndarray.take(indices, axis=None, out=None, mode='raise')

Return an array formed from the elements of a at the given indices.

Refer to numpy.take for full documentation.

See also:

numpy.take
  equivalent function

ndarray.put(indices, values, mode='raise')

Set a.flat[n] = values[n] for all n in indices.

Refer to numpy.put for full documentation.

See also:

numpy.put
  equivalent function

ndarray.repeat(repeats, axis=None)

Repeat elements of an array.

Refer to numpy.repeat for full documentation.

See also:

numpy.repeat
  equivalent function

ndarray.choose(choices, out=None, mode='raise')

Use an index array to construct a new array from a set of choices.

Refer to numpy.choose for full documentation.

See also:

numpy.choose
  equivalent function

ndarray.sort(axis=-1, kind='quicksort', order=None)

Sort an array, in-place.

Parameters

  axis : int, optional

  Axis along which to sort. Default is -1, which means sort along the last axis.

  kind : {'quicksort', 'mergesort', 'heapsort'}, optional

  Sorting algorithm. Default is 'quicksort'.

  order : list, optional

  When a is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

See also:
**numpy.sort**  
Return a sorted copy of an array.

**argsort**  
Indirect sort.

**lexsort**  
Indirect stable sort on multiple keys.

**searchsorted**  
Find elements in sorted array.

**partition**  
Partial sort.

**Notes**

See sort for notes on the different sorting algorithms.

**Examples**

```python
e = np.array([1, 4], [3, 1])
e.sort(axis=1)
e
array([[1, 4],  
        [1, 3]])
e.sort(axis=0)
e
array([[1, 3],  
        [1, 4]])
```

Use the `order` keyword to specify a field to use when sorting a structured array:

```python
e = np.array([('a', 2), ('c', 1), dtype=[('x', 'S1'), ('y', int)])
e.sort(order='y')
e
array([('c', 1), ('a', 2)],  
       dtype=[('x', '|S1'), ('y', '<i4')])
```

**ndarray.argsort (axis=-1, kind='quicksort', order=None)**

Returns the indices that would sort this array.

Refer to numpy.argsort for full documentation.

See also:

**numpy.argsort**  
equivalent function

**ndarray.partition (kth, axis=-1, kind='introselect', order=None)**

Rearranges the elements in the array in such a way that value of the element in kth position is in the position it would be in a sorted array. All elements smaller than the kth element are moved before this element and all equal or greater are moved behind it. The ordering of the elements in the two partitions is undefined.

New in version 1.8.0.

**Parameters**

- **kth**: int or sequence of ints

  Element index to partition by. The kth element value will be in its final sorted position and all smaller elements will be moved before it and all equal or greater elements behind
it. The order all elements in the partitions is undefined. If provided with a sequence of
kth it will partition all elements indexed by kth of them into their sorted position at once.

``` python
axis : int, optional
    Axis along which to sort. Default is -1, which means sort along the last axis.

kind : {'introselect'}, optional
    Selection algorithm. Default is ‘introselect’.

order : list, optional
    When a is an array with fields defined, this argument specifies which fields to compare
    first, second, etc. Not all fields need be specified.
```

See also:

numpy.partition
    Return a partitioned copy of an array.

argpartition
    Indirect partition.

sort
    Full sort.

Notes
See np.partition for notes on the different algorithms.

Examples
``` python
>>> a = np.array([3, 4, 2, 1])
>>> a.partition(a, 3)
array([2, 1, 3, 4])

>>> a.partition((1, 3))
array([1, 2, 3, 4])
```

``` python
ndarray.argpartition(kth, axis=-1, kind='introselect', order=None)
    Returns the indices that would partition this array.

    Refer to numpy.argpartition for full documentation.

    New in version 1.8.0.

    See also:

numpy.argpartition
    equivalent function
```

``` python
ndarray.searchsorted(v, side='left', sorter=None)
    Find indices where elements of v should be inserted in a to maintain order.

    For full documentation, see numpy.searchsorted

    See also:

numpy.searchsorted
    equivalent function
```
ndarray.nonzero()
Return the indices of the elements that are non-zero.
Refer to numpy.nonzero for full documentation.
See also:

numpy.nonzero
    equivalent function

ndarray.compress(condition, axis=None, out=None)
Return selected slices of this array along given axis.
Refer to numpy.compress for full documentation.
See also:

numpy.compress
    equivalent function

ndarray.diagonal(offset=0, axis1=0, axis2=1)
Return specified diagonals. In NumPy 1.9 the returned array is a read-only view instead of a copy as in previous NumPy versions. In NumPy 1.10 the read-only restriction will be removed.
Refer to numpy.diagonal for full documentation.
See also:

numpy.diagonal
    equivalent function

Calculation

Many of these methods take an argument named axis. In such cases,

- If axis is None (the default), the array is treated as a 1-D array and the operation is performed over the entire array. This behavior is also the default if self is a 0-dimensional array or array scalar. (An array scalar is an instance of the types/classes float32, float64, etc., whereas a 0-dimensional array is an ndarray instance containing precisely one array scalar.)

- If axis is an integer, then the operation is done over the given axis (for each 1-D subarray that can be created along the given axis).

Example of the axis argument
A 3-dimensional array of size 3 x 3 x 3, summed over each of its three axes

```python
>>> x
array([[[ 0,  1,  2],
        [ 3,  4,  5],
        [ 6,  7,  8]],
       [[ 9, 10, 11],
        [12, 13, 14],
        [15, 16, 17]],
       [[18, 19, 20],
        [21, 22, 23],
        [24, 25, 26]]])
>>> x.sum(axis=0)
array([[[27, 30, 33],
```
The parameter `dtype` specifies the data type over which a reduction operation (like summing) should take place. The default reduce data type is the same as the data type of `self`. To avoid overflow, it can be useful to perform the reduction using a larger data type.

For several methods, an optional `out` argument can also be provided and the result will be placed into the output array given. The `out` argument must be an `ndarray` and have the same number of elements. It can have a different data type in which case casting will be performed.

```python
ndarray.argmax([axis, out])
```
Return indices of the maximum values along the given axis.

Refer to `numpy.argmax` for full documentation.

See also:

```python
numpy.argmax
```
equivalent function

```python
ndarray.min([axis, out])
```
Return the minimum along a given axis.

Refer to `numpy.amin` for full documentation.

```python
ndarray.all([axis, out])
```
Returns True if all elements evaluate to True.

Refer to `numpy.all` for full documentation.

```python
ndarray.any([axis, out])
```
Returns True if any of the elements of `a` evaluate to True.

Refer to `numpy.any` for full documentation.
See also:

**numpy.amin**

Equivalent function

```
ndarray.argmin(axis=None, out=None)
```

Return indices of the minimum values along the given axis of `a`.

Refer to `numpy.argmin` for detailed documentation.

See also:

**numpy.argmin**

Equivalent function

```
ndarray.ptp(axis=None, out=None)
```

Peak to peak (maximum - minimum) value along a given axis.

Refer to `numpy.ptp` for full documentation.

See also:

**numpy.ptp**

Equivalent function

```
ndarray.clip(a_min, a_max, out=None)
```

Return an array whose values are limited to `[a_min, a_max]`.

Refer to `numpy.clip` for full documentation.

See also:

**numpy.clip**

Equivalent function

```
ndarray.conj()
```

Complex-conjugate all elements.

Refer to `numpy.conjugate` for full documentation.

See also:

**numpy.conjugate**

Equivalent function

```
ndarray.round(decimals=0, out=None)
```

Return `a` with each element rounded to the given number of decimals.

Refer to `numpy.around` for full documentation.

See also:

**numpy.around**

Equivalent function

```
ndarray.trace(offset=0, axis1=0, axis2=1, dtype=None, out=None)
```

Return the sum along diagonals of the array.

Refer to `numpy.trace` for full documentation.
See also:

numpy.trace
   equivalent function

ndarray.sum(axis=None, dtype=None, out=None)
   Return the sum of the array elements over the given axis.
   Refer to numpy.sum for full documentation.

See also:

numpy.sum
   equivalent function

ndarray.cumsum(axis=None, dtype=None, out=None)
   Return the cumulative sum of the elements along the given axis.
   Refer to numpy.cumsum for full documentation.

See also:

numpy.cumsum
   equivalent function

ndarray.mean(axis=None, dtype=None, out=None)
   Returns the average of the array elements along given axis.
   Refer to numpy.mean for full documentation.

See also:

numpy.mean
   equivalent function

ndarray.var(axis=None, dtype=None, out=None, ddof=0)
   Returns the variance of the array elements, along given axis.
   Refer to numpy.var for full documentation.

See also:

numpy.var
   equivalent function

ndarray.std(axis=None, dtype=None, out=None, ddof=0)
   Returns the standard deviation of the array elements along given axis.
   Refer to numpy.std for full documentation.

See also:

numpy.std
   equivalent function

ndarray.prod(axis=None, dtype=None, out=None)
   Return the product of the array elements over the given axis.
   Refer to numpy.prod for full documentation.
See also:

numpy.prod
equivalent function

ndarray.cumprod(axis=None, dtype=None, out=None)
Return the cumulative product of the elements along the given axis.
Refer to numpy.cumprod for full documentation.
See also:

numpy.cumprod
equivalent function

ndarray.all(axis=None, out=None)
Returns True if all elements evaluate to True.
Refer to numpy.all for full documentation.
See also:

numpy.all
equivalent function

ndarray.any(axis=None, out=None)
Returns True if any of the elements of a evaluate to True.
Refer to numpy.any for full documentation.
See also:

numpy.any
equivalent function

1.1.6 Arithmetic and comparison operations

Arithmetic and comparison operations on ndarrays are defined as element-wise operations, and generally yield ndarray objects as results.

Each of the arithmetic operations (+, −, *, /, //, %, divmod(), ** or pow(), <<, >>, &, ^, |, ~) and the comparisons (==, <, >, <=, >=, !) is equivalent to the corresponding universal function (or ufunc for short) in Numpy. For more information, see the section on Universal Functions.

Comparison operators:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Equivalent Method in Numpy</th>
</tr>
</thead>
<tbody>
<tr>
<td>x &lt; y</td>
<td>ndarray.<strong>lt</strong>(y) &lt;= x</td>
</tr>
<tr>
<td>x &lt;= y</td>
<td>ndarray.<strong>le</strong>(y) &lt;= x</td>
</tr>
<tr>
<td>x &gt; y</td>
<td>ndarray.<strong>gt</strong>(y) &gt;= x</td>
</tr>
<tr>
<td>x &gt;= y</td>
<td>ndarray.<strong>ge</strong>(y) &gt;= x</td>
</tr>
<tr>
<td>x == y</td>
<td>ndarray.<strong>eq</strong>(y) == x</td>
</tr>
<tr>
<td>x != y</td>
<td>ndarray.<strong>ne</strong>(y) != x</td>
</tr>
</tbody>
</table>

ndarray.__lt__
    x.__lt__(y) <= x < y

ndarray.__le__
    x.__le__(y) <= x <= y

ndarray.__gt__
    x.__gt__(y) <= x > y

ndarray.__ge__
    x.__ge__(y) <= x >= y

ndarray.__eq__
    x.__eq__(y) <= x == y

ndarray.__ne__
    x.__ne__(y) <= x != y
x.__le__(y) <=> x<=y

ndarray.__gt__
  x.__gt__(y) <=> x>y

ndarray.__ge__
  x.__ge__(y) <=> x>=y

ndarray.__eq__
  x.__eq__(y) <=> x==y

ndarray.__ne__
  x.__ne__(y) <=> x!=y

Truth value of an array (bool):

  __nonzero__
  x.__nonzero__() <=> x != 0

Note: Truth-value testing of an array invokes ndarray.__nonzero__, which raises an error if the number of elements in the array is larger than 1, because the truth value of such arrays is ambiguous. Use .any() and .all() instead to be clear about what is meant in such cases. (If the number of elements is 0, the array evaluates to False.)

Unary operations:

  __neg__
  x.__neg__() <=> -x

  __pos__
  x.__pos__() <=> +x

  __abs__
  x.__abs__() <=> abs(x)

  __invert__
  x.__invert__() <=> ~x

Arithmetic:

  __add__
  x.__add__(y) <=> x+y

  __sub__
  x.__sub__(y) <=> x-y

  __mul__
  x.__mul__(y) <=> x*y

  __div__
  x.__div__(y) <=> x/y

  __truediv__
  x.__truediv__(y) <=> x/y

  __floordiv__
  x.__floordiv__(y) <=> x/y

  __mod__
  x.__mod__(y) <=> x%y

  __divmod__
  divmod(x, y)

  __pow__
  pow(x, y)

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Table 1.15 – continued from previous page

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ndarray.<strong>lshift</strong></td>
<td>x__lshift__(y) == x&lt;&lt;y</td>
</tr>
<tr>
<td>ndarray.<strong>rshift</strong></td>
<td>x__rshift__(y) == x&gt;&gt;y</td>
</tr>
<tr>
<td>ndarray.<strong>and</strong></td>
<td>x__and__(y) == x&amp;y</td>
</tr>
<tr>
<td>ndarray.<strong>or</strong></td>
<td>x__or__(y) == x</td>
</tr>
<tr>
<td>ndarray.<strong>xor</strong></td>
<td>x__xor__(y) == x^y</td>
</tr>
</tbody>
</table>

Note:
- Any third argument to pow is silently ignored, as the underlying ufunc takes only two arguments.
- The three division operators are all defined; div is active by default, truediv is active when __future__ division is in effect.
- Because ndarray is a built-in type (written in C), the __r{op}__ special methods are not directly defined.
- The functions called to implement many arithmetic special methods for arrays can be modified using set_numeric_ops.
Arithmetic, in-place:
Warning: In place operations will perform the calculation using the precision decided by the data type of the two operands, but will silently downcast the result (if necessary) so it can fit back into the array. Therefore, for mixed precision calculations, \( A \{\text{op}\} B \) can be different than \( A = A \{\text{op}\} B \). For example, suppose \( a = \text{ones}(3,3) \). Then, \( a += 3j \) is different than \( a = a + 3j \); while they both perform the same computation, \( a += 3 \) casts the result to fit back in \( a \), whereas \( a = a + 3j \) re-binds the name \( a \) to the result.
1.1.7 Special methods

For standard library functions:

\[
\begin{align*}
\text{ndarray.__copy__} & \quad ([\text{order}]) \quad \text{Return a copy of the array.} \\
\text{ndarray.__deepcopy__} & \quad () \rightarrow \text{Deep copy of array.} \quad \text{Used if copy.deepcopy is called on an array.} \\
\text{ndarray.__reduce__} & \quad () \quad \text{For pickling.} \\
\text{ndarray.__setstate__} & \quad (\text{version, shape, dtype, ...}) \quad \text{For unpickling.}
\end{align*}
\]

\text{ndarray.__copy__} ([\text{order}])
\[
\text{Return a copy of the array.}
\]

\textbf{Parameters}

\begin{itemize}
\item \texttt{order} : \{‘C’, ‘F’, ‘A’\}, optional
\end{itemize}

If order is ‘C’ (False) then the result is contiguous (default). If order is ‘Fortran’ (True) then the result has fortran order. If order is ‘Any’ (None) then the result has fortran order only if the array already is in fortran order.

\text{ndarray.__deepcopy__} () \rightarrow \text{Deep copy of array.}
\[
\text{Used if copy.deepcopy is called on an array.}
\]

\text{ndarray.__reduce__} ()
\[
\text{For pickling.}
\]

\text{ndarray.__setstate__} (\texttt{version, shape, dtype, isfortran, rawdata})
\[
\text{For unpickling.}
\]

\textbf{Parameters}

\begin{itemize}
\item \texttt{version} : \text{int}
\end{itemize}

optional pickle version. If omitted defaults to 0.

\begin{itemize}
\item \texttt{shape} : \text{tuple}
\item \texttt{dtype} : \text{data-type}
\item \texttt{isFortran} : \text{bool}
\item \texttt{rawdata} : \text{string or list}
\end{itemize}

a binary string with the data (or a list if ‘a’ is an object array)

Basic customization:

\[
\begin{align*}
\text{ndarray.__new__} & \quad (\texttt{S, ...}) \quad \text{Returns either a new reference to self if dtype is not given or a new array of provided data type.} \\
\text{ndarray.__array__} & \quad (...) \\
\text{ndarray.__array_wrap__} & \quad (...) \\
\end{align*}
\]

\textbf{static} \text{ndarray.__new__} (\texttt{S, ...}) \rightarrow \text{a new object with type S, a subtype of T}

\text{ndarray.__array__} (\texttt{ldtype}) \rightarrow \text{reference if type unchanged, copy otherwise.}

\[
\text{Returns either a new reference to self if dtype is not given or a new array of provided data type if dtype is different from the current dtype of the array.}
\]

\text{ndarray.__array_wrap__} (\texttt{obj}) \rightarrow \text{Object of same type as ndarray object a.}

Container customization: (see \textit{Indexing})
**ndarray.__len__() <==> len(x)**

**ndarray.__getitem__**

\[ x.__getitem__(y) 
\underline{\text{==>}}
\] \[ x[y] \]

**ndarray.__setitem__**

\[ x.__setitem__(i, y) 
\underline{\text{==>}}
\] \[ x[i]=y \]

**ndarray.__getslice__**

\[ x.__getslice__(i, j) 
\underline{\text{==>}}
\] \[ x[i:j] \]

Use of negative indices is not supported.

**ndarray.__setslice__**

\[ x.__setslice__(i, j, y) 
\underline{\text{==>}}
\] \[ x[i:j]=y \]

Use of negative indices is not supported.

**ndarray.__contains__**

\[ x.__contains__(y) 
\underline{\text{==>}}
\] \[ y \text{ in } x \]

Conversion; the operations `complex`, `int`, `long`, `float`, `oct`, and `hex`. They work only on arrays that have one element in them and return the appropriate scalar.

**ndarray.__int__() <==> int(x)**

**ndarray.__long__() <==> long(x)**

**ndarray.__float__() <==> float(x)**

**ndarray.__oct__() <==> oct(x)**

**ndarray.__hex__() <==> hex(x)**

**ndarray.__int__() <==> int(x)**

**ndarray.__long__() <==> long(x)**

**ndarray.__float__() <==> float(x)**

**ndarray.__oct__() <==> oct(x)**

**ndarray.__hex__() <==> hex(x)**

String representations:

**ndarray.__str__() <==> str(x)**

**ndarray.__repr__() <==> repr(x)**
1.2 Scalars

Python defines only one type of a particular data class (there is only one integer type, one floating-point type, etc.). This can be convenient in applications that don’t need to be concerned with all the ways data can be represented in a computer. For scientific computing, however, more control is often needed.

In NumPy, there are 24 new fundamental Python types to describe different types of scalars. These type descriptors are mostly based on the types available in the C language that CPython is written in, with several additional types compatible with Python’s types.

Array scalars have the same attributes and methods as ndarrays. This allows one to treat items of an array partly on the same footing as arrays, smoothing out rough edges that result when mixing scalar and array operations.

Array scalars live in a hierarchy (see the Figure below) of data types. They can be detected using the hierarchy: For example, `isinstance(val, np.generic)` will return `True` if `val` is an array scalar object. Alternatively, what kind of array scalar is present can be determined using other members of the data type hierarchy. Thus, for example, `isinstance(val, np.complexfloating)` will return `True` if `val` is a complex valued type, while `isinstance(val, np.flexible)` will return true if `val` is one of the flexible itemsize array types (string, unicode, void).

1.2.1 Built-in scalar types

The built-in scalar types are shown below. Along with their (mostly) C-derived names, the integer, float, and complex data-types are also available using a bit-width convention so that an array of the right size can always be ensured (e.g. int8, float64, complex128). Two aliases (intp and uintp) pointing to the integer type that is sufficiently large to hold a C pointer are also provided. The C-like names are associated with character codes, which are shown in the table. Use of the character codes, however, is discouraged.

Some of the scalar types are essentially equivalent to fundamental Python types and therefore inherit from them as well as from the generic array scalar type:

<table>
<thead>
<tr>
<th>Array scalar type</th>
<th>Related Python type</th>
</tr>
</thead>
<tbody>
<tr>
<td>int_</td>
<td>IntType (Python 2 only)</td>
</tr>
<tr>
<td>float_</td>
<td>FloatType</td>
</tr>
<tr>
<td>complex_</td>
<td>ComplexType</td>
</tr>
<tr>
<td>str_</td>
<td>StringType</td>
</tr>
<tr>
<td>unicode_</td>
<td>UnicodeType</td>
</tr>
</tbody>
</table>

The bool_ data type is very similar to the Python BooleanType but does not inherit from it because Python’s BooleanType does not allow itself to be inherited from, and on the C-level the size of the actual bool data is not the same as a Python Boolean scalar.

**Warning:** The bool_ type is not a subclass of the int_ type (the bool_ is not even a number type). This is different than Python’s default implementation of bool as a sub-class of int.

---

1 However, array scalars are immutable, so none of the array scalar attributes are settable.
Figure 1.2: Figure: Hierarchy of type objects representing the array data types. Not shown are the two integer types intp and uintp which just point to the integer type that holds a pointer for the platform. All the number types can be obtained using bit-width names as well.
**Warning:** The `int_` type does not inherit from the `int` built-in under Python 3, because type `int` is no longer a fixed-width integer type.

**Tip:** The default data type in Numpy is `float_`.

In the tables below, `platform?` means that the type may not be available on all platforms. Compatibility with different C or Python types is indicated: two types are compatible if their data is of the same size and interpreted in the same way.

### Booleans:

<table>
<thead>
<tr>
<th>Type</th>
<th>Remarks</th>
<th>Character code</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>bool_</code></td>
<td>compatible: Python bool</td>
<td></td>
</tr>
<tr>
<td><code>bool8</code></td>
<td>8 bits</td>
<td></td>
</tr>
</tbody>
</table>

### Integers:

<table>
<thead>
<tr>
<th>Type</th>
<th>Remarks</th>
<th>Character code</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>byte</code></td>
<td>compatible: C char</td>
<td>'b'</td>
</tr>
<tr>
<td><code>short</code></td>
<td>compatible: C short</td>
<td>'h'</td>
</tr>
<tr>
<td><code>intc</code></td>
<td>compatible: C int</td>
<td>'i'</td>
</tr>
<tr>
<td><code>int_</code></td>
<td>compatible: Python int</td>
<td>'l'</td>
</tr>
<tr>
<td><code>longlong</code></td>
<td>compatible: C long long</td>
<td>'q'</td>
</tr>
<tr>
<td><code>intp</code></td>
<td>large enough to fit a pointer</td>
<td>'p'</td>
</tr>
<tr>
<td><code>int8</code></td>
<td>8 bits</td>
<td></td>
</tr>
<tr>
<td><code>int16</code></td>
<td>16 bits</td>
<td></td>
</tr>
<tr>
<td><code>int32</code></td>
<td>32 bits</td>
<td></td>
</tr>
<tr>
<td><code>int64</code></td>
<td>64 bits</td>
<td></td>
</tr>
</tbody>
</table>

### Unsigned integers:

<table>
<thead>
<tr>
<th>Type</th>
<th>Remarks</th>
<th>Character code</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>ubyte</code></td>
<td>compatible: C unsigned char</td>
<td>'B'</td>
</tr>
<tr>
<td><code>ushort</code></td>
<td>compatible: C unsigned short</td>
<td>'H'</td>
</tr>
<tr>
<td><code>uintc</code></td>
<td>compatible: C unsigned int</td>
<td>'I'</td>
</tr>
<tr>
<td><code>uint</code></td>
<td>compatible: Python int</td>
<td>'L'</td>
</tr>
<tr>
<td><code>ulonglong</code></td>
<td>compatible: C long long</td>
<td>'Q'</td>
</tr>
<tr>
<td><code>uintp</code></td>
<td>large enough to fit a pointer</td>
<td>'P'</td>
</tr>
<tr>
<td><code>uint8</code></td>
<td>8 bits</td>
<td></td>
</tr>
<tr>
<td><code>uint16</code></td>
<td>16 bits</td>
<td></td>
</tr>
<tr>
<td><code>uint32</code></td>
<td>32 bits</td>
<td></td>
</tr>
<tr>
<td><code>uint64</code></td>
<td>64 bits</td>
<td></td>
</tr>
</tbody>
</table>

### Floating-point numbers:

<table>
<thead>
<tr>
<th>Type</th>
<th>Remarks</th>
<th>Character code</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>half</code></td>
<td>compatible: C float</td>
<td>'e'</td>
</tr>
<tr>
<td><code>single</code></td>
<td>compatible: C double</td>
<td>'f'</td>
</tr>
<tr>
<td><code>double</code></td>
<td>compatible: Python float</td>
<td>'d'</td>
</tr>
<tr>
<td><code>float_</code></td>
<td>compatible: C long float</td>
<td>'g'</td>
</tr>
<tr>
<td><code>longfloat</code></td>
<td>16 bits</td>
<td></td>
</tr>
<tr>
<td><code>float16</code></td>
<td>32 bits</td>
<td></td>
</tr>
<tr>
<td><code>float32</code></td>
<td>64 bits</td>
<td></td>
</tr>
<tr>
<td><code>float64</code></td>
<td>96 bits, platform?</td>
<td></td>
</tr>
<tr>
<td><code>float96</code></td>
<td>128 bits, platform?</td>
<td></td>
</tr>
</tbody>
</table>

### Complex floating-point numbers:
NumPy Reference, Release 1.9.2

<table>
<thead>
<tr>
<th>Single</th>
<th>Complex compatible: Python complex</th>
<th>csingle</th>
<th>'F'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clongfloat</td>
<td>two 32-bit floats</td>
<td>complex_</td>
<td>'D'</td>
</tr>
<tr>
<td>Complex64</td>
<td>two 64-bit floats</td>
<td>complex64</td>
<td>'G'</td>
</tr>
<tr>
<td>Complex128</td>
<td>two 96-bit floats, platform?</td>
<td>complex128</td>
<td></td>
</tr>
<tr>
<td>Complex192</td>
<td>two 128-bit floats, platform?</td>
<td>complex192</td>
<td></td>
</tr>
<tr>
<td>Complex256</td>
<td>two 128-bit floats, platform?</td>
<td>complex256</td>
<td></td>
</tr>
</tbody>
</table>

Any Python object:

| object_ | any Python object | 'O' |

Note: The data actually stored in object arrays (i.e., arrays having dtype object_) are references to Python objects, not the objects themselves. Hence, object arrays behave more like usual Python lists, in the sense that their contents need not be of the same Python type.

The object type is also special because an array containing object_ items does not return an object_ object on item access, but instead returns the actual object that the array item refers to.

The following data types are flexible. They have no predefined size: the data they describe can be of different length in different arrays. (In the character codes # is an integer denoting how many elements the data type consists of.)

| str_ | compatible: Python str | 'S#' |
| unicode_ | compatible: Python unicode | 'U#' |
| void |                     | 'V#' |

Warning: Numeric Compatibility: If you used old typecode characters in your Numeric code (which was never recommended), you will need to change some of them to the new characters. In particular, the needed changes are c -> S1, b -> B, l -> h, s -> h, w -> H, and u -> I. These changes make the type character convention more consistent with other Python modules such as the struct module.

1.2.2 Attributes

The array scalar objects have an array priority of NPY_SCALAR_PRIORITY (-1,000,000,0). They also do not (yet) have a ctypes attribute. Otherwise, they share the same attributes as arrays:

- generic.flags: integer value of flags
- generic.shape: tuple of array dimensions
- generic.strides: tuple of bytes steps in each dimension
- generic.ndim: number of array dimensions
- generic.data: pointer to start of data
- generic.size: number of elements in the gentype
- generic.itemsize: length of one element in bytes
- generic.base: base object
- generic.dtype: get array descriptor
- generic.real: real part of scalar
- generic.imag: imaginary part of scalar
- generic.flat: a 1-d view of scalar
- generic.T: transpose
- generic.__array_interface__: Array protocol: Python side
- generic.__array_struct__: Array protocol: struct
- generic.__array_priority__: Array priority.
- generic.__array_wrap__: sc.__array_wrap__(obj) return scalar from array

1.2. Scalars
generic.\texttt{flags}
   integer value of flags

generic.\texttt{shape}
   tuple of array dimensions

generic.\texttt{strides}
   tuple of bytes steps in each dimension

generic.\texttt{ndim}
   number of array dimensions

generic.\texttt{data}
   pointer to start of data

generic.\texttt{size}
   number of elements in the gentype

generic.\texttt{itemsize}
   length of one element in bytes

generic.\texttt{base}
   base object

generic.\texttt{dtype}
   get array data-descriptor

generic.\texttt{real}
   real part of scalar

generic.\texttt{imag}
   imaginary part of scalar

generic.\texttt{flat}
   a 1-d view of scalar

generic.\texttt{T}
   transpose

generic.\texttt{\_array\_interface\_}
   Array protocol: Python side

generic.\texttt{\_array\_struct\_}
   Array protocol: struct

generic.\texttt{\_array\_priority\_}
   Array priority.

generic.\texttt{\_array\_wrap\_}()
   \texttt{sc.\_array\_wrap\_}(obj) return scalar from array

\subsection{1.2.3 Indexing}

See also:

\textit{Indexing, Data type objects (dtype)}

Array scalars can be indexed like 0-dimensional arrays: if \(x\) is an array scalar,

- \(x[()]\) returns a 0-dimensional \texttt{ndarray}
- \(x['field-name']\) returns the array scalar in the field \textit{field-name}. \((x\) can have fields, for example, when it corresponds to a record data type.)

1.2.4 Methods

Array scalars have exactly the same methods as arrays. The default behavior of these methods is to internally convert the scalar to an equivalent 0-dimensional array and to call the corresponding array method. In addition, math operations on array scalars are defined so that the same hardware flags are set and used to interpret the results as for ufunc, so that the error state used for ufuncs also carries over to the math on array scalars.

The exceptions to the above rules are given below:

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>generic</td>
<td>Base class for numpy scalar types.</td>
</tr>
<tr>
<td>generic.<strong>array</strong></td>
<td>sc.<strong>array</strong>(type) return 0-dim array</td>
</tr>
<tr>
<td>generic.<strong>array_wrap</strong></td>
<td>sc.<strong>array_wrap</strong>(obj) return scalar from array</td>
</tr>
<tr>
<td>generic.squeeze</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>generic.byteswap</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>generic.<strong>reduce</strong></td>
<td></td>
</tr>
<tr>
<td>generic.<strong>setstate</strong></td>
<td></td>
</tr>
<tr>
<td>generic.setflags</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
</tbody>
</table>

Class `numpy.generic`

Base class for numpy scalar types.

Class from which most (all?) numpy scalar types are derived. For consistency, exposes the same API as `ndarray`, despite many consequent attributes being either “get-only,” or completely irrelevant. This is the class from which it is strongly suggested users should derive custom scalar types.

Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>transpose</td>
</tr>
<tr>
<td>base</td>
<td>base object</td>
</tr>
<tr>
<td>data</td>
<td>pointer to start of data</td>
</tr>
<tr>
<td>dtype</td>
<td>get array data-descriptor</td>
</tr>
<tr>
<td>flags</td>
<td>integer value of flags</td>
</tr>
<tr>
<td>flat</td>
<td>a 1-d view of scalar</td>
</tr>
<tr>
<td>imag</td>
<td>imaginary part of scalar</td>
</tr>
<tr>
<td>itemsize</td>
<td>length of one element in bytes</td>
</tr>
<tr>
<td>nbytes</td>
<td>length of item in bytes</td>
</tr>
<tr>
<td>ndim</td>
<td>number of array dimensions</td>
</tr>
<tr>
<td>real</td>
<td>real part of scalar</td>
</tr>
<tr>
<td>shape</td>
<td>tuple of array dimensions</td>
</tr>
<tr>
<td>size</td>
<td>number of elements in the gentype</td>
</tr>
<tr>
<td>strides</td>
<td>tuple of bytes steps in each dimension</td>
</tr>
</tbody>
</table>

```
generic.T
transpose

generic.base
base object

generic.data
pointer to start of data

generic.dtype
get array data-descriptor

generic.flags
```
integer value of flags

generic.flat
   a 1-d view of scalar

generic.imag
   imaginary part of scalar

generic.itemsize
   length of one element in bytes

generic.nbytes
   length of item in bytes

generic.ndim
   number of array dimensions

generic.real
   real part of scalar

generic.shape
   tuple of array dimensions

generic.size
   number of elements in the gentype

generic.strides
   tuple of bytes steps in each dimension

Methods

all
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

any
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

argmax
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

argmin
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

argsort
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

astype
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

byteswap
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

dump
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

dumps
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

fill
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

flatten
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

getfield
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

item
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

itemset
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

max
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

mean
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

min
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possibly
   not implement attribute

newbyteorder([new_order]) Return a new dtype with a different byte order.
<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>nonzero</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>prod</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>ptp</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>put</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>ravel</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>repeat</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>reshape</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>reshape</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>resize</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>round</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>searchsorted</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>setfield</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>setflags</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>sort</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>squeeze</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>std</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>sum</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>swapaxes</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>take</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>tobytes</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>tofile</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>tolist</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>tostring</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>transpose</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>var</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
<tr>
<td>view</td>
<td>Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.</td>
</tr>
</tbody>
</table>

**generic.all()**

Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

**See also:**

The

**generic.any()**

Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

**See also:**

The

**generic.argmax()**

Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

**See also:**

The
generic.argmin()
    Not implemented (virtual attribute)
    
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the 
    attributes of the ndarray class so as to provide a uniform API.

    See also:
    
    The

generic.argsort()
    Not implemented (virtual attribute)
    
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the 
    attributes of the ndarray class so as to provide a uniform API.

    See also:
    
    The

generic.astype()
    Not implemented (virtual attribute)
    
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the 
    attributes of the ndarray class so as to provide a uniform API.

    See also:
    
    The

generic.byteswap()
    Not implemented (virtual attribute)
    
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the 
    attributes of the ndarray class so as to provide a uniform API.

    See also:
    
    The

generic.choose()
    Not implemented (virtual attribute)
    
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the 
    attributes of the ndarray class so as to provide a uniform API.

    See also:
    
    The

generic.clip()
    Not implemented (virtual attribute)
    
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the 
    attributes of the ndarray class so as to provide a uniform API.

    See also:
    
    The

generic.compress()
    Not implemented (virtual attribute)
    
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the 
    attributes of the ndarray class so as to provide a uniform API.

    See also:
The

generic.\texttt{conj}()  

\texttt{generic.conjugate()}

Not implemented (virtual attribute)

Class \texttt{generic} exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the \texttt{ndarray} class so as to provide a uniform API.

\textbf{See also:}

The

\texttt{generic.copy()}

Not implemented (virtual attribute)

Class \texttt{generic} exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the \texttt{ndarray} class so as to provide a uniform API.

\textbf{See also:}

The

\texttt{generic.cumprod()}

Not implemented (virtual attribute)

Class \texttt{generic} exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the \texttt{ndarray} class so as to provide a uniform API.

\textbf{See also:}

The

\texttt{generic.cumsum()}

Not implemented (virtual attribute)

Class \texttt{generic} exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the \texttt{ndarray} class so as to provide a uniform API.

\textbf{See also:}

The

\texttt{generic.diagonal()}

Not implemented (virtual attribute)

Class \texttt{generic} exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the \texttt{ndarray} class so as to provide a uniform API.

\textbf{See also:}

The

\texttt{generic.dump()}

Not implemented (virtual attribute)

Class \texttt{generic} exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the \texttt{ndarray} class so as to provide a uniform API.

\textbf{See also:}

The
generic.dumps()
Not implemented (virtual attribute)
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
The

generic.fill()
Not implemented (virtual attribute)
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
The

generic.flatten()
Not implemented (virtual attribute)
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
The

generic.getfield()
Not implemented (virtual attribute)
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
The

generic.item()
Not implemented (virtual attribute)
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
The

generic.itemset()
Not implemented (virtual attribute)
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
The

generic.max()
Not implemented (virtual attribute)
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
The

generic.mean()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The
generic.min()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The
generic.newbyteorder(new_order='S')
Return a new dtype with a different byte order.

Changes are also made in all fields and sub-arrays of the data type.

The new_order code can be any from the following:

• {'<', 'L'} - little endian
• {'>', 'B'} - big endian
• {'=', 'N'} - native order
• 'S' - swap dtype from current to opposite endian
• {'I', 'I'} - ignore (no change to byte order)

Parameters

new_order : str, optional
Byte order to force; a value from the byte order specifications above. The default value ('S') results in swapping the current byte order. The code does a case-insensitive check on the first letter of new_order for the alternatives above. For example, any of 'B' or 'b' or 'biggish' are valid to specify big-endian.

Returns

new_dtype : dtype
New dtype object with the given change to the byte order.

generic.nonzero()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The
generic.prod()
Not implemented (virtual attribute)
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.ptp()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.put()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.ravel()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.repeat()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.reshape()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.resize()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The
generic.round()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.searchsorted()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.setfield()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.setflags()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.sort()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.squeeze()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

generic.std()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
generic.sum()  
Not implemented (virtual attribute)  
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The
generic.swapaxes()  
Not implemented (virtual attribute)  
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The
generic.take()  
Not implemented (virtual attribute)  
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The
generic.tobytes()  

generic.tofile()  
Not implemented (virtual attribute)  
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The
generic.tolist()  
Not implemented (virtual attribute)  
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The
generic.tostring()  
Not implemented (virtual attribute)  
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The
generic.trace()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.
    See also:
    The

generic.transpose()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.
    See also:
    The

generic.var()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.
    See also:
    The

generic.view()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.
    See also:
    The

generic.__array__()
    sc.__array__(type) return 0-dim array

generic.__array_wrap__()
    sc.__array_wrap__(obj) return scalar from array

generic.squeeze()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.
    See also:
    The

generic.byteswap()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.
    See also:
    The

1.2. Scalars
generic.__reduce__()

generic.__setstate__()

generic.setflags()

    Not implemented (virtual attribute)

    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

    See also:

    The

1.2.5 Defining new types

There are two ways to effectively define a new array scalar type (apart from composing record dtypes from the built-in scalar types): One way is to simply subclass the ndarray and overwrite the methods of interest. This will work to a degree, but internally certain behaviors are fixed by the data type of the array. To fully customize the data type of an array you need to define a new data-type, and register it with NumPy. Such new types can only be defined in C, using the Numpy C-API.

1.3 Data type objects (dtype)

A data type object (an instance of numpy.dtype class) describes how the bytes in the fixed-size block of memory corresponding to an array item should be interpreted. It describes the following aspects of the data:

1. Type of the data (integer, float, Python object, etc.)
2. Size of the data (how many bytes is in e.g. the integer)
3. Byte order of the data (little-endian or big-endian)
4. If the data type is a record, an aggregate of other data types, (e.g., describing an array item consisting of an integer and a float),
   (a) what are the names of the “fields” of the record, by which they can be accessed,
   (b) what is the data-type of each field, and
   (c) which part of the memory block each field takes.
5. If the data type is a sub-array, what is its shape and data type.

To describe the type of scalar data, there are several built-in scalar types in Numpy for various precision of integers, floating-point numbers, etc. An item extracted from an array, e.g., by indexing, will be a Python object whose type is the scalar type associated with the data type of the array.

Note that the scalar types are not dtype objects, even though they can be used in place of one whenever a data type specification is needed in Numpy.

Struct data types are formed by creating a data type whose fields contain other data types. Each field has a name by which it can be accessed. The parent data type should be of sufficient size to contain all its fields; the parent is nearly always based on the void type which allows an arbitrary item size. Struct data types may also contain nested struct sub-array data types in their fields.

Finally, a data type can describe items that are themselves arrays of items of another data type. These sub-arrays must, however, be of a fixed size.
If an array is created using a data-type describing a sub-array, the dimensions of the sub-array are appended to the shape of the array when the array is created. Sub-arrays in a field of a record behave differently, see `Record Access`. Sub-arrays always have a C-contiguous memory layout.

**Example**

A simple data type containing a 32-bit big-endian integer: (see *Specifying and constructing data types* for details on construction)

```python
>>> dt = np.dtype('>i4')
>>> dt.byteorder
'>'
>>> dt.itemsize
4
>>> dt.name
'int32'
>>> dt.type is np.int32
True
```

The corresponding array scalar type is `int32`.

**Example**

A record data type containing a 16-character string (in field 'name') and a sub-array of two 64-bit floating-point number (in field 'grades'):

```python
>>> dt = np.dtype([('name', np.str_, 16), ('grades', np.float64, (2,))])
>>> dt['name']
dtype('|S16')
>>> dt['grades']
dtype(('float64',(2,)))
```

Items of an array of this data type are wrapped in an *array scalar* type that also has two fields:

```python
>>> x = np.array([('Sarah', (8.0, 7.0)), ('John', (6.0, 7.0))], dtype=dt)
>>> x[1]
('John', [6.0, 7.0])
>>> x[1]['grades']
array([ 6.,  7.])
>>> type(x[1])
<type 'numpy.void'>
>>> type(x[1]['grades'])
<type 'numpy.ndarray'>
```

### 1.3.1 Specifying and constructing data types

Whenever a data-type is required in a NumPy function or method, either a `dtype` object or something that can be converted to one can be supplied. Such conversions are done by the `dtype` constructor:

```python
dtype  Create a data type object.
```

```
class numpy.dtype

Create a data type object.

A numpy array is homogeneous, and contains elements described by a dtype object. A dtype object can be

```

1.3. Data type objects (`dtype`)
constructed from different combinations of fundamental numeric types.

**Parameters**

- **obj**
  - Object to be converted to a data type object.

- **align**
  - bool, optional
  - Add padding to the fields to match what a C compiler would output for a similar C-struct. Can be True only if obj is a dictionary or a comma-separated string. If a struct dtype is being created, this also sets a sticky alignment flag isalignedstruct.

- **copy**
  - bool, optional
  - Make a new copy of the data-type object. If False, the result may just be a reference to a built-in data-type object.

**See also:**

- `result_type`

**Examples**

Using array-scalar type:

```python
>>> np.dtype(np.int16)
dtype('int16')
```

Record, one field name ‘f1’, containing int16:

```python
>>> np.dtype([('f1', np.int16)])
dtype([('f1', '<i2')])
```

Record, one field named ‘f1’, in itself containing a record with one field:

```python
>>> np.dtype([('f1', {'f1': np.int16})])
dtype([('f1', [('f1', '<i2')])])
```

Record, two fields: the first field contains an unsigned int, the second an int32:

```python
>>> np.dtype([('f1', np.uint), ('f2', np.int32)])
dtype([('f1', '<u4'), ('f2', '<i4')])
```

Using array-protocol type strings:

```python
>>> np.dtype([('a','f8'),('b','S10')])
dtype([('a', '<f8'), ('b', '|S10')])
```

Using comma-separated field formats. The shape is (2,3):

```python
>>> np.dtype("i4, (2,3)f8")
dtype([('f0', '<i4'), ('f1', '<f8', (2, 3))])
```

Using tuples. int is a fixed type, 3 the field’s shape. void is a flexible type, here of size 10:

```python
>>> np.dtype([('hello',(np.int,3)),('world',np.void,10)])
dtype([('hello', '<i4', 3), ('world', '|V10')])
```

Subdivide int16 into 2 int8’s, called x and y. 0 and 1 are the offsets in bytes:

```python
>>> np.dtype((np.int16, {'x':(np.int8,0), 'y':(np.int8,1)}))
dtype(('i2', [('x', '1', 'i8'), ('y', '1', 'i8')])
```
Using dictionaries. Two fields named ‘gender’ and ‘age’:

```python
>>> np.dtype({'names': ['gender', 'age'], 'formats': ['S1', np.uint8]})
dtype([('gender', '|S1'), ('age', '|u1')])
```

Offsets in bytes, here 0 and 25:

```python
>>> np.dtype({'surname': ('S25', 0), 'age': (np.uint8, 25)})
dtype([('surname', '|S25'), ('age', '|u1')])
```

**Attributes**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>base</td>
<td>Array-interface compliant full description of the data-type.</td>
</tr>
<tr>
<td>descr</td>
<td>Dictionary of named fields defined for this data type, or None.</td>
</tr>
<tr>
<td>fields</td>
<td>Dictionary of named fields defined for this data type, or None.</td>
</tr>
<tr>
<td>hasobject</td>
<td>Boolean indicating whether this dtype contains any reference-counted objects in any fields or sub-dtypes.</td>
</tr>
<tr>
<td>isalignedstruct</td>
<td>Boolean indicating whether the dtype is a struct which maintains field alignment.</td>
</tr>
<tr>
<td>isbuiltin</td>
<td>Integer indicating how this dtype relates to the built-in dtypes.</td>
</tr>
<tr>
<td>isnative</td>
<td>Boolean indicating whether the byte order of this dtype is native to the platform.</td>
</tr>
<tr>
<td>metadata</td>
<td>A bit-width name for this data-type.</td>
</tr>
<tr>
<td>name</td>
<td>Ordered list of field names, or None if there are no fields.</td>
</tr>
<tr>
<td>names</td>
<td>A bit-width name for this data-type.</td>
</tr>
<tr>
<td>shape</td>
<td>Shape tuple of the sub-array if this data type describes a sub-array, and () otherwise.</td>
</tr>
<tr>
<td>str</td>
<td>The array-protocol typestring of this data-type object.</td>
</tr>
<tr>
<td>subdtype</td>
<td>Tuple (item_dtype, shape) if this dtype describes a sub-array, and None otherwise.</td>
</tr>
</tbody>
</table>

**Examples**

```python
>>> dt = np.dtype({'name', np.str_, 16}, {'grades', np.float64, (2,)})
```

```python
print dt.fields
{'grades': (dtype(('float64', (2,))), 16), 'name': (dtype('|S16'), 0)}
```

**dtype.hasobject**

Boolean indicating whether this dtype contains any reference-counted objects in any fields or sub-dtypes.
Recall that what is actually in the ndarray memory representing the Python object is the memory address of that object (a pointer). Special handling may be required, and this attribute is useful for distinguishing data types that may contain arbitrary Python objects and data-types that won’t.

**dtype.isalignedstruct**

Boolean indicating whether the dtype is a struct which maintains field alignment. This flag is sticky, so when combining multiple structs together, it is preserved and produces new dtypes which are also aligned.

**dtype.isbuiltin**

Integer indicating how this dtype relates to the built-in dtypes.

Read-only.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>if this is a structured array type, with fields</td>
</tr>
<tr>
<td>1</td>
<td>if this is a dtype compiled into numpy (such as ints, floats etc)</td>
</tr>
<tr>
<td>2</td>
<td>if the dtype is for a user-defined numpy type A user-defined type uses the numpy C-API machinery to extend numpy to handle a new array type. See user: user-defined data-types in the Numpy manual.</td>
</tr>
</tbody>
</table>

**Examples**

```python
>>> dt = np.dtype('i2')
>>> dt.isbuiltin
1
>>> dt = np.dtype('f8')
>>> dt.isbuiltin
1
>>> dt = np.dtype([('field1', 'f8')])
>>> dt.isbuiltin
0
```

**dtype.isnative**

Boolean indicating whether the byte order of this dtype is native to the platform.

**dtype.metadata**

**dtype.name**

A bit-width name for this data-type.

Un-sized flexible data-type objects do not have this attribute.

**dtype.names**

Ordered list of field names, or `None` if there are no fields.

The names are ordered according to increasing byte offset. This can be used, for example, to walk through all of the named fields in offset order.

**Examples**

```python
>>> dt = np.dtype([('name', np.str_, 16), ('grades', np.float64, (2,))])
>>> dt.names
('name', 'grades')
```

**dtype.shape**

Shape tuple of the sub-array if this data type describes a sub-array, and `()` otherwise.

**dtype.str**

The array-protocol typestring of this data-type object.

**dtype.subdtype**

Tuple `(item_dtype, shape)` if this dtype describes a sub-array, and `None` otherwise.
The *shape* is the fixed shape of the sub-array described by this data type, and *item_dtype* the data type of the array.

If a field whose dtype object has this attribute is retrieved, then the extra dimensions implied by *shape* are tacked on to the end of the retrieved array.

### Methods

```python
dtype.newbyteorder([new_order]) Return a new dtype with a different byte order.
```

Changes are also made in all fields and sub-arrays of the data type.

**Parameters**

`new_order` : string, optional

Byte order to force; a value from the byte order specifications below. The default value (`'S'`) results in swapping the current byte order. *new_order* codes can be any of:

- `'S'` - swap dtype from current to opposite endian
- `{'<', 'L'}` - little endian
- `{'>', 'B'}` - big endian
- `{'=', 'N'}` - native order
- `{'|', 'I'}` - ignore (no change to byte order)

The code does a case-insensitive check on the first letter of *new_order* for these alternatives. For example, any of ‘>’ or ‘B’ or ‘b’ or ‘brian’ are valid to specify big-endian.

**Returns**

`new_dtype` : dtype

New dtype object with the given change to the byte order.

### Notes

Changes are also made in all fields and sub-arrays of the data type.

### Examples

```python
>>> import sys
>>> sys_is_le = sys.byteorder == 'little'
>>> native_code = sys_is_le and '<' or '>
>>> swapped_code = sys_is_le and '>' or '<
>>> native_dt = np.dtype(native_code+'i2')
>>> swapped_dt = np.dtype(swapped_code+'i2')
>>> native_dt.newbyteorder('S') == swapped_dt
True
>>> native_dt.newbyteorder() == swapped_dt
True
>>> native_dt == swapped_dt.newbyteorder('S')
True
>>> native_dt == swapped_dt.newbyteorder('=')
True
>>> native_dt == swapped_dt.newbyteorder('N')
True
>>> native_dt == native_dt.newbyteorder('|')
True
```
>>> np.dtype('<i2') == native_dt.newbyteorder('<')
True
>>> np.dtype('<i2') == native_dt.newbyteorder('L')
True
>>> np.dtype('>i2') == native_dt.newbyteorder('>')
True
>>> np.dtype('>i2') == native_dt.newbyteorder('B')
True

What can be converted to a data-type object is described below:

**dtype object**

Used as-is.

**None**

The default data type: `float_`.

**Array-scalar types**

The 24 built-in *array scalar type objects* all convert to an associated data-type object. This is true for their sub-classes as well.

Note that not all data-type information can be supplied with a type-object: for example, *flexible* data-types have a default *itemsize* of 0, and require an explicitly given size to be useful.

**Example**

```python
>>> dt = np.dtype(np.int32)  # 32-bit integer
>>> dt = np.dtype(np.complex128)  # 128-bit complex floating-point number
```

**Generic types**

The generic hierarchical type objects convert to corresponding type objects according to the associations:

<table>
<thead>
<tr>
<th>number, inexact, floating</th>
<th>float</th>
</tr>
</thead>
<tbody>
<tr>
<td>complexfloating</td>
<td>cfloat</td>
</tr>
<tr>
<td>integer, signedinteger</td>
<td>int_</td>
</tr>
<tr>
<td>unsignedinteger</td>
<td>uint</td>
</tr>
<tr>
<td>character</td>
<td>string</td>
</tr>
<tr>
<td>generic, flexible</td>
<td>void</td>
</tr>
</tbody>
</table>

**Built-in Python types**

Several python types are equivalent to a corresponding array scalar when used to generate a `dtype` object:

```python
int_  bool_  float_  cfloat  string  unicode_  void  
(int)  (bool)  (float)  (cfloat)  (str)  (unicode)  (buffer) 
```

**Example**

```python
>>> dt = np.dtype(float)  # Python-compatible floating-point number
>>> dt = np.dtype(int)    # Python-compatible integer
>>> dt = np.dtype(object) # Python object
```
Types with `.dtype`:

Any type object with a `dtype` attribute: The attribute will be accessed and used directly. The attribute must return something that is convertible into a `dtype` object.

Several kinds of strings can be converted. Recognized strings can be prepended with ‘>' (big-endian), '<' (little-endian), or '=' (hardware-native, the default), to specify the byte order.

One-character strings

Each built-in data-type has a character code (the updated Numeric typecodes), that uniquely identifies it.

Example

```python
>>> dt = np.dtype('b')  # byte, native byte order
>>> dt = np.dtype('>H') # big-endian unsigned short
>>> dt = np.dtype('<f') # little-endian single-precision float
>>> dt = np.dtype('d')  # double-precision floating-point number
```

Array-protocol type strings (see `The Array Interface`)

The first character specifies the kind of data and the remaining characters specify the number of bytes per item. The item size may be ignored for some kinds (i.e., boolean, object), rounded to the next supported size (float, complex), or interpreted as the number of characters (Unicode). The supported kinds are

<table>
<thead>
<tr>
<th>Character</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>'b'</td>
<td>boolean</td>
</tr>
<tr>
<td>'i'</td>
<td>(signed) integer</td>
</tr>
<tr>
<td>'u'</td>
<td>unsigned integer</td>
</tr>
<tr>
<td>'f'</td>
<td>floating-point</td>
</tr>
<tr>
<td>'c'</td>
<td>complex-floating point</td>
</tr>
<tr>
<td>'O'</td>
<td>(Python) objects</td>
</tr>
<tr>
<td>'S', 'a'</td>
<td>(byte-)string</td>
</tr>
<tr>
<td>'U'</td>
<td>Unicode</td>
</tr>
<tr>
<td>'V'</td>
<td>raw data (void)</td>
</tr>
</tbody>
</table>

Example

```python
>>> dt = np.dtype('i4')  # 32-bit signed integer
>>> dt = np.dtype('f8')  # 64-bit floating-point number
>>> dt = np.dtype('c16') # 128-bit complex floating-point number
>>> dt = np.dtype('a25') # 25-character string
```

String with comma-separated fields

Numarray introduced a short-hand notation for specifying the format of a record as a comma-separated string of basic formats.

A basic format in this context is an optional shape specifier followed by an array-protocol type string. Parenthesis are required on the shape if it has more than one dimension. NumPy allows a modification on the format in that any string that can uniquely identify the type can be used to specify the data-type in a field. The generated data-type fields are named ‘f0’, ‘f1’, ‘f2’, ..., ‘f<N-1>’ where N (>1) is the number of comma-separated basic formats in the string. If the optional shape specifier is provided, then the data-type for the corresponding field describes a sub-array.

Example

- field named `f0` containing a 32-bit integer
- field named `f1` containing a 2 x 3 sub-array of 64-bit floating-point numbers
- field named `f2` containing a 32-bit floating-point number
```python
>>> dt = np.dtype("i4, (2,3)f8, f4")

• field named f0 containing a 3-character string
• field named f1 containing a sub-array of shape (3,) containing 64-bit unsigned integers
• field named f2 containing a 3 x 4 sub-array containing 10-character strings

>>> dt = np.dtype("a3, 3u8, (3,4)a10")
```

Type strings

Any string in `numpy.sctypeDict`.

Example

```python
>>> dt = np.dtype('uint32')  # 32-bit unsigned integer
>>> dt = np.dtype('Float64') # 64-bit floating-point number
```

(flexible_dtype, itemsize)

The first argument must be an object that is converted to a zero-sized flexible data-type object, the second argument is an integer providing the desired itemsize.

Example

```python
>>> dt = np.dtype((void, 10)) # 10-byte wide data block
>>> dt = np.dtype((str, 35)) # 35-character string
>>> dt = np.dtype(('U', 10)) # 10-character unicode string
```

(fixed_dtype, shape)

The first argument is any object that can be converted into a fixed-size data-type object. The second argument is the desired shape of this type. If the shape parameter is 1, then the data-type object is equivalent to fixed dtype. If `shape` is a tuple, then the new dtype defines a sub-array of the given shape.

Example

```python
>>> dt = np.dtype((np.int32, (2,2))) # 2 x 2 integer sub-array
>>> dt = np.dtype(('S10', 1)) # 10-character string
>>> dt = np.dtype(('i4, (2,3)f8, f4', (2,3))) # 2 x 3 record sub-array
```

```
[(field_name, field_dtype, field_shape), ...]
```

`obj` should be a list of fields where each field is described by a tuple of length 2 or 3. (Equivalent to the `descr` item in the `__array_interface__` attribute.)

The first element, `field_name`, is the field name (if this is `'` then a standard field name, `'f#'`, is assigned). The field name may also be a 2-tuple of strings where the first string is either a “title” (which may be any string or unicode string) or meta-data for the field which can be any object, and the second string is the “name” which must be a valid Python identifier.

The second element, `field_dtype`, can be anything that can be interpreted as a data-type.

The optional third element `field_shape` contains the shape if this field represents an array of the data-type in the second element. Note that a 3-tuple with a third argument equal to 1 is equivalent to a 2-tuple.

This style does not accept `align` in the `dtype` constructor as it is assumed that all of the memory is accounted for by the array interface description.
Example

Data-type with fields `big` (big-endian 32-bit integer) and `little` (little-endian 32-bit integer):

```python
>>> dt = np.dtype([('big', '>i4'), ('little', '<i4')])
```

Data-type with fields `R`, `G`, `B`, `A`, each being an unsigned 8-bit integer:

```python
>>> dt = np.dtype([('R','u1'), ('G','u1'), ('B','u1'), ('A','u1')])
```

This style has two required and three optional keys. The `names` and `formats` keys are required. Their respective values are equal-length lists with the field names and the field formats. The field names must be strings and the field formats can be any object accepted by `dtype` constructor.

When the optional keys `offsets` and `titles` are provided, their values must each be lists of the same length as the `names` and `formats` lists. The `offsets` value is a list of byte offsets (integers) for each field, while the `titles` value is a list of titles for each field (None can be used if no title is desired for that field). The `titles` can be any string or unicode object and will add another entry to the fields dictionary keyed by the title and referencing the same field tuple which will contain the title as an additional tuple member.

The `itemsize` key allows the total size of the dtype to be set, and must be an integer large enough so all the fields are within the dtype. If the dtype being constructed is aligned, the `itemsize` must also be divisible by the struct alignment.

Example

Data type with fields `r`, `g`, `b`, `a`, each being a 8-bit unsigned integer:

```python
>>> dt = np.dtype({'names': ['r','g','b','a'], ...
                           'formats': [uint8, uint8, uint8, uint8]})
```

Data type with fields `r` and `b` (with the given titles), both being 8-bit unsigned integers, the first at byte position 0 from the start of the field and the second at position 2:

```python
>>> dt = np.dtype({'names': ['r','b'], 'formats': ['u1', 'u1'], ...
                           'offsets': [0, 2], ...
                           'titles': ['Red pixel', 'Blue pixel']})
```

This usage is discouraged, because it is ambiguous with the other dict-based construction method. If you have a field called 'names' and a field called 'formats' there will be a conflict.

This style allows passing in the `fields` attribute of a data-type object.

`obj` should contain string or unicode keys that refer to (data-type, offset) or (data-type, offset, title) tuples.

Example

Data type containing field `col1` (10-character string at byte position 0), `col2` (32-bit float at byte position 10), and `col3` (integers at byte position 14):

```python
>>> dt = np.dtype({'col1': ('S10', 0), 'col2': (float32, 10),
                           'col3': (int, 14)})
```
This usage is discouraged. In NumPy 1.7 and later, it is possible to specify struct dtypes with overlapping fields, functioning like the ‘union’ type in C. The union mechanism is preferred.

Both arguments must be convertible to data-type objects in this case. The base_dtype is the data-type object that the new data-type builds on. This is how you could assign named fields to any built-in data-type object.

Example

32-bit integer, whose first two bytes are interpreted as an integer via field real, and the following two bytes via field imag.

```python
>>> dt = np.dtype((np.int32,{'real':(np.int16, 0),'imag':(np.int16, 2)})
```

32-bit integer, which is interpreted as consisting of a sub-array of shape (4,) containing 8-bit integers:

```python
>>> dt = np.dtype((np.int32, (np.int8, 4)))
```

32-bit integer, containing fields r, g, b, a that interpret the 4 bytes in the integer as four unsigned integers:

```python
>>> dt = np.dtype((‘i4’, 
    [‘r’,’u1’], [‘g’,’u1’], [‘b’,’u1’], [‘a’,’u1’]))
```

1.3.2 dtype

Numpy data type descriptions are instances of the dtype class.

Attributes

The type of the data is described by the following dtype attributes:

- **dtype.type**: The type object used to instantiate a scalar of this data-type.
- **dtype.kind**: A character code (one of ‘biufcOSUV’) identifying the general kind of data.
- **dtype.char**: A unique character code for each of the 21 different built-in types.
- **dtype.num**: A unique number for each of the 21 different built-in types.
- **dtype.str**: The array-protocol typestring of this data-type object.

**dtype.type**

The type object used to instantiate a scalar of this data-type.

**dtype.kind**

A character code (one of ‘biufcOSUV’) identifying the general kind of data.

```plaintext
b  boolean
i  signed integer
u  unsigned integer
f  floating-point
c  complex floating-point
O  object
S  (byte-)string
U  Unicode
V  void
```
A unique character code for each of the 21 different built-in types.

dtype.num
A unique number for each of the 21 different built-in types.
These are roughly ordered from least-to-most precision.

dtype.str
The array-protocol typestring of this data-type object.

Size of the data is in turn described by:

<table>
<thead>
<tr>
<th>dtype.name</th>
<th>A bit-width name for this data-type.</th>
</tr>
</thead>
<tbody>
<tr>
<td>dtype.itemsize</td>
<td>The element size of this data-type object.</td>
</tr>
</tbody>
</table>


dtype.name
A bit-width name for this data-type.

Un-sized flexible data-type objects do not have this attribute.

dtype.itemsize
The element size of this data-type object.

For 18 of the 21 types this number is fixed by the data-type. For the flexible data-types, this number can be anything.

Endianness of this data:

dtype.byteorder
A character indicating the byte-order of this data-type object.

One of:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>‘=’</td>
<td>native</td>
<td></td>
</tr>
<tr>
<td>‘&lt;’</td>
<td>little-endian</td>
<td></td>
</tr>
<tr>
<td>‘&gt;’</td>
<td>big-endian</td>
<td></td>
</tr>
<tr>
<td>‘</td>
<td>’</td>
<td>not applicable</td>
</tr>
</tbody>
</table>

All built-in data-type objects have byteorder either ‘=’ or ‘|’.

Examples

```python
>>> dt = np.dtype('i2')
>>> dt.byteorder
‘=’
>>> # endian is not relevant for 8 bit numbers
>>> np.dtype('i1').byteorder
‘|’
>>> # or ASCII strings
>>> np.dtype('S2').byteorder
‘|’
>>> # Even if specific code is given, and it is native
>>> # ‘=’ is the byteorder
>>> import sys
>>> sys_is_le = sys.byteorder == ’little’
>>> native_code = sys_is_le and ‘<’ or ‘>’
>>> swapped_code = sys_is_le and ‘>’ or ‘<’
>>> dt = np.dtype(native_code + ‘i2’)
```
>>> dt.byteorder
'='

>>> # Swapped code shows up as itself
>>> dt = np.dtype(swapped_code + 'i2')
>>> dt.byteorder == swapped_code
True

Information about sub-data-types in a record:

**dtype.fields**
Dictionary of named fields defined for this data type, or None.

The dictionary is indexed by keys that are the names of the fields. Each entry in the dictionary is a tuple fully
describing the field:

```
(dtype, offset[, title])
```

If present, the optional title can be any object (if it is a string or unicode then it will also be a key in the fields
dictionary, otherwise it’s meta-data). Notice also that the first two elements of the tuple can be passed directly
as arguments to the `ndarray.getfield` and `ndarray.setfield` methods.

**Examples**

```
>>> dt = np.dtype([('name', np.str_, 16), ('grades', np.float64, (2,))])
>>> print dt.fields
{'grades': (dtype(('float64',(2,))), 16), 'name': (dtype('|S16'), 0)}
```

**dtype.names**
Ordered list of field names, or None if there are no fields.

The names are ordered according to increasing byte offset. This can be used, for example, to walk through all
of the named fields in offset order.

**Examples**

```
>>> dt = np.dtype([('name', np.str_, 16), ('grades', np.float64, (2,))])
>>> dt.names
('name', 'grades')
```

For data types that describe sub-arrays:

**dtype.subdtype**
Tuple `(item_dtype, shape)` if this `dtype` describes a sub-array, and None otherwise.

**dtype.shape**
Shape tuple of the sub-array if this data type describes a sub-array, and () otherwise.

```
>>> dt.subdtype
Tuple (item_dtype, shape) if this dtype describes a sub-array, and None otherwise.
```

```
>>> dt.shape
Shape tuple of the sub-array if this data type describes a sub-array, and () otherwise.
```

```
dtype.subdtype
Tuple (item_dtype, shape) if this dtype describes a sub-array, and None otherwise.
```

The `shape` is the fixed shape of the sub-array described by this data type, and `item_dtype` the data type of the
array.

If a field whose dtype object has this attribute is retrieved, then the extra dimensions implied by `shape` are tacked
on to the end of the retrieved array.

**dtype.shape**

Shape tuple of the sub-array if this data type describes a sub-array, and () otherwise.

Attributes providing additional information:

dtype.hasobject

Boolean indicating whether this dtype contains any reference-counted objects in any fields or sub-dtypes.

Recall that what is actually in the ndarray memory representing the Python object is the memory address of that object (a pointer). Special handling may be required, and this attribute is useful for distinguishing data types that may contain arbitrary Python objects and data-types that won’t.

dtype.flags

Bit-flags describing how this data type is to be interpreted.

Bit-masks are in `numpy.core.multiarray` as the constants `ITEM_HASOBJECT`, `LIST_PICKLE`, `ITEM_IS_POINTER`, `NEEDS_INIT`, `NEEDS_PYAPI`, `USE_GETITEM`, `USE_SETITEM`. A full explanation of these flags is in C-API documentation; they are largely useful for user-defined data-types.

dtype.isbuiltin

Integer indicating how this dtype relates to the built-in dtypes.

Read-only.

- 0 if this is a structured array type, with fields
- 1 if this is a dtype compiled into numpy (such as ints, floats etc)
- 2 if the dtype is for a user-defined numpy type A user-defined type uses the numpy C-API machinery to extend numpy to handle a new array type. See `user.user-defined-data-types` in the Numpy manual.

**Examples**

```python
>>> dt = np.dtype('i2')
>>> dt.isbuiltin
1
>>> dt = np.dtype('f8')
>>> dt.isbuiltin
1
>>> dt = np.dtype([('field1', 'f8')])
>>> dt.isbuiltin
0
```

dtype.isnative

Boolean indicating whether the byte order of this dtype is native to the platform.

dtype.descr

Array-interface compliant full description of the data-type.

The format is that required by the ‘descr’ key in the `__array_interface__` attribute.

dtype.alignment

The required alignment (bytes) of this data-type according to the compiler.
More information is available in the C-API section of the manual.

**Methods**

Data types have the following method for changing the byte order:

```python
dtype.newbyteorder([new_order])  # Return a new dtype with a different byte order.
```

**dtype.newbyteorder(new_order='S')**

Return a new dtype with a different byte order.

Changes are also made in all fields and sub-arrays of the data type.

**Parameters**

- `new_order` : string, optional
  Byte order to force; a value from the byte order specifications below. The default value
  (‘S’) results in swapping the current byte order. **new_order** codes can be any of:

  * ‘S’ - swap dtype from current to opposite endian
  * {'<', 'L'} - little endian
  * {'>', 'B'} - big endian
  * {'=', 'N'} - native order
  * {'|', 'I'} - ignore (no change to byte order)

  The code does a case-insensitive check on the first letter of **new_order** for these alternatives. For example, any of ‘>’ or ‘B’ or ‘b’ or ‘brian’ are valid to specify big-endian.

**Returns**

- `new_dtype` : dtype
  New dtype object with the given change to the byte order.

**Notes**

Changes are also made in all fields and sub-arrays of the data type.

**Examples**

```python
>>> import sys
>>> sys_is_le = sys.byteorder == 'little'
>>> native_code = sys_is_le and '<' or '>
>>> swapped_code = sys_is_le and '>' or '<
>>> native_dt = np.dtype(native_code+'i2')
>>> swapped_dt = np.dtype(swapped_code+'i2')
>>> native_dt.newbyteorder('S') == swapped_dt
True
>>> native_dt.newbyteorder() == swapped_dt
True
>>> native_dt == swapped_dt.newbyteorder('S')
True
>>> native_dt == swapped_dt.newbyteorder('=')
True
>>> native_dt == swapped_dt.newbyteorder('N')
True
>>> native_dt == native_dt.newbyteorder('|')
True
>>> np.dtype('<i2') == native_dt.newbyteorder('<')
```
True

>>> np.dtype('<i2') == native_dt.newbyteorder('L')
True
>>> np.dtype('>i2') == native_dt.newbyteorder('>')
True
>>> np.dtype('>i2') == native_dt.newbyteorder('B')
True

The following methods implement the pickle protocol:

```
dtype.__reduce__
dtype.__setstate__
```

dtype.__reduce__()

dtype.__setstate__()

## 1.4 Indexing

**ndarrays** can be indexed using the standard Python `x[obj]` syntax, where `x` is the array and `obj` the selection. There are three kinds of indexing available: record access, basic slicing, advanced indexing. Which one occurs depends on `obj`.

**Note:** In Python, `x[(exp1, exp2, ..., expN)]` is equivalent to `x[exp1, exp2, ..., expN]`; the latter is just syntactic sugar for the former.

### 1.4.1 Basic Slicing and Indexing

Basic slicing extends Python’s basic concept of slicing to N dimensions. Basic slicing occurs when `obj` is a `slice` object (constructed by `start:stop:step` notation inside of brackets), an integer, or a tuple of slice objects and integers. `Ellipsis` and `newaxis` objects can be interspersed with these as well. In order to remain backward compatible with a common usage in Numeric, basic slicing is also initiated if the selection object is any non-ndarray sequence (such as a `list`) containing `slice` objects, the `Ellipsis` object, or the `newaxis` object, but not for integer arrays or other embedded sequences.

The simplest case of indexing with `N` integers returns an *array scalar* representing the corresponding item. As in Python, all indices are zero-based: for the `i`-th index `n_i`, the valid range is `0 \leq n_i < d_i` where `d_i` is the `i`-th element of the shape of the array. Negative indices are interpreted as counting from the end of the array (*i.e.*, if `n_i < 0`, it means `n_i + d_i`).

All arrays generated by basic slicing are always views of the original array.

The standard rules of sequence slicing apply to basic slicing on a per-dimension basis (including using a step index). Some useful concepts to remember include:

- The basic slice syntax is `i:j:k` where `i` is the starting index, `j` is the stopping index, and `k` is the step (`k ≠ 0`). This selects the `m` elements (in the corresponding dimension) with index values `i, i + k, ..., i + (m - 1)k` where `m = q + (r ≠ 0)` and `q` and `r` are the quotient and remainder obtained by dividing `j - i` by `k`: `j - i = q k + r`, so that `i + (m - 1)k < j`.

**Example**
```python
>>> x = np.array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> x[1:7:2]
array([1, 3, 5])
```

- Negative \( i \) and \( j \) are interpreted as \( n + i \) and \( n + j \) where \( n \) is the number of elements in the corresponding dimension. Negative \( k \) makes stepping go towards smaller indices.

**Example**
```python
>>> x[1:-10]
array([8, 9])
```}

- Assume \( n \) is the number of elements in the dimension being sliced. Then, if \( i \) is not given it defaults to 0 for \( k > 0 \) and \( n - 1 \) for \( k < 0 \). If \( j \) is not given it defaults to \( n \) for \( k > 0 \) and -1 for \( k < 0 \). If \( k \) is not given it defaults to 1. Note that :: is the same as : and means select all indices along this axis.

**Example**
```python
>>> x[5:]
array([5, 6, 7, 8, 9])
```}

- If the number of objects in the selection tuple is less than \( N \), then : is assumed for any subsequent dimensions.

**Example**
```python
>>> x = np.array([[1, 2], [3, 4]])
>>> x.shape
(2, 2)
>>> x[1:2]
array([[3, 4]])
```}

- **Ellipsis** expand to the number of : objects needed to make a selection tuple of the same length as \( x.ndim \). There may only be a single ellipsis present.

**Example**
```python
>>> x[...,0]
array([[1, 2],
       [3, 4]])
```}

- Each newaxis object in the selection tuple serves to expand the dimensions of the resulting selection by one unit-length dimension. The added dimension is the position of the newaxis object in the selection tuple.

**Example**
```python
>>> x[:,np.newaxis,:].shape
(2, 1, 3)
```}

- An integer, \( i \), returns the same values as \( i:i+1 \) except the dimensionality of the returned object is reduced by 1. In particular, a selection tuple with the \( p \)-th element an integer (and all other entries : ) returns the corresponding

```
```
sub-array with dimension \( N - I \). If \( N = I \) then the returned object is an array scalar. These objects are explained in *Scalars*.

- If the selection tuple has all entries: except the \( p \)-th entry which is a slice object \( i:j:k \), then the returned array has dimension \( N \) formed by concatenating the sub-arrays returned by integer indexing of elements \( i, i+k, \ldots, i+(m-I)k \lt j \).

- Basic slicing with more than one non-\( : \) entry in the slicing tuple, acts like repeated application of slicing using a single non-\( : \) entry, where the non-\( : \) entries are successively taken (with all other non-\( : \) entries replaced by \( : \)). Thus, \( x[ind1,\ldots,ind2,:) \) acts like \( x[ind1][\ldots,ind2,:) \) under basic slicing.

**Warning:** The above is not true for advanced indexing.

- You may use slicing to set values in the array, but (unlike lists) you can never grow the array. The size of the value to be set in \( x[obj] = value \) must be (broadcastable) to the same shape as \( x[obj] \).

**Note:** Remember that a slicing tuple can always be constructed as \( obj \) and used in the \( x[obj] \) notation. Slice objects can be used in the construction in place of the \( [start:stop:step] \) notation. For example, \( x[1:10:5,:::-1] \) can also be implemented as \( obj = (slice(1,10,5), slice(None,None,-1)) \); \( x[obj] \). This can be useful for constructing generic code that works on arrays of arbitrary dimension.

**numpy.**\texttt{newaxis}

The \texttt{newaxis} object can be used in all slicing operations to create an axis of length one. :const: \texttt{newaxis} is an alias for ‘None’, and ‘None’ can be used in place of this with the same result.

### 1.4.2 Advanced Indexing

Advanced indexing is triggered when the selection object, \( obj \), is a non-tuple sequence object, an \texttt{ndarray} (of data type integer or bool), or a tuple with at least one sequence object or \texttt{ndarray} (of data type integer or bool). There are two types of advanced indexing: integer and Boolean.

Advanced indexing always returns a copy of the data (contrast with basic slicing that returns a view).

**Warning:** The definition of advanced indexing means that \( x[ (1,2,3), ] \) is fundamentally different than \( x[ (1,2,3) ] \). The latter is equivalent to \( x[1,2,3] \) which will trigger basic selection while the former will trigger advanced indexing. Be sure to understand why this is occurs.

Also recognize that \( x[[1,2,3]] \) will trigger advanced indexing, whereas \( x[[1,2,slice(None)]] \) will trigger basic slicing.

#### Integer array indexing

Integer array indexing allows selection of arbitrary items in the array based on their \( N \)-dimensional index. Each integer array represents a number of indexes into that dimension.

#### Purely integer array indexing

When the index consists of as many integer arrays as the array being indexed has dimensions, the indexing is straightforward, but different from slicing.

Advanced indexes always are broadcast and iterated as \texttt{one}:

\[
\text{result}[i_1, \ldots, i_M] = x[ind_1[i_1, \ldots, i_M], \ldots, ind_N[i_1, \ldots, i_M]]
\]
Note that the result shape is identical to the (broadcast) indexing array shapes \texttt{ind\_1, ..., ind\_N}.

**Example**

From each row, a specific element should be selected. The row index is just \([0, 1, 2]\) and the column index specifies the element to choose for the corresponding row, here \([0, 1, 0]\). Using both together the task can be solved using advanced indexing:

```python
>>> x = np.array([[1, 2], [3, 4], [5, 6]])
>>> x[[0, 1, 2], [0, 1, 0]]
array([1, 4, 5])
```

To achieve a behaviour similar to the basic slicing above, broadcasting can be used. The function \texttt{ix\_} can help with this broadcasting. This is best understood with an example.

**Example**

From a 4x3 array the corner elements should be selected using advanced indexing. Thus all elements for which the column is one of \([0, 2]\) and the row is one of \([0, 3]\) need to be selected. To use advanced indexing one needs to select all elements explicitly. Using the method explained previously one could write:

```python
>>> x = np.array([[ 0, 1, 2],
...                [ 3, 4, 5],
...                [ 6, 7, 8],
...                [ 9, 10, 11]])
>>> rows = np.array([[0, 0],
...                   [3, 3]], dtype=np.intp)
>>> columns = np.array([[0, 2],
...                      [0, 2]], dtype=np.intp)
>>> x[rows, columns]
array([[ 0, 2],
       [ 9, 11]])
```

However, since the indexing arrays above just repeat themselves, broadcasting can be used (compare operations such as \texttt{rows[:, np.newaxis] + columns}) to simplify this:

```python
>>> rows = np.array([0, 3], dtype=np.intp)
>>> columns = np.array([0, 2], dtype=np.intp)
>>> rows[:, np.newaxis]
array([[0],
       [3]])
```

```python
>>> x[np.ix_(rows, columns)]
array([[ 0, 2],
       [ 9, 11]])
```

This broadcasting can also be achieved using the function \texttt{ix\_}:

```python
>>> x[np.ix_(rows, columns)]
array([[ 0, 2],
       [ 9, 11]])
```

Note that without the \texttt{np.ix\_} call, only the diagonal elements would be selected, as was used in the previous example. This difference is the most important thing to remember about indexing with multiple advanced indexes.

**Combining advanced and basic indexing**

When there is at least one slice (:), ellipsis (...) or \texttt{np.newaxis} in the index (or the array has more dimensions than there are advanced indexes), then the behaviour can be more complicated. It is like concatenating the indexing result for each advanced index element.
In the simplest case, there is only a single advanced index. A single advanced index can for example replace a slice and the result array will be the same, however, it is a copy and may have a different memory layout. A slice is preferable when it is possible.

**Example**

```python
>>> x[1:2, 1:3]
array([[4, 5]])
```

```python
>>> x[1:2, [1, 2]]
array([[4, 5]])
```

The easiest way to understand the situation may be to think in terms of the result shape. There are two parts to the indexing operation, the subspace defined by the basic indexing (excluding integers) and the subspace from the advanced indexing part. Two cases of index combination need to be distinguished:

- The advanced indexes are separated by a slice, ellipsis or newaxis. For example `x[arr1, :, arr2]`.
- The advanced indexes are all next to each other. For example `x[... , arr1, arr2, :]` but not `x[arr1, :, 1]` since 1 is an advanced index in this regard.

In the first case, the dimensions resulting from the advanced indexing operation come first in the result array, and the subspace dimensions after that. In the second case, the dimensions from the advanced indexing operations are inserted into the result array at the same spot as they were in the initial array (the latter logic is what makes simple advanced indexing behave just like slicing).

**Example**

Suppose `x.shape` is `(10,20,30)` and `ind` is a `(2,3,4)`-shaped indexing `intp` array, then `result = x[... , ind, :]` has shape `(10,2,3,4,30)` because the `(20,)`-shaped subspace has been replaced with a `(2,3,4)`-shaped broadcasted indexing subspace. If we let `i, j, k` loop over the `(2,3,4)`-shaped subspace then `result[... , i, j, k, :] = x[... , ind[1, j, k], :]`. This example produces the same result as `x.take(ind, axis=-2)`.

**Example**

Let `x.shape` be `(10,20,30,40,50)` and suppose `ind_1` and `ind_2` can be broadcast to the shape `(2,3,4)`. Then `x[... , ind_1, ind_2]` has shape `(10,2,3,4,50)` because the `(20,30)`-shaped subspace from `X` has been replaced with the `(2,3,4)` subspace from the indices. However, `x[... , ind_1, :, ind_2]` has shape `(2,3,4,10,50)` because there is no unambiguous place to drop in the indexing subspace, thus it is tacked-on to the beginning. It is always possible to use `.transpose()` to move the subspace anywhere desired. Note that this example cannot be replicated using `take`.

**Boolean array indexing**

This advanced indexing occurs when `obj` is an array object of Boolean type, such as may be returned from comparison operators. A single boolean index array is practically identical to `x[obj.nonzero()]` where, as described above, `obj.nonzero()` returns a tuple (of length `obj.ndim`) of integer index arrays showing the True elements of `obj`. However, it is faster when `obj.shape == x.shape`.

If `obj.ndim == x.ndim, x[obj]` returns a 1-dimensional array filled with the elements of `x` corresponding to the True values of `obj`. The search order will be C-style (last index varies the fastest). If `obj` has True values at entries that are outside of the bounds of `x`, then an index error will be raised. If `obj` is smaller than `x` it is identical to filling it with False.

**Example**
A common use case for this is filtering for desired element values. For example one may wish to select all entries from an array which are not NaN:

```python
>>> x = np.array([[1., 2.], [np.nan, 3.], [np.nan, np.nan]])
>>> x[~np.isnan(x)]
array([ 1., 2., 3.])
```

Or wish to add a constant to all negative elements:

```python
>>> x = np.array([1., -1., -2., 3])
>>> x[x < 0] += 20
>>> x
array([ 1., 19., 18., 3.])
```

In general if an index includes a Boolean array, the result will be identical to inserting `obj.nonzero()` into the same position and using the integer array indexing mechanism described above. `x[ind_1, boolean_array, ind_2]` is equivalent to `x[(ind_1,) + boolean_array.nonzero() + (ind_2,)].` 

If there is only one Boolean array and no integer indexing array present, this is straight forward. Care must only be taken to make sure that the boolean index has exactly as many dimensions as it is supposed to work with.

**Example**

From an array, select all rows which sum up to less or equal two:

```python
>>> x = np.array([[0, 1], [1, 1], [2, 2]])
>>> rowsum = x.sum(-1)
>>> x[rowsum <= 2, :]
array([[0, 1],
       [1, 1]])
```

But if `rowsum` would have two dimensions as well:

```python
>>> rowsum = x.sum(-1, keepdims=True)
>>> rowsum.shape
(3, 1)
>>> x[rowsum <= 2, :]    # fails
IndexError: too many indices
>>> x[rowsum <= 2]
array([[0, 1]])
```

The last one giving only the first elements because of the extra dimension. Compare `rowsum.nonzero()` to understand this example.

Combining multiple Boolean indexing arrays or a Boolean with an integer indexing array can best be understood with the `obj.nonzero()` analogy. The function `ix_` also supports boolean arrays and will work without any surprises.

**Example**

Use boolean indexing to select all rows adding up to an even number. At the same time columns 0 and 2 should be selected with an advanced integer index. Using the `ix_` function this can be done with:

```python
>>> x = array([[ 0, 1, 2],
...            [ 3, 4, 5],
...            [ 6, 7, 8],
...            [ 9,10,11]])
>>> rows = (x.sum(-1) % 2) == 0
>>> rows
array([False, True, False, True], dtype=bool)
```
>>> columns = [0, 2]
>>> x[np.ix_((rows, columns)]
array([[ 3,  5],
       [ 9, 11]])

Without the np.ix_ call or only the diagonal elements would be selected.

Or without np.ix_ (compare the integer array examples):

>>> rows = rows.nonzero()[0]
>>> x[rows[:, np.newaxis], columns]
array([[ 3,  5],
       [ 9, 11]])

1.4.3 Detailed notes

These are some detailed notes, which are not of importance for day to day indexing (in no particular order):

- The native NumPy indexing type is intp and may differ from the default integer array type. intp is the smallest data type sufficient to safely index any array; for advanced indexing it may be faster than other types.

- For advanced assignments, there is in general no guarantee for the iteration order. This means that if an element is set more than once, it is not possible to predict the final result.

- An empty (tuple) index is a full scalar index into a zero dimensional array. x[] returns a scalar if x is zero dimensional and a view otherwise. On the other hand x[...] always returns a view.

- If a zero dimensional array is present in the index and it is a full integer index the result will be a scalar and not a zero dimensional array. (Advanced indexing is not triggered.)

- When an ellipsis (...) is present but has no size (i.e. replaces zero :) the result will still always be an array. A view if no advanced index is present, otherwise a copy.

- the nonzero equivalence for Boolean arrays does not hold for zero dimensional boolean arrays.

- When the result of an advanced indexing operation has no elements but an individual index is out of bounds, whether or not an IndexError is raised is undefined (e.g. x[[], [123]] with 123 being out of bounds).

- When a casting error occurs during assignment (for example updating a numerical array using a sequence of strings), the array being assigned to may end up in an unpredictable partially updated state. However, if any other error (such as an out of bounds index) occurs, the array will remain unchanged.

- The memory layout of an advanced indexing result is optimized for each indexing operation and no particular memory order can be assumed.

- When using a subclass (especially one which manipulates its shape), the default ndarray.__setitem__ behaviour will call __getitem__ for basic indexing but not for advanced indexing. For such a subclass it may be preferable to call ndarray.__setitem__ with a base class ndarray view on the data. This must be done if the subclasses __getitem__ does not return views.

1.4.4 Record Access

See also:

Data type objects (dtype), Scalars

If the ndarray object is a record array, i.e. its data type is a record data type, the fields of the array can be accessed by indexing the array with strings, dictionary-like.
Indexing `x[‘field-name’]` returns a new view to the array, which is of the same shape as `x` (except when the field is a sub-array) but of data type `x.dtype[‘field-name’]` and contains only the part of the data in the specified field. Also record array scalars can be "indexed" this way.

Indexing into a record array can also be done with a list of field names, e.g. `x[['field-name1','field-name2']]`. Currently this returns a new array containing a copy of the values in the fields specified in the list. As of NumPy 1.7, returning a copy is being deprecated in favor of returning a view. A copy will continue to be returned for now, but a FutureWarning will be issued when writing to the copy. If you depend on the current behavior, then we suggest copying the returned array explicitly, i.e. use `x[['field-name1','field-name2']].copy()`. This will work with both past and future versions of NumPy.

If the accessed field is a sub-array, the dimensions of the sub-array are appended to the shape of the result.

**Example**

```python
>>> x = np.zeros((2,2), dtype=[('a', np.int32), ('b', np.float64, (3,3))])
>>> x['a'].shape
(2, 2)
>>> x['a'].dtype
dtype('int32')
>>> x['b'].shape
(2, 2, 3, 3)
>>> x['b'].dtype
dtype('float64')
```

### 1.4.5 Flat Iterator indexing

`x.flat` returns an iterator that will iterate over the entire array (in C-contiguous style with the last index varying the fastest). This iterator object can also be indexed using basic slicing or advanced indexing as long as the selection object is not a tuple. This should be clear from the fact that `x.flat` is a 1-dimensional view. It can be used for integer indexing with 1-dimensional C-style-flat indices. The shape of any returned array is therefore the shape of the integer indexing object.

### 1.5 Iterating Over Arrays

The iterator object `nditer`, introduced in NumPy 1.6, provides many flexible ways to visit all the elements of one or more arrays in a systematic fashion. This page introduces some basic ways to use the object for computations on arrays in Python, then concludes with how one can accelerate the inner loop in Cython. Since the Python exposure of `nditer` is a relatively straightforward mapping of the C array iterator API, these ideas will also provide help working with array iteration from C or C++.

#### 1.5.1 Single Array Iteration

The most basic task that can be done with the `nditer` is to visit every element of an array. Each element is provided one by one using the standard Python iterator interface.

**Example**

```python
>>> a = np.arange(6).reshape(2,3)
>>> for x in np.nditer(a):
...     print x,
... 0 1 2 3 4 5
```
An important thing to be aware of for this iteration is that the order is chosen to match the memory layout of the array instead of using a standard C or Fortran ordering. This is done for access efficiency, reflecting the idea that by default one simply wants to visit each element without concern for a particular ordering. We can see this by iterating over the transpose of our previous array, compared to taking a copy of that transpose in C order.

Example

```python
>>> a = np.arange(6).reshape(2,3)
>>> for x in np.nditer(a.T):
...     print x,
... 0 1 2 3 4 5

>>> for x in np.nditer(a.T.copy(order='C')):
...     print x,
... 0 3 1 4 2 5
```

The elements of both $a$ and $a.T$ get traversed in the same order, namely the order they are stored in memory, whereas the elements of $a.T.copy(order='C')$ get visited in a different order because they have been put into a different memory layout.

**Controlling Iteration Order**

There are times when it is important to visit the elements of an array in a specific order, irrespective of the layout of the elements in memory. The `nditer` object provides an `order` parameter to control this aspect of iteration. The default, having the behavior described above, is order='K' to keep the existing order. This can be overridden with order='C' for C order and order='F' for Fortran order.

Example

```python
>>> a = np.arange(6).reshape(2,3)
>>> for x in np.nditer(a, order='F'):
...     print x,
... 0 3 1 4 2 5

>>> for x in np.nditer(a.T, order='C'):
...     print x,
... 0 3 1 4 2 5
```

**Modifying Array Values**

By default, the `nditer` treats the input array as a read-only object. To modify the array elements, you must specify either read-write or write-only mode. This is controlled with per-operand flags.

Regular assignment in Python simply changes a reference in the local or global variable dictionary instead of modifying an existing variable in place. This means that simply assigning to $x$ will not place the value into the element of the array, but rather switch $x$ from being an array element reference to being a reference to the value you assigned. To actually modify the element of the array, $x$ should be indexed with the ellipsis.

Example
Using an External Loop

In all the examples so far, the elements of \( a \) are provided by the iterator one at a time, because all the looping logic is internal to the iterator. While this is simple and convenient, it is not very efficient. A better approach is to move the one-dimensional innermost loop into your code, external to the iterator. This way, NumPy’s vectorized operations can be used on larger chunks of the elements being visited.

The \texttt{nditer} will try to provide chunks that are as large as possible to the inner loop. By forcing ‘C’ and ‘F’ order, we get different external loop sizes. This mode is enabled by specifying an iterator flag.

Observe that with the default of keeping native memory order, the iterator is able to provide a single one-dimensional chunk, whereas when forcing Fortran order, it has to provide three chunks of two elements each.

Example

```python
>>> a = np.arange(6).reshape(2,3)
>>> for x in np.nditer(a, flags=['external_loop']):
...     print x,
... [0 1 2 3 4 5]

>>> for x in np.nditer(a, flags=['external_loop'], order='F'):
...     print x,
... [0 3] [1 4] [2 5]
```

Tracking an Index or Multi-Index

During iteration, you may want to use the index of the current element in a computation. For example, you may want to visit the elements of an array in memory order, but use a C-order, Fortran-order, or multidimensional index to look up values in a different array.

The Python iterator protocol doesn’t have a natural way to query these additional values from the iterator, so we introduce an alternate syntax for iterating with an \texttt{nditer}. This syntax explicitly works with the iterator object itself, so its properties are readily accessible during iteration. With this looping construct, the current value is accessible by indexing into the iterator, and the index being tracked is the property \texttt{index} or \texttt{multi_index} depending on what was requested.

The Python interactive interpreter unfortunately prints out the values of expressions inside the while loop during each iteration of the loop. We have modified the output in the examples using this looping construct in order to be more readable.

Example
```
>>> a = np.arange(6).reshape(2,3)
>>> it = np.nditer(a, flags=['f_index'])
>>> while not it.finished:
...    print "%d <%d>" % (it[0], it.index),
...    it.iternext()
... 0 <0> 1 <2> 2 <4> 3 <1> 4 <3> 5 <5>

>>> it = np.nditer(a, flags=['multi_index'])
>>> while not it.finished:
...    print "%d <%s>" % (it[0], it.multi_index),
...    it.iternext()
... 0 <(0, 0)> 1 <(0, 1)> 2 <(0, 2)> 3 <(1, 0)> 4 <(1, 1)> 5 <(1, 2)>

>>> it = np.nditer(a, flags=['multi_index'], op_flags=['writeonly'])
>>> while not it.finished:
...    it[0] = it.multi_index[1] - it.multi_index[0]
...    it.iternext()
... 
>>> a
array([[0, 1, 2],
       [-1, 0, 1]])
```

Tracking an index or multi-index is incompatible with using an external loop, because it requires a different index value per element. If you try to combine these flags, the `nditer` object will raise an exception.

**Example**
```
>>> a = np.zeros((2,3))
>>> it = np.nditer(a, flags=['c_index', 'external_loop'])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: Iterator flag EXTERNAL_LOOP cannot be used if an index or multi-index is being tracked
```

**Buffering the Array Elements**

When forcing an iteration order, we observed that the external loop option may provide the elements in smaller chunks because the elements can’t be visited in the appropriate order with a constant stride. When writing C code, this is generally fine, however in pure Python code this can cause a significant reduction in performance.

By enabling buffering mode, the chunks provided by the iterator to the inner loop can be made larger, significantly reducing the overhead of the Python interpreter. In the example forcing Fortran iteration order, the inner loop gets to see all the elements in one go when buffering is enabled.

**Example**
```
>>> a = np.arange(6).reshape(2,3)
>>> for x in np.nditer(a, flags=['external_loop'], order='F'):
...    print x,
... [0 3] [1 4] [2 5]
```
Iterating as a Specific Data Type

There are times when it is necessary to treat an array as a different data type than it is stored as. For instance, one may want to do all computations on 64-bit floats, even if the arrays being manipulated are 32-bit floats. Except when writing low-level C code, it’s generally better to let the iterator handle the copying or buffering instead of casting the data type yourself in the inner loop.

There are two mechanisms which allow this to be done, temporary copies and buffering mode. With temporary copies, a copy of the entire array is made with the new data type, then iteration is done in the copy. Write access is permitted through a mode which updates the original array after all the iteration is complete. The major drawback of temporary copies is that the temporary copy may consume a large amount of memory, particularly if the iteration data type has a larger itemsize than the original one.

Buffering mode mitigates the memory usage issue and is more cache-friendly than making temporary copies. Except for special cases, where the whole array is needed at once outside the iterator, buffering is recommended over temporary copying. Within NumPy, buffering is used by the ufuncs and other functions to support flexible inputs with minimal memory overhead.

In our examples, we will treat the input array with a complex data type, so that we can take square roots of negative numbers. Without enabling copies or buffering mode, the iterator will raise an exception if the data type doesn’t match precisely.

Example

```python
>>> a = np.arange(6).reshape(2,3) - 3
>>> for x in np.nditer(a, op_dtypes=['complex128']):
...     print np.sqrt(x),
...
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Iterator operand required copying or buffering, but neither copying nor buffering was enabled
```

In copying mode, `‘copy’` is specified as a per-operand flag. This is done to provide control in a per-operand fashion. Buffering mode is specified as an iterator flag.

Example

```python
>>> a = np.arange(6).reshape(2,3) - 3
>>> for x in np.nditer(a, op_dtypes=['complex128']):
...     print np.sqrt(x),
...
1.73205080757j 1.41421356237j 1j 0j (1+0j) (1.41421356237+0j)
```

```python
>>> for x in np.nditer(a, flags=['buffered'], op_dtypes=['complex128']):
...     print np.sqrt(x),
...
1.73205080757j 1.41421356237j 1j 0j (1+0j) (1.41421356237+0j)
```
The iterator uses NumPy's casting rules to determine whether a specific conversion is permitted. By default, it enforces 'safe' casting. This means, for example, that it will raise an exception if you try to treat a 64-bit float array as a 32-bit float array. In many cases, the rule 'same_kind' is the most reasonable rule to use, since it will allow conversion from 64 to 32-bit float, but not from float to int or from complex to float.

Example

```python
>>> a = np.arange(6.)
>>> for x in np.nditer(a, flags=['buffered'], op_dtypes=['float32']):
...    print x,
...
Traceback (most recent call last):
  File "<stdin>" , line 1, in <module>
TypeError: Iterator operand 0 dtype could not be cast from dtype('float64') to dtype('float32') according to the rule 'safe'

>>> for x in np.nditer(a, flags=['buffered'], op_dtypes=['float32'], casting='same_kind'):
...    print x,
...
0.0 1.0 2.0 3.0 4.0 5.0

>>> for x in np.nditer(a, flags=['buffered'], op_dtypes=['int32'], casting='same_kind'):
...    print x,
...
Traceback (most recent call last):
  File "<stdin>" , line 1, in <module>
TypeError: Iterator operand 0 dtype could not be cast from dtype('float64') to dtype('int32') according to the rule 'same_kind'
```

One thing to watch out for is conversions back to the original data type when using a read-write or write-only operand. A common case is to implement the inner loop in terms of 64-bit floats, and use 'same_kind' casting to allow the other floating-point types to be processed as well. While in read-only mode, an integer array could be provided, read-write mode will raise an exception because conversion back to the array would violate the casting rule.

Example

```python
>>> a = np.arange(6)
>>> for x in np.nditer(a, flags=['buffered'], op_dtypes=['float64'], casting='same_kind'):
...     x[...] = x / 2.0
...
Traceback (most recent call last):
  File "<stdin>" , line 2, in <module>
TypeError: Iterator requested dtype could not be cast from dtype('float64') to dtype('int64'), the operand 0 dtype, according to the rule 'same_kind'
```

1.5. Iterating Over Arrays

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1.5.2 Broadcasting Array Iteration

NumPy has a set of rules for dealing with arrays that have differing shapes which are applied whenever functions take multiple operands which combine element-wise. This is called broadcasting. The `nditer` object can apply these rules for you when you need to write such a function.

As an example, we print out the result of broadcasting a one and a two dimensional array together.

**Example**

```python
>>> a = np.arange(3)
>>> b = np.arange(6).reshape(2,3)
>>> for x, y in np.nditer([a, b]):
...     print "%d:%d " % (x, y),
... 0:0 1:1 2:2 0:3 1:4 2:5
```

When a broadcasting error occurs, the iterator raises an exception which includes the input shapes to help diagnose the problem.

**Example**

```python
>>> a = np.arange(2)
>>> b = np.arange(6).reshape(2,3)
>>> for x, y in np.nditer([a, b]):
...     print "%d:%d " % (x, y),
... Traceback (most recent call last):
  File "<stdin>"., line 1, in <module>
ValueError: operands could not be broadcast together with shapes (2) (2,3)
```

**Iterator-Allocated Output Arrays**

A common case in NumPy functions is to have outputs allocated based on the broadcasting of the input, and additionally have an optional parameter called ‘out’ where the result will be placed when it is provided. The `nditer` object provides a convenient idiom that makes it very easy to support this mechanism.

We’ll show how this works by creating a function `square` which squares its input. Let’s start with a minimal function definition excluding ‘out’ parameter support.

**Example**

```python
>>> def square(a):
...     it = np.nditer([a, None])
...     for x, y in it:
...         y[...] = x*x
...     return it.operands[1]
...>>> square([[1,2,3]])
array([1, 4, 9])
```

By default, the `nditer` uses the flags ‘allocate’ and ‘writeonly’ for operands that are passed in as None. This means we were able to provide just the two operands to the iterator, and it handled the rest.
When adding the ‘out’ parameter, we have to explicitly provide those flags, because if someone passes in an array as
‘out’, the iterator will default to ‘readonly’, and our inner loop would fail. The reason ‘readonly’ is the default for input
arrays is to prevent confusion about unintentionally triggering a reduction operation. If the default were ‘readwrite’,
y any broadcasting operation would also trigger a reduction, a topic which is covered later in this document.

While we’re at it, let’s also introduce the ‘no_broadcast’ flag, which will prevent the output from being broadcast.
This is important, because we only want one input value for each output. Aggregating more than one input value
is a reduction operation which requires special handling. It would already raise an error because reductions must
be explicitly enabled in an iterator flag, but the error message that results from disabling broadcasting is much more
understandable for end-users. To see how to generalize the square function to a reduction, look at the sum of squares
function in the section about Cython.

For completeness, we’ll also add the ‘external_loop’ and ‘buffered’ flags, as these are what you will typically want for
performance reasons.

Example

```python
>>> def square(a, out=None):
    ...     it = np.nditer([a, out],
    ...         flags = ['external_loop', 'buffered'],
    ...         op_flags = [['readonly'],
    ...                ['writeonly', 'allocate', 'no_broadcast']]
    ...     for x, y in it:
    ...         y[...] = x*x
    ...     return it.operands[1]
    ...

>>> square([1,2,3])
array([1, 4, 9])

>>> b = np.zeros((3,))
>>> square([1,2,3], out=b)
array([1., 4., 9.])

>>> square(np.arange(6).reshape(2,3), out=b)
Traceback (most recent call last):
  File "<stdin>"", line 1, in <module>
  File "<stdin>"", line 4, in square
ValueError: non-broadcastable output operand with shape (3) doesn’t match the broadcast shape (2,3)
```

Outer Product Iteration

Any binary operation can be extended to an array operation in an outer product fashion like in `outer`, and the `nditer`
object provides a way to accomplish this by explicitly mapping the axes of the operands. It is also possible to do this
with `newaxis` indexing, but we will show you how to directly use the `nditer` `op_axes` parameter to accomplish this
with no intermediate views.

We’ll do a simple outer product, placing the dimensions of the first operand before the dimensions of the second
operand. The `op_axes` parameter needs one list of axes for each operand, and provides a mapping from the iterator’s
axes to the axes of the operand.
Suppose the first operand is one dimensional and the second operand is two dimensional. The iterator will have three dimensions, so \texttt{op_axes} will have two 3-element lists. The first list picks out the one axis of the first operand, and is -1 for the rest of the iterator axes, with a final result of \([0, -1, -1]\). The second list picks out the two axes of the second operand, but shouldn’t overlap with the axes picked out in the first operand. Its list is \([-1, 0, 1]\). The output operand maps onto the iterator axes in the standard manner, so we can provide None instead of constructing another list.

The operation in the inner loop is a straightforward multiplication. Everything to do with the outer product is handled by the iterator setup.

\begin{verbatim}
>>> a = np.arange(3)
>>> b = np.arange(8).reshape(2,4)
>>> it = np.nditer([a, b, None], flags=['external_loop'],
... op_axes=[[0, -1, -1], [-1, 0, 1], None])
>>> for x, y, z in it:
...     z[[...]] = x*y
...
>>> it.operands[2]
array([[ 0,  0,  0,  0],
       [ 0,  0,  0,  0],
       [ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 0,  2,  4,  6],
       [ 8, 10, 12, 14]])
\end{verbatim}

\section*{Reduction Iteration}

Whenever a writeable operand has fewer elements than the full iteration space, that operand is undergoing a reduction. The \texttt{nditer} object requires that any reduction operand be flagged as read-write, and only allows reductions when ‘reduce\_ok’ is provided as an iterator flag.

For a simple example, consider taking the sum of all elements in an array.

\begin{verbatim}
>>> a = np.arange(24).reshape(2,3,4)
>>> b = np.array(0)
>>> for x, y in np.nditer([a, b], flags=['reduce_ok', 'external_loop'],
... op_flags=[['readonly'], ['readwrite']]):
...     y[...] += x
...
>>> b
array(276)
>>> np.sum(a)
276
\end{verbatim}

Things are a little bit more tricky when combining reduction and allocated operands. Before iteration is started, any reduction operand must be initialized to its starting values. Here’s how we can do this, taking sums along the last axis of \(a\).

\begin{verbatim}
>>> a = np.arange(24).reshape(2,3,4)
>>> it = np.nditer([a, None], flags=['reduce_ok', 'external_loop'],
... op_flags=[['readonly'], ['readwrite', 'allocate']]),
...     z=x
...
>>> a
array([[[  0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15],
        [16, 17, 18, 19, 20, 21, 22, 23]],
       [[  0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15],
        [16, 17, 18, 19, 20, 21, 22, 23]]])
\end{verbatim}
To do buffered reduction requires yet another adjustment during the setup. Normally the iterator construction involves copying the first buffer of data from the readable arrays into the buffer. Any reduction operand is readable, so it may be read into a buffer. Unfortunately, initialization of the operand after this buffering operation is complete will not be reflected in the buffer that the iteration starts with, and garbage results will be produced.

The iterator flag “delay_bufalloc” is there to allow iterator-allocated reduction operands to exist together with buffering. When this flag is set, the iterator will leave its buffers uninitialized until it receives a reset, after which it will be ready for regular iteration. Here’s how the previous example looks if we also enable buffering.

Example

```python
>>> a = np.arange(24).reshape(2,3,4)
>>> it = np.nditer([a, None], flags=['reduce_ok', 'external_loop',
... 'buffered', 'delay_bufalloc'],
... op_axes=[None, [0,1,-1]],
... op_flags=[[readonly'], ['readwrite', 'allocate']],
... it.operands[1][...]] = 0
>>> it.reset()
>>> for x, y in it:
... y[...] += x
... it.operands[1]
array([[ 6, 22, 38],
[54, 70, 86]])
```

1.5.3 Putting the Inner Loop in Cython

Those who want really good performance out of their low level operations should strongly consider directly using the iteration API provided in C, but for those who are not comfortable with C or C++, Cython is a good middle ground with reasonable performance tradeoffs. For the `nditer` object, this means letting the iterator take care of broadcasting, dtype conversion, and buffering, while giving the inner loop to Cython.

For our example, we’ll create a sum of squares function. To start, let’s implement this function in straightforward Python. We want to support an ‘axis’ parameter similar to the numpy `sum` function, so we will need to construct a list for the `op_axes` parameter. Here’s how this looks.

Example

```python
>>> def axis_to_axeslist(axis, ndim):
... if axis is None:
... return [-1] * ndim
... else:
... if type(axis) is not tuple:
... op_axes=[None, [0,1,-1]]
```

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... axis = (axis,)
... axeslist = [1] * ndim
... for i in axis:
...     axeslist[i] = -1
... ax = 0
... for i in range(ndim):
...     if axeslist[i] != -1:
...         axeslist[i] = ax
...     ax += 1
... return axeslist

>>> def sum_squares_py(arr, axis=None, out=None):
...     axeslist = axis_to_axeslist(axis, arr.ndim)
...     it = np.nditer([arr, out], flags=['reduce_ok', 'external_loop',
...                          'buffered', 'delay_bufalloc'],
...                    op_flags=[['readonly'], ['readwrite', 'allocate']],
...                    op_axes=[None, axeslist],
...                    op_dtypes=['float64', 'float64'])
...     it.operands[1][...] = 0
...     it.reset()
...     for x, y in it:
...         y[...] += x*x
...     return it.operands[1]

>>> a = np.arange(6).reshape(2,3)
>>> sum_squares_py(a)
array(55.0)
>>> sum_squares_py(a, axis=-1)
array([ 5., 50.])

To Cython-ize this function, we replace the inner loop (y[...] += x*x) with Cython code that’s specialized for the float64 dtype. With the ‘external_loop’ flag enabled, the arrays provided to the inner loop will always be one-dimensional, so very little checking needs to be done.

Here’s the listing of sum_squares.pyx:

```python
import numpy as np
cimport numpy as np
cimport cython
def axis_to_axeslist(axis, ndim):
    if axis is None:
        return [-1] * ndim
    else:
        if type(axis) is not tuple:
            axis = (axis,)
        axeslist = [1] * ndim
        for i in axis:
            axeslist[i] = -1
        ax = 0
        for i in range(ndim):
            if axeslist[i] != -1:
                axeslist[i] = ax
                ax += 1
        return axeslist

@cython.boundscheck(False)
def sum_squares_cy(arr, axis=None, out=None):
```

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cdef np.ndarray[double] x
cdef np.ndarray[double] y
cdef int size
cdef double value

axeslist = axis_to_axeslist(axis, arr.ndim)
it = np.nditer([arr, out], flags=['reduce_ok', 'external_loop',
                   'buffered', 'delay_bufalloc'],
                      op_flags=[['readonly'], ['readwrite', 'allocate']],
                      op_axes=[None, axeslist],
                      op_dtypes=['float64', 'float64'])

it.operands[1][...] = 0
it.reset()

for xarr, yarr in it:
    x = xarr
    y = yarr
    size = x.shape[0]
    for i in range(size):
        value = x[i]
        y[i] = y[i] + value * value

return it.operands[1]

On this machine, building the .pyx file into a module looked like the following, but you may have to find some Cython tutorials to tell you the specifics for your system configuration:

$ cython sum_squares.pyx
$ gcc -shared -pthread -fPIC -fwrapv -O2 -Wall -I/usr/include/python2.7 -fno-strict-aliasing -o sum_squares.so sum_squares.c

Running this from the Python interpreter produces the same answers as our native Python/NumPy code did.

Example

```python
>>> from sum_squares import sum_squares_cy
>>> a = np.arange(6).reshape(2,3)
```
```python
>>> sum_squares_cy(a)
array(55.0)
```
```python
>>> sum_squares_cy(a, axis=-1)
array([ 5., 50.])
```

Doing a little timing in IPython shows that the reduced overhead and memory allocation of the Cython inner loop is providing a very nice speedup over both the straightforward Python code and an expression using NumPy’s built-in sum function:

```python
>>> a = np.random.rand(1000,1000)
```
```python
>>> timeit sum_squares_py(a, axis=-1)
10 loops, best of 3: 37.1 ms per loop
```
```python
>>> timeit np.sum(a*a, axis=-1)
10 loops, best of 3: 20.9 ms per loop
```
```python
>>> timeit sum_squares_cy(a, axis=-1)
100 loops, best of 3: 11.8 ms per loop
```
```python
>>> np.all(sum_squares_cy(a, axis=-1) == np.sum(a*a, axis=-1))
True
```
```python
>>> np.all(sum_squares_py(a, axis=-1) == np.sum(a*a, axis=-1))
```

1.5. Iterating Over Arrays
1.6 Standard array subclasses

The `ndarray` in NumPy is a “new-style” Python built-in-type. Therefore, it can be inherited from (in Python or in C) if desired. Therefore, it can form a foundation for many useful classes. Often whether to sub-class the array object or to simply use the core array component as an internal part of a new class is a difficult decision, and can be simply a matter of choice. NumPy has several tools for simplifying how your new object interacts with other array objects, and so the choice may not be significant in the end. One way to simplify the question is by asking yourself if the object you are interested in can be replaced as a single array or does it really require two or more arrays at its core.

Note that `asarray` always returns the base-class `ndarray`. If you are confident that your use of the array object can handle any subclass of an `ndarray`, then `asanyarray` can be used to allow subclasses to propagate more cleanly through your subroutine. In principal a subclass could redefine any aspect of the array and therefore, under strict guidelines, `asanyarray` would rarely be useful. However, most subclasses of the array object will not redefine certain aspects of the array object such as the buffer interface, or the attributes of the array. One important example, however, of why your subroutine may not be able to handle an arbitrary subclass of an array is that matrices redefine the “*” operator to be matrix-multiplication, rather than element-by-element multiplication.

1.6.1 Special attributes and methods

See also:

Subclassing `ndarray`

NumPy provides several hooks that classes can customize:

```python
class __array_finalize__(self)
    This method is called whenever the system internally allocates a new array from `obj`, where `obj` is a subclass (subtype) of the `ndarray`. It can be used to change attributes of `self` after construction (so as to ensure a 2-d matrix for example), or to update meta-information from the “parent.” Subclasses inherit a default implementation of this method that does nothing.

class __array_prepare__(array, context=None)
    At the beginning of every `ufunc`, this method is called on the input object with the highest array priority, or the output object if one was specified. The output array is passed in and whatever is returned is passed to the ufunc. Subclasses inherit a default implementation of this method which simply returns the output array unmodified. Subclasses may opt to use this method to transform the output array into an instance of the subclass and update metadata before returning the array to the ufunc for computation.

class __array_wrap__(array, context=None)
    At the end of every `ufunc`, this method is called on the input object with the highest array priority, or the output object if one was specified. The ufunc-computed array is passed in and whatever is returned is passed to the user. Subclasses inherit a default implementation of this method, which transforms the array into a new instance of the object’s class. Subclasses may opt to use this method to transform the output array into an instance of the subclass and update metadata before returning the array to the user.

class __array_priority__
    The value of this attribute is used to determine what type of object to return in situations where there is more than one possibility for the Python type of the returned object. Subclasses inherit a default value of 1.0 for this attribute.

class __array__(dtype]
    If a class (ndarray subclass or not) having the `__array__` method is used as the output object of an `ufunc`, results will be written to the object returned by `__array__`. Similar conversion is done on input arrays.
```
1.6.2 Matrix objects

`matrix` objects inherit from the `ndarray` and therefore, they have the same attributes and methods of ndarrays. There are six important differences of matrix objects, however, that may lead to unexpected results when you use matrices but expect them to act like arrays:

1. Matrix objects can be created using a string notation to allow Matlab-style syntax where spaces separate columns and semicolons (`;`) separate rows.

2. Matrix objects are always two-dimensional. This has far-reaching implications, in that `m.ravel()` is still two-dimensional (with a 1 in the first dimension) and item selection returns two-dimensional objects so that sequence behavior is fundamentally different than arrays.

3. Matrix objects over-ride multiplication to be matrix-multiplication. **Make sure you understand this for functions that you may want to receive matrices. Especially in light of the fact that `asanyarray(m)` returns a matrix when `m` is a matrix.**

4. Matrix objects over-ride power to be matrix raised to a power. The same warning about using power inside a function that uses `asanyarray(...)` to get an array object holds for this fact.

5. The default `__array_priority__` of matrix objects is 10.0, and therefore mixed operations with ndarrays always produce matrices.

6. Matrices have special attributes which make calculations easier. These are

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>matrix.T</code></td>
<td>Returns the transpose of the matrix.</td>
</tr>
<tr>
<td><code>matrix.H</code></td>
<td>Returns the (complex) conjugate transpose of self.</td>
</tr>
<tr>
<td><code>matrix.I</code></td>
<td>Returns the (multiplicative) inverse of invertible self.</td>
</tr>
<tr>
<td><code>matrix.A</code></td>
<td>Return self as an ndarray object.</td>
</tr>
</tbody>
</table>

**matrix.T**

Returns the transpose of the matrix.

Does **not** conjugate! For the complex conjugate transpose, use `.H`.

**Parameters**

None

**Returns**

`ret` : matrix object

The (non-conjugated) transpose of the matrix.

**See also:**

`transpose`, `getH`

**Examples**

```python
>>> m = np.matrix(' [1, 2; 3, 4]')
>>> m
matrix([[1, 2],
        [3, 4]])
>>> m.getT()
matrix([[1, 3],
        [2, 4]])

matrix.H

Returns the (complex) conjugate transpose of self.

Equivalent to `np.transpose(self)` if `self` is real-valued.
Parameters
None

Returns
ret : matrix object
complex conjugate transpose of self

Examples
>>> x = np.matrix(np.arange(12).reshape((3,4)))
>>> z = x - 1j*x; z
matrix([[ 0. +0.j, 1. -1.j, 2. -2.j, 3. -3.j],
>>> z.getH()
matrix([[ 0. +0.j, 4. +4.j, 8. +8.j],
       [ 1. +1.j, 5. +5.j, 9. +9.j],
       [ 2. +2.j, 6. +6.j, 10.+10.j],
       [ 3. +3.j, 7. +7.j, 11.+11.j]])

matrix.I
Returns the (multiplicative) inverse of invertible self.

Parameters
None

Returns
ret : matrix object
If self is non-singular, ret is such that ret * self == self * ret ==
np.matrix(np.eye(self[0,:].size) all return True.

Raises
numpy.linalg.LinAlgError: Singular matrix
If self is singular.

See also:

linalg.inv

Examples
>>> m = np.matrix(' [1, 2; 3, 4]'); m
matrix([[1, 2],
        [3, 4]])
>>> m.getI()
matrix([[-2. ,  1. ],
        [ 1.5, -0.5]])
>>> m.getI() * m
matrix([[ 1.,  0.],
        [ 0.,  1.]])

matrix.A
Return self as an ndarray object.

Equivalent to np.asarray(self).

Parameters
None
Returns

```
ret : ndarray
    self as an ndarray
```

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])

>>> x.getA()
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
```

**Warning:** Matrix objects over-ride multiplication, ‘*’, and power, ‘**’, to be matrix-multiplication and matrix power, respectively. If your subroutine can accept sub-classes and you do not convert to base-class arrays, then you must use the ufuncs multiply and power to be sure that you are performing the correct operation for all inputs.

The matrix class is a Python subclass of the ndarray and can be used as a reference for how to construct your own subclass of the ndarray. Matrices can be created from other matrices, strings, and anything else that can be converted to an ndarray. The name “mat” is an alias for “matrix” in NumPy.

```
```

### class `numpy.matrix`

Returns a matrix from an array-like object, or from a string of data. A matrix is a specialized 2-D array that retains its 2-D nature through operations. It has certain special operators, such as `*` (matrix multiplication) and `**` (matrix power).

**Parameters**

- `data` : array_like or string
  - If `data` is a string, it is interpreted as a matrix with commas or spaces separating columns, and semicolons separating rows.

- `dtype` : data-type
  - Data-type of the output matrix.

- `copy` : bool
  - If `data` is already an `ndarray`, then this flag determines whether the data is copied (the default), or whether a view is constructed.

**See also:**

- `array`

**Examples**

```
>>> a = np.matrix('1 2; 3 4')
>>>
```

```
```python
>>> np.matrix([[1, 2], [3, 4]])
matrix([[1, 2],
        [3, 4]])
```

### Attributes

- **A**: Return `self` as an `ndarray` object.
- **A1**: Return `self` as a flattened `ndarray`.
- **H**: Returns the (complex) conjugate transpose of `self`.
- **I**: Returns the (multiplicative) inverse of invertible `self`.
- **T**: Returns the transpose of the matrix.
- **base**: Base object if memory is from some other object.
- **ctypes**: An object to simplify the interaction of the array with the ctypes module.
- **data**: Python buffer object pointing to the start of the array’s data.
- **dtype**: Data-type of the array’s elements.
- **flags**: Information about the memory layout of the array.
- **flat**: A 1-D iterator over the array.
- **imag**: The imaginary part of the array.
- **itemsize**: Length of one array element in bytes.
- **nbytes**: Total bytes consumed by the elements of the array.
- **ndim**: Number of array dimensions.
- **real**: The real part of the array.
- **shape**: Tuple of array dimensions.
- **size**: Number of elements in the array.
- **strides**: Tuple of bytes to step in each dimension when traversing an array.

```python
matrix.A
Return self as an ndarray object.

Equivalent to `np.asarray(self)`.

Parameters
None

Returns

**ret**: ndarray

`self` as an ndarray

Examples

```python
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.getA()
array([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
```

matrix.A1
Return self as a flattened ndarray.

Equivalent to `np.asarray(x).ravel()`.

Parameters
None
Returns

ret : ndarray

self, 1-D, as an ndarray

Examples

>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0, 1, 2, 3],
        [ 4, 5, 6, 7],
        [ 8, 9, 10, 11]])

>>> x.getA1()
array([ 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11])

matrix.H
Returns the (complex) conjugate transpose of self.
Equivalent to np.transpose(self) if self is real-valued.

Parameters
None

Returns
ret : matrix object
complex conjugate transpose of self

Examples

>>> x = np.matrix(np.arange(12).reshape((3,4)))
>>> z = x - 1j*x; z
matrix([[ 0. +0.j, 1. -1.j, 2. -2.j, 3. -3.j],

>>> z.getH()
matrix([[ 0. +0.j, 4. +4.j, 8. +8.j],
        [ 1. +1.j, 5. +5.j, 9. +9.j],
        [ 2. +2.j, 6. +6.j, 10.+10.j],
        [ 3. +3.j, 7. +7.j, 11.+11.j]])

matrix.I
Returns the (multiplicative) inverse of invertible self.

Parameters
None

Returns
ret : matrix object

If self is non-singular, ret is such that ret * self == self * ret ==
np.matrix(np.eye(self[0,:].size)) all return True.

Raises
numpy.linalg.LinAlgError: Singular matrix

If self is singular.

See also:
linalg.inv
Examples

```python
>>> m = np.matrix('[1, 2; 3, 4]'); m
matrix([[1, 2],
        [3, 4]])
>>> m.getI()
matrix([[ 2.,  1.],
        [-1.5, 0.5]])
>>> m.getI() * m
matrix([[ 1.,  0.],
        [ 0.,  1.]])
```

**matrix.T**

Returns the transpose of the matrix.

Does *not* conjugate! For the complex conjugate transpose, use .H.

**Parameters**

None

**Returns**

ret : matrix object

The (non-conjugated) transpose of the matrix.

**See also:**

 transpose, getH

Examples

```python
>>> m = np.matrix('[1, 2; 3, 4]')
>>> m
matrix([[1, 2],
        [3, 4]])
>>> m.getT()
matrix([[1, 3],
        [2, 4]])
```

**matrix.base**

Base object if memory is from some other object.

Examples

The base of an array that owns its memory is None:

```python
>>> x = np.array([1, 2, 3, 4])
>>> x.base is None
True
```

Slicing creates a view, whose memory is shared with x:

```python
>>> y = x[2:]
>>> y.base is x
True
```

**matrix.ctypes**

An object to simplify the interaction of the array with the ctypes module.

This attribute creates an object that makes it easier to use arrays when calling shared libraries with the ctypes module. The returned object has, among others, data, shape, and strides attributes (see Notes below) which themselves return ctypes objects that can be used as arguments to a shared library.
Parameters
None

Returns
c : Python object

Possessing attributes data, shape, strides, etc.

See also:
numpy.ctypeslib

Notes
Below are the public attributes of this object which were documented in “Guide to NumPy” (we have omitted undocumented public attributes, as well as documented private attributes):

• data: A pointer to the memory area of the array as a Python integer. This memory area may contain data that is not aligned, or not in correct byte-order. The memory area may not even be writeable. The array flags and data-type of this array should be respected when passing this attribute to arbitrary C-code to avoid trouble that can include Python crashing. User Beware! The value of this attribute is exactly the same as self._array_interface_['data'][0].

• shape (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the C-integer corresponding to dtype('p') on this platform. This base-type could be c_int, c_long, or c_longlong depending on the platform. The c_intp type is defined accordingly in numpy.ctypeslib. The ctypes array contains the shape of the underlying array.

• strides (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the same as for the shape attribute. This ctypes array contains the strides information from the underlying array. This strides information is important for showing how many bytes must be jumped to get to the next element in the array.

• data_as(obj): Return the data pointer cast to a particular c-types object. For example, calling self._as_parameter_ is equivalent to self.data_as(ctypes.c_void_p). Perhaps you want to use the data as a pointer to a ctypes array of floating-point data: self.data_as(ctypes.POINTER(ctypes.c_double)).

• shape_as(obj): Return the shape tuple as an array of some other c-types type. For example: self.shape_as(ctypes.c_short).

• strides_as(obj): Return the strides tuple as an array of some other c-types type. For example: self.strides_as(ctypes.c_longlong).

Be careful using the ctypes attribute - especially on temporary arrays or arrays constructed on the fly. For example, calling (a+b).ctypes.data_as(ctypes.c_void_p) returns a pointer to memory that is invalid because the array created as (a+b) is deallocated before the next Python statement. You can avoid this problem using either c=a+b or ct=(a+b).ctypes. In the latter case, ct will hold a reference to the array until ct is deleted or re-assigned.

If the ctypes module is not available, then the ctypes attribute of array objects still returns something useful, but ctypes objects are not returned and errors may be raised instead. In particular, the object will still have the as parameter attribute which will return an integer equal to the data attribute.

Examples
>>> import ctypes
>>> x
array([[0, 1],
       [2, 3]])
>>> x.astype.data
30439712

1.6. Standard array subclasses
matrix.data
Python buffer object pointing to the start of the array’s data.

matrix.dtype
Data-type of the array’s elements.

Parameters
None

Returns
d : numpy dtype object

See also:
numpy.dtype

Examples
>>> x
array([[0, 1],
       [2, 3]])
>>> x.dtype
dtype('int32')
>>> type(x.dtype)
<type 'numpy.dtype'>

matrix.flags
Information about the memory layout of the array.

Notes
The flags object can be accessed dictionary-like (as in a.flags['WRITEABLE']), or by using lowercase attribute names (as in a.flags.writeable). Short flag names are only supported in dictionary access.

Only the UPDATEIFCOPY, WRITEABLE, and ALIGNED flags can be changed by the user, via direct assignment to the attribute or dictionary entry, or by calling ndarray.setflags.

The array flags cannot be set arbitrarily:

• UPDATEIFCOPY can only be set False.

• ALIGNED can only be set True if the data is truly aligned.

• WRITEABLE can only be set True if the array owns its own memory or the ultimate owner of the memory exposes a writeable buffer interface or is a string.
Arrays can be both C-style and Fortran-style contiguous simultaneously. This is clear for 1-dimensional arrays, but can also be true for higher dimensional arrays.

Even for contiguous arrays a stride for a given dimension \( \text{arr.strides}[\text{dim}] \) may be arbitrary if \( \text{arr.shape}[\text{dim}] == 1 \) or the array has no elements. It does not generally hold that \( \text{self.strides}[-1] == \text{self.itemsize} \) for C-style contiguous arrays or \( \text{self.strides}[0] == \text{self.itemsize} \) for Fortran-style contiguous arrays is true.

**Attributes**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_CONTIGUOUS (C)</td>
<td>This data is in a single, C-style contiguous segment.</td>
</tr>
<tr>
<td>F_CONTIGUOUS (F)</td>
<td>This data is in a single, Fortran-style contiguous segment.</td>
</tr>
<tr>
<td>OWN_DATA (O)</td>
<td>The array owns the memory it uses or borrows it from another object.</td>
</tr>
<tr>
<td>WRITEABLE (W)</td>
<td>The data area can be written to. Setting this to False locks the data, making it read-only. A view (slice, etc.) inherits WRITEABLE from its base array at creation time, but a view of a writeable array may be subsequently locked while the base array remains writeable. (The opposite is not true, in that a view of a locked array may not be made writeable. However, currently, locking a base object does not lock any views that already reference it, so under that circumstance it is possible to alter the contents of a locked array via a previously created writeable view onto it.) Attempting to change a non-writeable array raises a RuntimeError exception. The data and all elements are aligned appropriately for the hardware.</td>
</tr>
<tr>
<td>ALIGNED (A)</td>
<td>This array is a copy of some other array. When this array is deallocated, the base array will be updated with the contents of this array.</td>
</tr>
<tr>
<td>UPDATEIFCOPY (U)</td>
<td>F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FNC</td>
<td>F_CONTIGUOUS or C_CONTIGUOUS (one-segment test).</td>
</tr>
<tr>
<td>FORC</td>
<td>BEHAVED</td>
</tr>
<tr>
<td>BEHAVED (B)</td>
<td>BEHAVED and C_CONTIGUOUS.</td>
</tr>
<tr>
<td>CARRAY (CA)</td>
<td>BEHAVED and F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FARRAY (FA)</td>
<td></td>
</tr>
</tbody>
</table>

**matrix.flat**

A 1-D iterator over the array.

This is a `numpy.flatiter` instance, which acts similarly to, but is not a subclass of, Python’s built-in iterator object.

**See also:**

**flatten**

Return a copy of the array collapsed into one dimension.

**flatiter**

**Examples**

```python
>>> x = np.arange(1, 7).reshape(2, 3)
>>> x
```
```python
code
array([[1, 2, 3],
       [4, 5, 6]])
>>> x.flat[3]
4
>>> x.T
array([[1, 4],
       [2, 5],
       [3, 6]])
>>> x.T.flat[3]
5
>>> type(x.flat)
<type 'numpy.flatiter'>
```

An assignment example:
```python
code
>>> x.flat = 3; x
array([[3, 3, 3],
       [3, 3, 3]])
>>> x.flat[[1,4]] = 1; x
array([[3, 1, 3],
       [3, 1, 3]])
```

### `matrix.imag`
The imaginary part of the array.

**Examples**
```python
code
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.imag
array([ 0.        , 0.70710678])
>>> x.imag.dtype
dtype('float64')
```

### `matrix.itemsize`
Length of one array element in bytes.

**Examples**
```python
code
>>> x = np.array([1,2,3], dtype=np.float64)
>>> x.itemsize
8
>>> x = np.array([1,2,3], dtype=np.complex128)
>>> x.itemsize
16
```

### `matrix.nbytes`
Total bytes consumed by the elements of the array.

**Notes**
Does not include memory consumed by non-element attributes of the array object.

**Examples**
```python
code
>>> x = np.zeros((3,5,2), dtype=np.complex128)
>>> x.nbytes
480
>>> np.prod(x.shape) * x.itemsize
480
matrix.ndim
Number of array dimensions.

Examples
>>> x = np.array([1, 2, 3])
>>> x.ndim
1
>>> y = np.zeros((2, 3, 4))
>>> y.ndim
3

matrix.real
The real part of the array.

See also:

numpy.real
equivalent function

Examples
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.real
array([ 1. , 0.70710678])
>>> x.real.dtype
dtype('float64')

matrix.shape
Tuple of array dimensions.

Notes
May be used to “reshape” the array, as long as this would not require a change in the total number of elements.

Examples
>>> x = np.array([1, 2, 3, 4])
>>> x.shape
(4,)
>>> y = np.zeros((2, 3, 4))
>>> y.shape
(2, 3, 4)
>>> y.shape = (3, 8)
>>> y
array([[ 0., 0., 0., 0., 0., 0., 0., 0.],
       [ 0., 0., 0., 0., 0., 0., 0., 0.],
       [ 0., 0., 0., 0., 0., 0., 0., 0.]])
>>> y.shape = (3, 6)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: total size of new array must be unchanged
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: total size of new array must be unchanged

matrix.size
Number of elements in the array.
Equivalent to \texttt{np.prod(a.shape)} i.e., the product of the array’s dimensions.

\textbf{Examples}

```python
>>> x = np.zeros((3, 5, 2), dtype=np.complex128)
>>> x.size
30
>>> np.prod(x.shape)
30
```

\textbf{matrix.strides}

Tuple of bytes to step in each dimension when traversing an array.

The byte offset of element (i[0], i[1], ..., i[n]) in an array \texttt{a} is:

\[
\text{offset} = \sum (\text{np.array(i) \times a.strides})
\]

A more detailed explanation of strides can be found in the “ndarray.rst” file in the NumPy reference guide.

\textbf{See also:}

numpy.lib.stride_tricks.as_strided

\textbf{Notes}

Imagine an array of 32-bit integers (each 4 bytes):

\[
x = \text{np.array([[0, 1, 2, 3, 4],}
[5, 6, 7, 8, 9]], \text{dtype=np.int32})
\]

This array is stored in memory as 40 bytes, one after the other (known as a contiguous block of memory). The strides of an array tell us how many bytes we have to skip in memory to move to the next position along a certain axis. For example, we have to skip 4 bytes (1 value) to move to the next column, but 20 bytes (5 values) to get to the same position in the next row. As such, the strides for the array \texttt{x} will be (20, 4).

\textbf{Examples}

```python
>>> y = np.reshape(np.arange(2*3*4), (2,3,4))
>>> y
array([[[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]],
       [[12, 13, 14, 15],
        [16, 17, 18, 19],
        [20, 21, 22, 23]])
>>> y.strides
(48, 16, 4)
>>> y[1,1,1]
17
>>> offset = sum(y.strides * np.array((1,1,1)))
>>> offset/y.itemsize
17

>>> x = np.reshape(np.arange(5*6*7*8), (5,6,7,8)).transpose(2,3,1,0)
>>> x.strides
(32, 4, 224, 1344)
>>> i = np.array([3,5,2,2])
>>> offset = sum(i * x.strides)
>>> x[i]
813
```
```python
>>> offset / x.itemsize
813
```

## Methods

- **all([axis, out])**:
  Test whether all matrix elements along a given axis evaluate to True.

- **any([axis, out])**:
  Test whether any array element along a given axis evaluates to True.

- **argmax([axis, out])**:
  Indices of the maximum values along an axis.

- **argmin([axis, out])**:
  Return the indices of the minimum values along an axis.

- **argpartition(kth[, axis, kind, order])**:
  Returns the indices that would partition this array.

- **argsort([axis, kind, order])**:
  Returns the indices that would sort this array.

- **astype(dtype[, order, casting, subok, copy])**:
  Copy of the array, cast to a specified type.

- **byteswap(inplace)**:
  Swap the bytes of the array elements Toggle between low-endian and big-endian data representation by returning a byteswapped array, optionally swapped in-place.

- **choose(choices[, out, mode])**:
  Use an index array to construct a new array from a set of choices.

- **clip(a_min, a_max[, out])**:
  Return an array whose values are limited to [a_min, a_max].

- **compress(condition[, axis, out])**:
  Return selected slices of this array along given axis.

- **conj()**:
  Return the complex conjugate, element-wise.

- **copy([order])**:
  Return a copy of the array.

- **cumprod([axis, dtype, out])**:
  Return the cumulative product of the elements along the given axis.

- **cumsum([axis, dtype, out])**:
  Return the cumulative sum of the elements along the given axis.

- **diagonal([offset, axis1, axis2])**:
  Return specified diagonals.

- **dot(b[, out])**:
  Dot product of two arrays.

- **dump(file)**:
  Dump a pickle of the array to the specified file.

- **dumps()**:
  Returns the pickle of the array as a string.

- **fill(value)**:
  Fill the array with a scalar value.

- **flatten([order])**:
  Return a copy of the array collapsed into one dimension.

- **getA()**:
  Return `self` as an `ndarray` object.

- **getA1()**:
  Return `self` as a flattened `ndarray`.

- **getH()**:
  Returns the (complex) conjugate transpose of `self`.

- **getI()**:
  Returns the (multiplicative) inverse of invertible `self`.

- **getT()**:
  Returns the transpose of the matrix.

- **getfield(dtype[, offset])**:
  Returns a field of the given array as a certain type.

- **item(*args)**:
  Copy an element of an array to a standard Python scalar and return it.

- **itemset(*args)**:
  Insert scalar into an array (scalar is cast to array’s dtype, if possible) There must be at least 1 argument, and define the last argument as `item`.

- **max([axis, out])**:
  Return the maximum value along an axis.

- **mean([axis, dtype, out])**:
  Returns the average of the matrix elements along the given axis.

- **min([axis, out])**:
  Return the minimum value along an axis.

- **newbyteorder([new_order])**:
  Return the array with the same data viewed with a different byte order.

- **partition(kth[, axis, kind, order])**:
  Rearranges the elements in the array in such a way that value of the element in kth position is in the position it would be in a sorted array.

- **prod([axis, dtype, out])**:
  Return the product of the array elements over the given axis.

- **ptp([axis, out])**:
  Peak-to-peak (maximum - minimum) value along the given axis.

- **put(indices, values[, mode])**:
  Set `a.flat[n] = values[n]` for all `n` in indices.

- **ravel([order])**:
  Return a flattened array.

- **repeat(repeats[, axis])**:
  Repeat elements of an array.

- **reshape(shape[, order])**:
  Returns an array containing the same data with a new shape.

- **resize(new_shape[, refcheck])**:
  Change shape and size of array in-place.

- **round(decimals, out)**:
  Return `a` with each element rounded to the given number of decimals.

- **searchsorted(v[, side, sorter])**:
  Find indices where elements of v should be inserted in a to maintain order.

- **setfield(val, dtype[, offset])**:
  Put a value into a specified place in a field defined by a data-type.

- **setflags([write, align, uic])**:
  Set array flags WRITEABLE, ALIGNED, and UPDATEIFCOPY, respectively.

- **sort([axis, kind, order])**:
  Sort an array, in-place.

**1.6. Standard array subclasses**

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<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>squeeze(axis)</code></td>
<td>Remove single-dimensional entries from the shape of <code>a</code>.</td>
</tr>
<tr>
<td><code>std([axis, dtype, out, ddof])</code></td>
<td>Return the standard deviation of the array elements along the given axis.</td>
</tr>
<tr>
<td><code>sum([axis, dtype, out])</code></td>
<td>Returns the sum of the matrix elements, along the given axis.</td>
</tr>
<tr>
<td><code>swapaxes(axis1, axis2)</code></td>
<td>Return a view of the array with <code>axis1</code> and <code>axis2</code> interchanged.</td>
</tr>
<tr>
<td><code>take(indices[, axis, out, mode])</code></td>
<td>Construct Python bytes containing the raw data bytes in the array.</td>
</tr>
<tr>
<td><code>tobyeast([order])</code></td>
<td>Write array to a file as text or binary (default).</td>
</tr>
<tr>
<td><code>tolist()</code></td>
<td>Return the matrix as a (possibly nested) list.</td>
</tr>
<tr>
<td><code>tostring([order])</code></td>
<td>Construct Python bytes containing the raw data bytes in the array.</td>
</tr>
<tr>
<td><code>trace(offset, axis1, axis2, dtype, out)</code></td>
<td>Return the sum along diagonals of the array.</td>
</tr>
<tr>
<td><code>transpose(*axes)</code></td>
<td>Returns a view of the array with axes transposed.</td>
</tr>
<tr>
<td><code>var([axis, dtype, out, ddof])</code></td>
<td>Returns the variance of the matrix elements, along the given axis.</td>
</tr>
<tr>
<td><code>view([dtype, type])</code></td>
<td>New view of array with the same data.</td>
</tr>
</tbody>
</table>

### matrix.all

Test whether all matrix elements along a given axis evaluate to True.

**Parameters**

See ‘numpy.all’ for complete descriptions

See also:

`numpy.all`

**Notes**

This is the same as `ndarray.all`, but it returns a `matrix` object.

**Examples**

```python
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> y = x[0]; y
matrix([[0, 1, 2, 3]])
>>> (x == y)
matrix([[ True,  True,  True,  True],
        [False, False, False, False],
        [False, False, False, False]], dtype=bool)
>>> (x == y).all()
False
>>> (x == y).all(0)
matrix([[False, False, False, False]], dtype=bool)
>>> (x == y).all(1)
matrix([[ True],
        [False],
        [False]], dtype=bool)
```

**matrix.any**

Test whether any array element along a given axis evaluates to True.

Refer to `numpy.any` for full documentation.

**Parameters**

- **axis**: int, optional
  - Axis along which logical OR is performed
**NumPy Reference, Release 1.9.2**

out : ndarray, optional

Output to existing array instead of creating new one, must have same shape as expected output

Returns

any : bool, ndarray

Returns a single bool if axis is None; otherwise, returns ndarray

matrix.argmax(\texttt{axis=\text{None}, out=\text{None}})

Indices of the maximum values along an axis.

Parameters

See ‘numpy.argmax‘ for complete descriptions

See also:

\texttt{numpy.argmax}

Notes

This is the same as \texttt{ndarray.argmax}, but returns a \texttt{matrix} object where \texttt{ndarray.argmax} would return an \texttt{ndarray}.

Examples

\begin{verbatim}
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0, 1, 2, 3],
        [ 4, 5, 6, 7],
        [ 8, 9, 10, 11]])
>>> x.argmax()
11
>>> x.argmax(0)
matrix([[2, 2, 2, 2]])
>>> x.argmax(1)
matrix([[3],
        [3],
        [3]])
\end{verbatim}

matrix.argmin(\texttt{axis=\text{None}, out=\text{None}})

Return the indices of the minimum values along an axis.

Parameters

See ‘numpy.argmin‘ for complete descriptions.

See also:

\texttt{numpy.argmin}

Notes

This is the same as \texttt{ndarray.argmin}, but returns a \texttt{matrix} object where \texttt{ndarray.argmin} would return an \texttt{ndarray}.

Examples

\begin{verbatim}
>>> x = -np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0, -1, -2, -3],
        [ -4, -5, -6, -7],
        [ -8, -9, -10, -11]])
>>> x.argmin()
11
\end{verbatim}
```
>>> x.argmin(0)
matrix([[2, 2, 2, 2]])
>>> x.argmin(1)
matrix([[3],
        [3],
        [3]])
```

```
matrix.argpartition (kth, axis=-1, kind='introselect', order=None)
Returns the indices that would partition this array.

Refer to `numpy.argpartition` for full documentation.

New in version 1.8.0.

See also:

```
numpy.argpartition
   equivalent function
```

```
matrix.argsort (axis=-1, kind='quicksort', order=None)
Returns the indices that would sort this array.

Refer to `numpy.argsort` for full documentation.

See also:

```
numpy.argsort
   equivalent function
```

```
matrix.astype (dtype, order='K', casting='unsafe', subok=True, copy=True)
Copy of the array, cast to a specified type.

Parameters
```
dtype : str or dtype
Typecode or data-type to which the array is cast.

order : {'C', 'F', 'A', 'K'}, optional
Controls the memory layout order of the result. ‘C’ means C order, ‘F’ means Fortran order. ‘A’ means ‘F’ order if all the arrays are Fortran contiguous, ‘C’ order otherwise, and ‘K’ means as close to the order the array elements appear in memory as possible. Default is ‘K’.

casting : {'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional
Controls what kind of data casting may occur. Defaults to ‘unsafe’ for backwards compatibility.
- ‘no’ means the data types should not be cast at all.
- ‘equiv’ means only byte-order changes are allowed.
- ‘safe’ means only casts which can preserve values are allowed.
- ‘same_kind’ means only safe casts or casts within a kind, like float64 to float32, are allowed.
- ‘unsafe’ means any data conversions may be done.

subok : bool, optional
```
If True, then sub-classes will be passed-through (default), otherwise the returned array will be forced to be a base-class array.

`copy` : bool, optional

By default, astype always returns a newly allocated array. If this is set to false, and the dtype, order, and subok requirements are satisfied, the input array is returned instead of a copy.

Returns

`arr_t` : ndarray

Unless copy is False and the other conditions for returning the input array are satisfied (see description for copy input paramter), `arr_t` is a new array of the same shape as the input array, with dtype, order given by dtype, order.

Raises

ComplexWarning

When casting from complex to float or int. To avoid this, one should use a.real.astype(t).

Notes

Starting in NumPy 1.9, astype method now returns an error if the string dtype to cast to is not long enough in ‘safe’ casting mode to hold the max value of integer/float array that is being casted. Previously the casting was allowed even if the result was truncated.

Examples

```python
>>> x = np.array([1, 2, 2.5])
>>> x
array([ 1. , 2. , 2.5])

>>> x.astype(int)
array([1, 2, 2])
```

`matrix.byteswap` (inplace)

Swap the bytes of the array elements

Toggle between low-endian and big-endian data representation by returning a byteswapped array, optionally swapped in-place.

Parameters

`inplace` : bool, optional

If True, swap bytes in-place, default is False.

Returns

`out` : ndarray

The byteswapped array. If inplace is True, this is a view to self.

Examples

```python
>>> A = np.array([1, 256, 8755], dtype=np.int16)
>>> map(hex, A)
['0x1', '0x100', '0x2233']

>>> A.byteswap(True)
array([256, 1, 13090], dtype=int16)
>>> map(hex, A)
['0x100', '0x1', '0x3322']
```
Arrays of strings are not swapped

```python
>>> A = np.array(['ceg', 'fac'])
>>> A.byteswap()
array(['ceg', 'fac'],
      dtype='|S3')
```

**matrix.choose**(choices, out=None, mode='raise')

Use an index array to construct a new array from a set of choices.

Refer to `numpy.choose` for full documentation.

See also:

- `numpy.choose`
  - equivalent function

**matrix.clip**(a_min, a_max, out=None)

Return an array whose values are limited to `[a_min, a_max]`.

Refer to `numpy.clip` for full documentation.

See also:

- `numpy.clip`
  - equivalent function

**matrix.compress**(condition, axis=None, out=None)

Return selected slices of this array along given axis.

Refer to `numpy.compress` for full documentation.

See also:

- `numpy.compress`
  - equivalent function

**matrix.conj**( )

Complex-conjugate all elements.

Refer to `numpy.conjugate` for full documentation.

See also:

- `numpy.conjugate`
  - equivalent function

**matrix.conjugate**( )

Return the complex conjugate, element-wise.

Refer to `numpy.conjugate` for full documentation.

See also:

- `numpy.conjugate`
  - equivalent function

**matrix.copy**(order='C')

Return a copy of the array.
Parameters

order : {'C', 'F', 'A', 'K'}, optional

Controls the memory layout of the copy. ‘C’ means C-order, ‘F’ means F-order, ‘A’
means ‘F’ if a is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of a as
closely as possible. (Note that this function and :func:numpy.copy are very similar, but
have different default values for their order= arguments.)

See also:
numpy.copy, numpy.copyto

Examples

>>> x = np.array([[1, 2, 3], [4, 5, 6]], order='F')

>>> y = x.copy()

>>> x.fill(0)

>>> x
array([[0, 0, 0],
       [0, 0, 0]])

>>> y
array([[1, 2, 3],
       [4, 5, 6]])

>>> y.flags['C_CONTIGUOUS']
True

matrix.cumprod(axis=None, dtype=None, out=None)
Return the cumulative product of the elements along the given axis.
Refer to numpy.cumprod for full documentation.

See also:

numpy.cumprod

   equivalent function

matrix.cumsum(axis=None, dtype=None, out=None)
Return the cumulative sum of the elements along the given axis.
Refer to numpy.cumsum for full documentation.

See also:

numpy.cumsum

   equivalent function

matrix.diagonal(offset=0, axis1=0, axis2=1)
Return specified diagonals. In NumPy 1.9 the returned array is a read-only view instead of a copy as in
previous NumPy versions. In NumPy 1.10 the read-only restriction will be removed.
Refer to numpy.diagonal for full documentation.

See also:

numpy.diagonal

   equivalent function

1.6. Standard array subclasses
matrix.dot(b, out=None)

Dot product of two arrays.

Refer to numpy.dot for full documentation.

See also:

numpy.dot

equivalent function

Examples

>>> a = np.eye(2)
>>> b = np.ones((2, 2)) * 2
>>> a.dot(b)
array([[ 2.,  2.],
       [ 2.,  2.]])

This array method can be conveniently chained:

>>> a.dot(b).dot(b)
array([[ 8.,  8.],
       [ 8.,  8.]])

matrix.dump(file)

Dump a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

Parameters

file : str

A string naming the dump file.

matrix.dumps()

Returns the pickle of the array as a string. pickle.loads or numpy.loads will convert the string back to an array.

Parameters

None

matrix.fill(value)

Fill the array with a scalar value.

Parameters

value : scalar

All elements of a will be assigned this value.

Examples

>>> a = np.array([1, 2])
>>> a.fill(0)
>>> a
array([0, 0])

>>> a = np.empty(2)
>>> a.fill(1)
>>> a
array([1., 1.])

matrix.flatten(order='C')

Return a copy of the array collapsed into one dimension.
Parameters

order: {'C', 'F', 'A'}, optional

Whether to flatten in C (row-major), Fortran (column-major) order, or preserve the
C/Fortran ordering from a. The default is ‘C’.

Returns

y : ndarray

A copy of the input array, flattened to one dimension.

See also:

ravel
Return a flattened array.

flat
A 1-D flat iterator over the array.

Examples

>>> a = np.array([[1,2], [3,4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])

matrix.getA()

Return self as an ndarray object.

Equivalent to np.asarray(self).

Parameters

None

Returns

ret : ndarray

self as an ndarray

Examples

>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0, 1, 2, 3],
        [ 4, 5, 6, 7],
        [ 8, 9, 10, 11]])
>>> x.getA()
array([[ 0, 1, 2, 3],
        [ 4, 5, 6, 7],
        [ 8, 9, 10, 11]])

matrix.getA1()

Return self as a flattened ndarray.

Equivalent to np.asarray(x).ravel()

Parameters

None

Returns

ret : ndarray

self, 1-D, as an ndarray
Examples

```python
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
```

```
>>> x.getA1()
array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11])
```

documentation.

```python
matrix.getH()
Returns the (complex) conjugate transpose of self.

Equivalent to np.transpose(self) if self is real-valued.

Parameters
None

Returns
ret : matrix object
complex conjugate transpose of self
```

Examples

```python
>>> x = np.matrix(np.arange(12).reshape((3,4)))
```

```python
>>> z = x - 1j*x; z
matrix([[ 0. +0.j, 1. -1.j, 2. -2.j, 3. -3.j],
```

```
>>> z.getH()
matrix([[ 0. +0.j, 4. +4.j, 8. +8.j],
        [ 1. +1.j, 5. +5.j, 9. +9.j],
        [ 2. +2.j, 6. +6.j, 10.+10.j],
        [ 3. +3.j, 7. +7.j, 11.+11.j]])
```

```python
matrix.getI()
Returns the (multiplicative) inverse of invertible self.

Parameters
None

Returns
ret : matrix object
If self is non-singular, ret is such that ret * self == self * ret ==
np.matrix(np.eye(self[0,:].size)) all return True.

Raises
numpy.linalg.LinAlgError: Singular matrix
If self is singular.

See also:
linalg.inv
```

Examples

```python
>>> m = np.matrix('[[1, 2; 3, 4]]'); m
matrix([[1, 2],
        [3, 4]])
```

```
>>> m.getI()
matrix([[-2. ,  1. ],
        [ 1. , -0.5]])
```
matrix.getT()

Returns the transpose of the matrix.

Does not conjugate! For the complex conjugate transpose, use .H.

Parameters
None

Returns
ret : matrix object

The (non-conjugated) transpose of the matrix.

See also:
transpose, getH

Examples

```python
>>> m = np.matrix('[1, 2; 3, 4]')
>>> m
matrix([[1, 2],
        [3, 4]])
>>> m.getT()
matrix([[1, 3],
        [2, 4]])
```

matrix.getfield(dtype, offset=0)

Returns a field of the given array as a certain type.

A field is a view of the array data with a given data-type. The values in the view are determined by the given type and the offset into the current array in bytes. The offset needs to be such that the view dtype fits in the array dtype; for example an array of dtype complex128 has 16-byte elements. If taking a view with a 32-bit integer (4 bytes), the offset needs to be between 0 and 12 bytes.

Parameters
dtype : str or dtype
    The data type of the view. The dtype size of the view can not be larger than that of the array itself.

offset : int
    Number of bytes to skip before beginning the element view.

Examples

```python
>>> x = np.diag([1.+1.j]*2)
>>> x[1, 1] = 2 + 4.j
>>> x
array([[ 1.+1.j, 0.+0.j],
       [ 0.+0.j, 2.+4.j]])
>>> x.getfield(np.float64)
array([[ 1., 0.],
       [ 0., 2.]]
```

By choosing an offset of 8 bytes we can select the complex part of the array for our view:
>>> x.getfield(np.float64, offset=8)
array([[ 1.,  0.],
       [ 0.,  4.]]

matrix.item(*args)
Copy an element of an array to a standard Python scalar and return it.

Parameters
*args : Arguments (variable number and type)
  • none: in this case, the method only works for arrays with one element (a.size == 1), which element is copied into a standard Python scalar object and returned.
  • int_type: this argument is interpreted as a flat index into the array, specifying which element to copy and return.
  • tuple of int_types: functions as does a single int_type argument, except that the argument is interpreted as an nd-index into the array.

Returns
z : Standard Python scalar object
A copy of the specified element of the array as a suitable Python scalar

Notes
When the data type of a is longdouble or clongdouble, item() returns a scalar array object because there is no available Python scalar that would not lose information. Void arrays return a buffer object for item(), unless fields are defined, in which case a tuple is returned.

item is very similar to a[args], except, instead of an array scalar, a standard Python scalar is returned. This can be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using Python’s optimized math.

Examples
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[3, 1, 7],
       [2, 8, 3],
       [8, 5, 3]])
>>> x.item(3)
2
>>> x.item(7)
5
>>> x.item((0, 1))
1
>>> x.item((2, 2))
3

matrix.itemset(*args)
Insert scalar into an array (scalar is cast to array’s dtype, if possible)

There must be at least 1 argument, and define the last argument as item. Then, a.itemset(*args) is equivalent to but faster than a[args] = item. The item should be a scalar value and args must select a single item in the array a.

Parameters
*args : Arguments
If one argument: a scalar, only used in case \( a \) is of size 1. If two arguments: the last argument is the value to be set and must be a scalar, the first argument specifies a single array element location. It is either an int or a tuple.

**Notes**

Compared to indexing syntax, *itemset* provides some speed increase for placing a scalar into a particular location in an *ndarray*, if you must do this. However, generally this is discouraged: among other problems, it complicates the appearance of the code. Also, when using *itemset* (and *item*) inside a loop, be sure to assign the methods to a local variable to avoid the attribute look-up at each loop iteration.

**Examples**

```python
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[3, 1, 7],
       [2, 8, 3],
       [8, 5, 3]])
>>> x.itemset(4, 0)
>>> x.itemset((2, 2), 9)
>>> x
array([[3, 1, 7],
       [2, 0, 3],
       [8, 5, 9]])
```

**matrix.max (axis=None, out=None)**

Return the maximum value along an axis.

**Parameters**

See ‘amax‘ for complete descriptions

**See also:**

amax, ndarray.max

**Notes**

This is the same as ndarray.max, but returns a matrix object where ndarray.max would return an ndarray.

**Examples**

```python
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.max()
11
>>> x.max(0)
matrix([[ 8,  9, 10, 11]])
>>> x.max(1)
matrix([[ 3],
        [ 7],
        [11]])
```

**matrix.mean (axis=None, dtype=None, out=None)**

Returns the average of the matrix elements along the given axis.

Refer to numpy.mean for full documentation.

**See also:**

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numpy.mean

Notes
Same as ndarray.mean except that, where that returns an ndarray, this returns a matrix object.

Examples
```python
>>> x = np.matrix(np.arange(12).reshape((3, 4)))
>>> x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.mean()
5.5
>>> x.mean(0)
matrix([[ 4.,  5.,  6.,  7.]])
>>> x.mean(1)
matrix([[ 1.5],
        [ 5.5],
        [ 9.5]])
```

matrix.min (axis=None, out=None)
Return the minimum value along an axis.

Parameters
See ‘amin’ for complete descriptions.

See also:
amin, ndarray.min

Notes
This is the same as ndarray.min, but returns a matrix object where ndarray.min would return an ndarray.

Examples
```python
>>> x = -np.matrix(np.arange(12).reshape((3, 4))); x
matrix([[ 0, -1, -2, -3],
        [-4, -5, -6, -7],
        [-8, -9, -10, -11]])
>>> x.min()
-11
>>> x.min(0)
matrix([[ -8, -9, -10, -11]])
>>> x.min(1)
matrix([[ -3],
        [ -7],
        [-11]])
```

matrix.newbyteorder (new_order='S')
Return the array with the same data viewed with a different byte order.

Equivalent to:
```python
arr.view(arr.dtype.newbyteorder(new_order))
```

Changes are also made in all fields and sub-arrays of the array data type.
Parameters

new_order : string, optional

Byte order to force; a value from the byte order specifications above. new_order codes can be any of:

* 'S' - swap dtype from current to opposite endian
* {'<', 'L'} - little endian
* {'>', 'B'} - big endian
* {'=', 'N'} - native order
* {'|', 'I'} - ignore (no change to byte order)

The default value ('S') results in swapping the current byte order. The code does a case-insensitive check on the first letter of new_order for the alternatives above. For example, any of ‘B’ or ‘b’ or ‘biggish’ are valid to specify big-endian.

Returns

new_arr : array

New array object with the dtype reflecting given change to the byte order.

matrix.nonzero()

Return the indices of the elements that are non-zero.

Refer to numpy.nonzero for full documentation.

See also:

numpy.nonzero

equivalent function

matrix.partition(kth, axis=-1, kind='introselect', order=None)

Rearranges the elements in the array in such a way that value of the element in kth position is in the position it would be in a sorted array. All elements smaller than the kth element are moved before this element and all equal or greater are moved behind it. The ordering of the elements in the two partitions is undefined.

New in version 1.8.0.

Parameters

kth : int or sequence of ints

Element index to partition by. The kth element value will be in its final sorted position and all smaller elements will be moved before it and all equal or greater elements behind it. The order all elements in the partitions is undefined. If provided with a sequence of kth it will partition all elements indexed by kth of them into their sorted position at once.

axis : int, optional

Axis along which to sort. Default is -1, which means sort along the last axis.

kind : {'introselect'}, optional

Selection algorithm. Default is ‘introselect’.

order : list, optional

When a is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

See also:
**numpy.partition**
Return a partitioned copy of an array.

**argpartition**
Indirect partition.

**sort**
Full sort.

**Notes**
See np.partition for notes on the different algorithms.

**Examples**
```python
g = np.array([3, 4, 2, 1])
g.argmax()  # return 0
```

**matrix.prod** *(axis=None, dtype=None, out=None)*
Return the product of the array elements over the given axis.

Refer to prod for full documentation.

See also:
prod, ndarray.prod

**Notes**
Same as ndarray.prod, except, where that returns an ndarray, this returns a matrix object instead.

**Examples**
```python
g = np.matrix(np.arange(12).reshape((3,4)))
g.prod()  # return 0
```

**matrix.ptp** *(axis=None, out=None)*
Peak-to-peak (maximum - minimum) value along the given axis.

Refer to numpy.ptp for full documentation.

See also:
numpy.ptp
Notes

Same as `ndarray.ptp`, except, where that would return an `ndarray` object, this returns a `matrix` object.

Examples

```python
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
```

```python
>>> x.ptp()
11
```

```python
>>> x.ptp(0)
matrix([[ 8,  8,  8,  8]])
```

```python
>>> x.ptp(1)
matrix([[3],
        [3],
        [3]])
```

`matrix.put(indices, values, mode='raise')`

Set `a.flat[n] = values[n]` for all `n` in `indices`.

Refer to `numpy.put` for full documentation.

See also:

- `numpy.put` equivalent function

`matrix.ravel([order])`

Return a flattened array.

Refer to `numpy.ravel` for full documentation.

See also:

- `numpy.ravel` equivalent function

`ndarray.flat`

a flat iterator on the array.

`matrix.repeat(repeats, axis=None)`

Repeat elements of an array.

Refer to `numpy.repeat` for full documentation.

See also:

- `numpy.repeat` equivalent function

`matrix.reshape(shape, order='C')`

Returns an array containing the same data with a new shape.

Refer to `numpy.reshape` for full documentation.

See also:
numpy.reshape
equivalent function

matrix.resize(new_shape, refcheck=True)
Change shape and size of array in-place.

Parameters

new_shape : tuple of ints, or n ints
Shape of resized array.
refcheck : bool, optional
If False, reference count will not be checked. Default is True.

Returns
None

Raises

ValueError
If a does not own its own data or references or views to it exist, and the data memory must be changed.

SystemError
If the order keyword argument is specified. This behaviour is a bug in NumPy.

See also:

resize
Return a new array with the specified shape.

Notes
This reallocates space for the data area if necessary.
Only contiguous arrays (data elements consecutive in memory) can be resized.
The purpose of the reference count check is to make sure you do not use this array as a buffer for another Python object and then reallocate the memory. However, reference counts can increase in other ways so if you are sure that you have not shared the memory for this array with another Python object, then you may safely set refcheck to False.

Examples
Shrinking an array: array is flattened (in the order that the data are stored in memory), resized, and re-shaped:

```python
>>> a = np.array([[0, 1], [2, 3]], order='C')
>>> a.resize((2, 1))
>>> a
array([[0],
       [1]])
```

```python
>>> a = np.array([[0, 1], [2, 3]], order='F')
>>> a.resize((2, 1))
>>> a
array([[0],
       [2]])
```

Enlarging an array: as above, but missing entries are filled with zeros:
```python
>>> b = np.array([[0, 1], [2, 3]])
>>> b.resize(2, 3)  # new_shape parameter doesn’t have to be a tuple
>>> b
array([[0, 1, 2],
       [3, 0, 0]])

Referencing an array prevents resizing...

```
Returns
None

See also:
getfield

Examples
>>> x = np.eye(3)
>>> x.getfield(np.float64)
array([[ 1., 0., 0.],
       [ 0., 1., 0.],
       [ 0., 0., 1.]])
>>> x.setfield(3, np.int32)
>>> x.getfield(np.int32)
array([[3, 3, 3],
       [3, 3, 3],
       [3, 3, 3]])

matrix.setflags(write=None, align=None, uic=None)
Set array flags WRITEABLE, ALIGNED, and UPDATEIFCOPY, respectively.
These Boolean-valued flags affect how numpy interprets the memory area used by a (see Notes below).
The ALIGNED flag can only be set to True if the data is actually aligned according to the type. The UPDATEIFCOPY flag can never be set to True if the array owns its own memory, or the ultimate owner of the memory exposes a writeable buffer interface, or is a string. (The exception for string is made so that unpickling can be done without copying memory.)

Parameters
write : bool, optional
Describes whether or not a can be written to.
align : bool, optional
Describes whether or not a is aligned properly for its type.
uic : bool, optional
Describes whether or not a is a copy of another “base” array.

Notes
Array flags provide information about how the memory area used for the array is to be interpreted. There are 6 Boolean flags in use, only three of which can be changed by the user: UPDATEIFCOPY, WRITEABLE, and ALIGNED.
WRITEABLE (W) the data area can be written to;
ALIGNED (A) the data and strides are aligned appropriately for the hardware (as determined by the compiler);
UPDATEIFCOPY (U) this array is a copy of some other array (referenced by .base). When this array is deallocated, the base array will be updated with the contents of this array.

All flags can be accessed using their first (upper case) letter as well as the full name.

**Examples**

```python
>>> y
array([[3, 1, 7],
       [2, 0, 0],
       [8, 5, 9]])
>>> y.flags
C_CONTIGUOUS : True
F_CONTIGUOUS : False
OWNDATA : True
WRITEABLE : True
ALIGNED : True
UPDATEIFCOPY : False

>>> y.setflags(write=0, align=0)
>>> y.flags
C_CONTIGUOUS : True
F_CONTIGUOUS : False
OWNDATA : True
WRITEABLE : False
ALIGNED : False
UPDATEIFCOPY : False

>>> y.setflags(uic=1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: cannot set UPDATEIFCOPY flag to True

matrix.sort (axis=-1, kind='quicksort', order=None)
Sort an array, in-place.

**Parameters**

- **axis**: int, optional
  
  Axis along which to sort. Default is -1, which means sort along the last axis.

- **kind**: {'quicksort', 'mergesort', 'heapsort'}, optional
  
  Sorting algorithm. Default is 'quicksort'.

- **order**: list, optional
  
  When a is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

**See also:**

- **numpy.sort**
  
  Return a sorted copy of an array.

- **argsort**
  
  Indirect sort.

- **lexsort**
  
  Indirect stable sort on multiple keys.
**searchsorted**
Find elements in sorted array.

**partition**
Partial sort.

**Notes**
See `sort` for notes on the different sorting algorithms.

**Examples**
```python
g = np.array([[1, 4], [3, 1]])
g.sort(axis=1)
g
array([[1, 4],
       [1, 3]])
g.sort(axis=0)
g
array([[1, 3],
       [1, 4]])
```

Use the `order` keyword to specify a field to use when sorting a structured array:
```python
g = np.array([('a', 2), ('c', 1)], dtype=[('x', 'S1'), ('y', int)])
g.sort(order='y')
g
array([('c', 1), ('a', 2)],
      dtype=[('x', '|S1'), ('y', '<i4')])
```

**matrix.squeeze** *(axis=None)*
Remove single-dimensional entries from the shape of `a`.

Refer to `numpy.squeeze` for full documentation.

See also:

* `numpy.squeeze`

**matrix.std** *(axis=None, dtype=None, out=None, ddof=0)*
Return the standard deviation of the array elements along the given axis.

Refer to `numpy.std` for full documentation.

See also:

* `numpy.std`

**Notes**
This is the same as `ndarray.std`, except that where an `ndarray` would be returned, a `matrix` object is returned instead.

**Examples**
```python
>>> x = np.matrix(np.arange(12).reshape((3, 4)))
>>> x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
```
```python
>>> x.std()
3.4520525295346629
>>> x.std(0)
matrix([[ 3.26598632,  3.26598632,  3.26598632,  3.26598632]])
>>> x.std(1)
matrix([[ 1.11803399],
        [ 1.11803399],
        [ 1.11803399]])
```

```markdown
matrix.sum(axis=None, dtype=None, out=None)

Returns the sum of the matrix elements, along the given axis.

Refer to `numpy.sum` for full documentation.

See also:

`numpy.sum`

**Notes**

This is the same as `ndarray.sum`, except that where an `ndarray` would be returned, a `matrix` object is returned instead.

**Examples**

```python
>>> x = np.matrix([[1, 2], [4, 3]])
>>> x.sum()
10
>>> x.sum(axis=1)
matrix([[3],
        [7]])
>>> x.sum(axis=1, dtype='float')
matrix([[ 3.],
        [ 7.]])
>>> out = np.zeros((1, 2), dtype='float')
>>> x.sum(axis=1, dtype='float', out=out)
matrix([[ 3.],
        [ 7.]])
```

```python
matrix.swapaxes(axis1, axis2)

Return a view of the array with `axis1` and `axis2` interchanged.

Refer to `numpy.swapaxes` for full documentation.

See also:

`numpy.swapaxes`

**equivalent function**

```python
matrix.take(indices, axis=None, out=None, mode='raise')

Return an array formed from the elements of `a` at the given indices.

Refer to `numpy.take` for full documentation.

See also:

`numpy.take`

**equivalent function**
```
NumPy Reference, Release 1.9.2

matrix.tobytes(order=’C’)
Construct Python bytes containing the raw data bytes in the array.
Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object can be
produced in either ‘C’ or ‘Fortran’, or ‘Any’ order (the default is ‘C’-order). ‘Any’ order means C-order
unless the F_CONTIGUOUS flag in the array is set, in which case it means ‘Fortran’ order.
New in version 1.9.0.
Parameters
order : {‘C’, ‘F’, None}, optional
Order of the data for multidimensional arrays: C, Fortran, or the same as for the original
array.
Returns
s : bytes
Python bytes exhibiting a copy of a‘s raw data.
Examples
>>> x = np.array([[0, 1], [2, 3]])
>>> x.tobytes()
b’\x00\x00\x00\x00\x01\x00\x00\x00\x02\x00\x00\x00\x03\x00\x00\x00’
>>> x.tobytes(’C’) == x.tobytes()
True
>>> x.tobytes(’F’)
b’\x00\x00\x00\x00\x02\x00\x00\x00\x01\x00\x00\x00\x03\x00\x00\x00’

matrix.tofile(fid, sep=”“, format=”%s”)
Write array to a file as text or binary (default).
Data is always written in ‘C’ order, independent of the order of a. The data produced by this method can
be recovered using the function fromfile().
Parameters
fid : file or str
An open file object, or a string containing a filename.
sep : str
Separator between array items for text output. If “” (empty), a binary file is written,
equivalent to file.write(a.tobytes()).
format : str
Format string for text file output. Each entry in the array is formatted to text by first
converting it to the closest Python type, and then using “format” % item.
Notes
This is a convenience function for quick storage of array data. Information on endianness and precision
is lost, so this method is not a good choice for files intended to archive data or transport data between
machines with different endianness. Some of these problems can be overcome by outputting the data as
text files, at the expense of speed and file size.
matrix.tolist()
Return the matrix as a (possibly nested) list.
See ndarray.tolist for full documentation.
See also:
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Chapter 1. Array objects


Examples

```python
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
```
```python
>>> x.tolist()
[[0, 1, 2, 3], [4, 5, 6, 7], [8, 9, 10, 11]]
```

matrix.tostring(order='C')
Construct Python bytes containing the raw data bytes in the array.

Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object can be produced in either 'C' or 'Fortran', or 'Any' order (the default is 'C'-order). 'Any' order means C-order unless the F_CONTIGUOUS flag in the array is set, in which case it means 'Fortran' order.

This function is a compatibility alias for tobytes. Despite its name it returns bytes not strings.

Parameters

- **order**: {'C', 'F', None}, optional
  Order of the data for multidimensional arrays: C, Fortran, or the same as for the original array.

Returns

- **s**: bytes
  Python bytes exhibiting a copy of a’s raw data.

Examples

```python
>>> x = np.array([[0, 1], [2, 3]])
```
```python
>>> x.tobytes()  
'b\x00\x00\x00\x00\x01\x00\x00\x00\x02\x00\x00\x00\x03\x00\x00\x00\x00\x00\x00\x00'
```
```python
>>> x.tobytes('C') == x.tobytes()
True
```
```python
>>> x.tobytes('F')
'b\x00\x00\x00\x00\x02\x00\x00\x00\x01\x00\x00\x00\x03\x00\x00\x00\x00\x00\x00\x00'
```

matrix.trace(offset=0, axis1=0, axis2=1, dtype=None, out=None)
Return the sum along diagonals of the array.

Refer to `numpy.trace` for full documentation.

See also:

- `numpy.trace`
  equivalent function

matrix.transpose(*axes)
Returns a view of the array with axes transposed.

For a 1-D array, this has no effect. (To change between column and row vectors, first cast the 1-D array into a matrix object.) For a 2-D array, this is the usual matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided and `a.shape = (i[0], i[1], ... i[n-2], i[n-1])`, then `a.transpose().shape = (i[n-1], i[n-2], ... i[1], i[0])`. 

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Parameters
axes : None, tuple of ints, or n ints
  • None or no argument: reverses the order of the axes.
  • tuple of ints: i in the j-th place in the tuple means a’s i-th axis becomes a.transpose()’s j-th axis.
  • n ints: same as an n-tuple of the same ints (this form is intended simply as a “convenience” alternative to the tuple form)

Returns
out : ndarray
  View of a, with axes suitably permuted.

See also:
ndarray.T
  Array property returning the array transposed.

Examples
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])

matrix.var (axis=None, dtype=None, out=None, ddof=0)
Returns the variance of the matrix elements, along the given axis.

Refer to numpy.var for full documentation.

See also:
numpy.var

Notes
This is the same as ndarray.var, except that where an ndarray would be returned, a matrix object is returned instead.

Examples
>>> x = np.matrix(np.arange(12).reshape((3, 4)))
>>> x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.var()
11.916666666666666
>>> x.var(0)
matrix([[ 10.66666667,  10.66666667,  10.66666667,  10.66666667]])
matrix\texttt{}.view (\texttt{dtype=}\texttt{None, type=}\texttt{None})

New view of array with the same data.

**Parameters**

\texttt{dtype} : data-type or ndarray sub-class, optional

Data-type descriptor of the returned view, e.g., float32 or int16. The default, None, results in the view having the same data-type as \texttt{a}. This argument can also be specified as an ndarray sub-class, which then specifies the type of the returned object (this is equivalent to setting the \texttt{type} parameter).

\texttt{type} : Python type, optional

Type of the returned view, e.g., ndarray or matrix. Again, the default None results in type preservation.

**Notes**

\texttt{a.view()} is used two different ways:

\texttt{a.view(some\_dtype)} or \texttt{a.view(dtype=some\_dtype)} constructs a view of the array’s memory with a different data-type. This can cause a reinterpretation of the bytes of memory.

\texttt{a.view(ndarray\_subclass)} or \texttt{a.view(type=ndarray\_subclass)} just returns an instance of\texttt{ndarray\_subclass} that looks at the same array (same shape, dtype, etc.) This does not cause a reinterpretation of the memory.

For \texttt{a.view(some\_dtype)}, if \texttt{some\_dtype} has a different number of bytes per entry than the previous dtype (for example, converting a regular array to a structured array), then the behavior of the view cannot be predicted just from the superficial appearance of \texttt{a} (shown by \texttt{print(a)}). It also depends on exactly how \texttt{a} is stored in memory. Therefore if \texttt{a} is C-ordered versus fortran-ordered, versus defined as a slice or transpose, etc., the view may give different results.

**Examples**

```python
>>> x = np.array([(1, 2)], dtype=[('a', np.int8), ('b', np.int8)])
```

Viewing array data using a different type and dtype:

```python
>>> y = x.view(dtype=np.int16, type=np.matrix)
```

```python
>>> y
matrix([[513]], dtype=int16)
```

```python
>>> print type(y)
<class 'numpy.matrixlib.defmatrix.matrix'>
```

Creating a view on a structured array so it can be used in calculations

```python
>>> x = np.array([(1, 2), (3, 4)], dtype=[('a', np.int8), ('b', np.int8)])
>>> xv = x.view(dtype=np.int8).reshape(-1,2)
>>> xv
array([[1, 2],
       [3, 4]], dtype=int8)
>>> xv.mean(0)
array([2., 3.])
```

Making changes to the view changes the underlying array
```python
>>> xv[0, 1] = 20
>>> print x
[(1, 20) (3, 4)]

Using a view to convert an array to a record array:

```python
>>> z = x.view(np.recarray)
``` python
>>> z.a
array([1], dtype=int8)
```

Views share data:

```python
>>> x[0] = (9, 10)
>>> z[0]
(9, 10)
```

Views that change the dtype size (bytes per entry) should normally be avoided on arrays defined by slices, transposes, fortran-ordering, etc.:

```python
>>> x = np.array([[1, 2, 3], [4, 5, 6]], dtype=np.int16)
>>> y = x[:, 0:2]
>>> y
array([[1, 2],
       [4, 5]], dtype=int16)
>>> y.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: new type not compatible with array.
```

```python
>>> z = y.copy()
>>> z.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: new type not compatible with array.
```

numpy.asmatrix(data, dtype=None)

Interpret the input as a matrix.

Unlike matrix, asmatrix does not make a copy if the input is already a matrix or an ndarray. Equivalent to `matrix(data, copy=False)`.

**Parameters**

- **data**: array_like
  Input data.

**Returns**

- **mat**: matrix
  `data` interpreted as a matrix.

**Examples**

```python
>>> x = np.array([[1, 2], [3, 4]])
>>> m = np.asmatrix(x)
>>> x[0, 0] = 5
```
```
>>> m
matrix([[5, 2],
        [3, 4]])
```

**numpy.bmat**(obj, ldict=None, gdict=None)

Build a matrix object from a string, nested sequence, or array.

**Parameters**

- **obj** : str or array_like

  Input data. Names of variables in the current scope may be referenced, even if `obj` is a string.

**Returns**

- **out** : matrix

  Returns a matrix object, which is a specialized 2-D array.

**See also:**

matrix

**Examples**

```python
>>> A = np.mat('1 1; 1 1')
>>> B = np.mat('2 2; 2 2')
>>> C = np.mat('3 4; 5 6')
>>> D = np.mat('7 8; 9 0')
```

All the following expressions construct the same block matrix:

```python
>>> np.bmat([[A, B], [C, D]])
matrix([[1, 1, 2, 2],
        [1, 1, 2, 2],
        [3, 4, 7, 8],
        [5, 6, 9, 0]])
```

```python
>>> np.bmat(np.r_[np.c_[A, B], np.c_[C, D]])
matrix([[1, 1, 2, 2],
        [1, 1, 2, 2],
        [3, 4, 7, 8],
        [5, 6, 9, 0]])
```

```python
>>> np.bmat('A,B; C,D')
matrix([[1, 1, 2, 2],
        [1, 1, 2, 2],
        [3, 4, 7, 8],
        [5, 6, 9, 0]])
```

**Example 1:** Matrix creation from a string

```python
>>> a=mat('1 2 3; 4 5 3')
>>> print(a*a.T).I
[[ 0.2924 -0.1345]
 [-0.1345 0.0819]]
```

**Example 2:** Matrix creation from nested sequence

```python
>>> mat([[1,5,10],[1.0,3,4j]])
matrix([[ 1.+0.j, 5.+0.j, 10.+0.j],
        [ 1.+0.j, 3.+0.j, 0.+4.j]])
```

**Example 3:** Matrix creation from an array

1.6. Standard array subclasses

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>>> mat(random.rand(3,3)).T

matrix([[ 0.7699, 0.7922, 0.3294],
         [ 0.2792, 0.0101, 0.9219],
         [ 0.3398, 0.7571, 0.8197]])

1.6.3 Memory-mapped file arrays

Memory-mapped files are useful for reading and/or modifying small segments of a large file with regular layout, without reading the entire file into memory. A simple subclass of the ndarray uses a memory-mapped file for the data buffer of the array. For small files, the overhead of reading the entire file into memory is typically not significant, however for large files using memory mapping can save considerable resources.

Memory-mapped file arrays have one additional method (besides those they inherit from the ndarray): `.flush()` which must be called manually by the user to ensure that any changes to the array actually get written to disk.

**Note:** Memory-mapped arrays use the the Python memory-map object which (prior to Python 2.5) does not allow files to be larger than a certain size depending on the platform. This size is always < 2GB even on 64-bit systems.

```
memmap
memmap.flush()  # Create a memory-map to an array stored in a binary file on disk.
memmap.flush()  # Write any changes in the array to the file on disk.
```

class `numpy.memmap`

Create a memory-map to an array stored in a binary file on disk.

Memory-mapped files are used for accessing small segments of large files on disk, without reading the entire file into memory. Numpy’s memmap’s are array-like objects. This differs from Python’s `mmap` module, which uses file-like objects.

This subclass of ndarray has some unpleasant interactions with some operations, because it doesn’t quite fit properly as a subclass. An alternative to using this subclass is to create the `mmap` object yourself, then create an ndarray with ndarray.__new__ directly, passing the object created in its ‘buffer=’ parameter.

This class may at some point be turned into a factory function which returns a view into an mmap buffer.

Delete the memmap instance to close.

**Parameters**

- **filename** : str or file-like object
  - The file name or file object to be used as the array data buffer.

- **dtype** : data-type, optional
  - The data-type used to interpret the file contents. Default is `uint8`.

- **mode** : {'r+', 'r', 'w+', 'c'}, optional
  - The file is opened in this mode:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>'r'</td>
<td>Open existing file for reading only.</td>
</tr>
<tr>
<td>'r+'</td>
<td>Open existing file for reading and writing.</td>
</tr>
<tr>
<td>'w+'</td>
<td>Create or overwrite existing file for reading and writing.</td>
</tr>
<tr>
<td>'c'</td>
<td>Copy-on-write: assignments affect data in memory, but changes are not saved to disk. The file on disk is read-only.</td>
</tr>
</tbody>
</table>

Default is ‘r+’.

- **offset** : int, optional
In the file, array data starts at this offset. Since offset is measured in bytes, it should normally be a multiple of the byte-size of dtype. When mode != ‘r’, even positive offsets beyond end of file are valid; The file will be extended to accommodate the additional data. By default, memmap will start at the beginning of the file, even if filename is a file pointer fp and fp.tell() != 0.

**shape**: tuple, optional

The desired shape of the array. If mode == ‘r’ and the number of remaining bytes after offset is not a multiple of the byte-size of dtype, you must specify shape. By default, the returned array will be 1-D with the number of elements determined by file size and data-type.

**order**: {'C', 'F'}, optional

Specify the order of the ndarray memory layout: C (row-major) or Fortran (column-major). This only has an effect if the shape is greater than 1-D. The default order is ‘C’.

**Notes**

The memmap object can be used anywhere an ndarray is accepted. Given a memmap fp, isinstance(fp, numpy.ndarray) returns True.

Memory-mapped arrays use the Python memory-map object which (prior to Python 2.5) does not allow files to be larger than a certain size depending on the platform. This size is always < 2GB even on 64-bit systems.

**Examples**

```python
>>> data = np.arange(12, dtype='float32')
>>> data.resize((3,4))

This example uses a temporary file so that doctest doesn’t write files to your directory. You would use a ‘normal’ filename.

```python
>>> from tempfile import mkdtemp
>>> import os.path as path

```python
>>> filename = path.join(mkdtemp(), 'newfile.dat')

```python
Create a memmap with dtype and shape that matches our data:

```python
>>> fp = np.memmap(filename, dtype='float32', mode='w+', shape=(3,4))
>>> fp
memmap([[ 0., 0., 0., 0.],
         [ 0., 0., 0., 0.],
         [ 0., 0., 0., 0.]], dtype=float32)

Write data to memmap array:

```python
>>> fp[:] = data[:]
>>> fp
memmap([[ 0., 1., 2., 3.],
         [ 4., 5., 6., 7.],
         [ 8., 9., 10., 11.]], dtype=float32)

>>> fp.filename == path.abspath(filename)
True

Deletion flushes memory changes to disk before removing the object:
>>> del fp

Load the memmap and verify data was stored:
>>> newfp = np.memmap(filename, dtype='float32', mode='r', shape=(3,4))
>>> newfp
memmap([[ 0., 1., 2., 3.],
        [ 4., 5., 6., 7.],
        [ 8., 9., 10., 11.]], dtype=float32)

Read-only memmap:
>>> fpr = np.memmap(filename, dtype='float32', mode='r', shape=(3,4))
>>> fpr.flags.writeable
False

Copy-on-write memmap:
>>> fpc = np.memmap(filename, dtype='float32', mode='c', shape=(3,4))
>>> fpc.flags.writeable
True

It’s possible to assign to copy-on-write array, but values are only written into the memory copy of the array, and not written to disk:

>>> fpc
memmap([[ 0., 1., 2., 3.],
        [ 4., 5., 6., 7.],
        [ 8., 9., 10., 11.]], dtype=float32)
>>> fpc[0,:] = 0
>>> fpc
memmap([[ 0., 0., 0., 0.],
        [ 4., 5., 6., 7.],
        [ 8., 9., 10., 11.]], dtype=float32)

File on disk is unchanged:

>>> fpr
memmap([[ 0., 1., 2., 3.],
        [ 4., 5., 6., 7.],
        [ 8., 9., 10., 11.]], dtype=float32)

Offset into a memmap:

>>> fpo = np.memmap(filename, dtype='float32', mode='r', offset=16)
>>> fpo
memmap([ 4., 5., 6., 7., 8., 9., 10., 11.], dtype=float32)

Attributes

| filename | (str) Path to the mapped file. |
| offset   | (int) Offset position in the file. |
| mode     | (str) File mode. |

Methods

flush()   Write any changes in the array to the file on disk.
memmap.flush()
    Write any changes in the array to the file on disk.
    For further information, see memmap.

Parameters
    None

See also:
    memmap

Example:

>>> a = memmap('newfile.dat', dtype=float, mode='w+', shape=1000)
>>> a[10] = 10.0
>>> a[30] = 30.0
>>> del a
>>> b = fromfile('newfile.dat', dtype=float)
>>> print b[10], b[30]
10.0 30.0
>>> a = memmap('newfile.dat', dtype=float)
>>> print a[10], a[30]
10.0 30.0

1.6.4 Character arrays (numpy.char)

See also:
    Creating character arrays (numpy.char)

Note: The chararray class exists for backwards compatibility with Numarray, it is not recommended for
new development. Starting from numpy 1.4, if one needs arrays of strings, it is recommended to use arrays of dtype
object_, string_ or unicode_, and use the free functions in the numpy.char module for fast vectorized
string operations.

These are enhanced arrays of either string_ type or unicode_ type. These arrays inherit from the ndarray,
but specially-define the operations +, *, and % on a (broadcasting) element-by-element basis. These operations are
not available on the standard ndarray of character type. In addition, the chararray has all of the standard
string (and unicode) methods, executing them on an element-by-element basis. Perhaps the easiest way to create
a chararray is to use self.view(chararray) where self is an ndarray of str or unicode data-type. However, a
chararray can also be created using the numpy.chararray constructor, or via the numpy.char.array function:

<table>
<thead>
<tr>
<th>chararray</th>
<th>Provides a convenient view on arrays of string and unicode values.</th>
</tr>
</thead>
<tbody>
<tr>
<td>core.defchararray.array(obj[, itemsize, ...])</td>
<td>Create a chararray.</td>
</tr>
</tbody>
</table>

class numpy.chararray

1.6. Standard array subclasses
Provides a convenient view on arrays of string and unicode values.

**Note:** The `chararray` class exists for backwards compatibility with Numarray, it is not recommended for new development. Starting from numpy 1.4, if one needs arrays of strings, it is recommended to use arrays of `dtype object`, `string` or `unicode`, and use the free functions in the `numpy.char` module for fast vectorized string operations.

Versus a regular Numpy array of type `str` or `unicode`, this class adds the following functionality:

1. values automatically have whitespace removed from the end when indexed
2. comparison operators automatically remove whitespace from the end when comparing values
3. vectorized string operations are provided as methods (e.g. `endswith`) and infix operators (e.g. `+`, `*`, `%`)

Chararrays should be created using `numpy.char.array` or `numpy.char.asarray`, rather than this constructor directly.

This constructor creates the array, using `buffer` (with `offset` and `strides`) if it is not None. If `buffer` is None, then constructs a new array with `strides` in “C order”, unless both `len(shape) >= 2` and `order='Fortran'`, in which case `strides` is in “Fortran order”.

**Parameters**

- `shape` : tuple
  Shape of the array.
- `itemsize` : int, optional
  Length of each array element, in number of characters. Default is 1.
- `unicode` : bool, optional
  Are the array elements of type unicode (True) or string (False). Default is False.
- `buffer` : int, optional
  Memory address of the start of the array data. Default is None, in which case a new array is created.
- `offset` : int, optional
  Fixed stride displacement from the beginning of an axis? Default is 0. Needs to be >=0.
- `strides` : array_like of ints, optional
  Strides for the array (see `ndarray.strides` for full description). Default is None.
- `order` : {'C', 'F'}, optional
  The order in which the array data is stored in memory: ‘C’ -> “row major” order (the default), ‘F’ -> “column major” (Fortran) order.

**Examples**

```python
>>> charar = np.chararray((3, 3))
>>> charar[:] = 'a'
>>> charar
chararray([[a', 'a', 'a'],
          ['a', 'a', 'a'],
          ['a', 'a', 'a']],
         dtype='|S1')
```
>>> charar = np.chararray(charar.shape, itemsize=5)
>>> charar[:] = 'abc'
>>> charar
chararray([['abc', 'abc', 'abc'],
           ['abc', 'abc', 'abc'],
           ['abc', 'abc', 'abc']],
dtype='|S5')

Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>Same as self.transpose(), except that self is returned if self.ndim &lt; 2.</td>
</tr>
<tr>
<td>base</td>
<td>Base object if memory is from some other object.</td>
</tr>
<tr>
<td>ctypes</td>
<td>An object to simplify the interaction of the array with the ctypes module.</td>
</tr>
<tr>
<td>data</td>
<td>Python buffer object pointing to the start of the array’s data.</td>
</tr>
<tr>
<td>dtype</td>
<td>Data-type of the array’s elements.</td>
</tr>
<tr>
<td>flags</td>
<td>Information about the memory layout of the array.</td>
</tr>
<tr>
<td>flat</td>
<td>A 1-D iterator over the array.</td>
</tr>
<tr>
<td>imag</td>
<td>The imaginary part of the array.</td>
</tr>
<tr>
<td>itemsize</td>
<td>Length of one array element in bytes.</td>
</tr>
<tr>
<td>nbytes</td>
<td>Total bytes consumed by the elements of the array.</td>
</tr>
<tr>
<td>ndim</td>
<td>Number of array dimensions.</td>
</tr>
<tr>
<td>real</td>
<td>The real part of the array.</td>
</tr>
<tr>
<td>shape</td>
<td>Tuple of array dimensions.</td>
</tr>
<tr>
<td>size</td>
<td>Number of elements in the array.</td>
</tr>
<tr>
<td>strides</td>
<td>Tuple of bytes to step in each dimension when traversing an array.</td>
</tr>
</tbody>
</table>

chararray.T
Same as self.transpose(), except that self is returned if self.ndim < 2.

Examples

```python
>>> x = np.array([[1.,2.],[3.,4.]]
>>> x
array([[ 1., 2.],
       [ 3., 4.]])
>>> x.T
array([[ 1., 3.],
       [ 2., 4.]])
>>> x = np.array([1.,2.,3.,4.])
>>> x
array([ 1., 2., 3., 4.])
>>> x.T
array([ 1., 2., 3., 4.])
```

chararray.base
Base object if memory is from some other object.

Examples

The base of an array that owns its memory is None:

```python
>>> x = np.array([1,2,3,4])
>>> x.base is None
True
```

Slicing creates a view, whose memory is shared with `x`:

```python
>>> charar[0] = 'abc'
>>> charar
chararray([['abc', 'abc', 'abc'],
           ['abc', 'abc', 'abc'],
           ['abc', 'abc', 'abc']],
dtype='|S5')
```
>>> y = x[2:]
>>> y.base is x
True

chararray.ctypes

An object to simplify the interaction of the array with the ctypes module.

This attribute creates an object that makes it easier to use arrays when calling shared libraries with the ctypes module. The returned object has, among others, data, shape, and strides attributes (see Notes below) which themselves return ctypes objects that can be used as arguments to a shared library.

Parameters
None

Returns
c : Python object

Possessing attributes data, shape, strides, etc.

See also:
numpy.ctypeslib

Notes

Below are the public attributes of this object which were documented in “Guide to NumPy” (we have omitted undocumented public attributes, as well as documented private attributes):

•data: A pointer to the memory area of the array as a Python integer. This memory area may contain data that is not aligned, or not in correct byte-order. The memory area may not even be writeable. The array flags and data-type of this array should be respected when passing this attribute to arbitrary C-code to avoid trouble that can include Python crashing. User Beware! The value of this attribute is exactly the same as self._array_interface_['data'][0].

•shape (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the C-integer corresponding to dtype('p') on this platform. This base-type could be c_int, c_long, or c_longlong depending on the platform. The c_intp type is defined accordingly in numpy.ctypeslib. The ctypes array contains the shape of the underlying array.

•strides (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the same as for the shape attribute. This ctypes array contains the strides information from the underlying array. This strides information is important for showing how many bytes must be jumped to get to the next element in the array.

•data_as(obj): Return the data pointer cast to a particular c-types object. For example, calling self._as_parameter_ is equivalent to self.data_as(ctypes.c_void_p). Perhaps you want to use the data as a pointer to a ctypes array of floating-point data: self.data_as(ctypes.POINTER(ctypes.c_double)).

•shape_as(obj): Return the shape tuple as an array of some other c-types type. For example: self.shape_as(ctypes.c_short).

•strides_as(obj): Return the strides tuple as an array of some other c-types type. For example: self.strides_as(ctypes.c_longlong).

Be careful using the ctypes attribute - especially on temporary arrays or arrays constructed on the fly. For example, calling (a+b).ctypes.data_as(ctypes.c_void_p) returns a pointer to memory that is invalid because the array created as (a+b) is deallocated before the next Python statement. You can avoid this problem using either c=a+b or ct=(a+b).ctypes. In the latter case, ct will hold a reference to the array until ct is deleted or re-assigned.
If the ctypes module is not available, then the ctypes attribute of array objects still returns something useful, but ctypes objects are not returned and errors may be raised instead. In particular, the object will still have the as parameter attribute which will return an integer equal to the data attribute.

**Examples**

```python
globals()['ctypes']
```

```python
array([[0, 1],
       [2, 3]])
```

```python
x.ctypes.data
```

```python
30439712
```

```python
x.ctypes.data_as(ctypes.POINTER(ctypes.c_long)).contents
```

```python
c_long(0)
```

```python
x.ctypes.data_as(ctypes.POINTER(ctypes.c_longlong)).contents
```

```python
c_longlong(4294967296L)
```

```python
x.ctypes.shape
```

```python
<numpy.core._internal.c_long_Array_2 object at 0x01FFF580>
```

```python
x.ctypes.shape_as(ctypes.c_long)
```

```python
<numpy.core._internal.c_long_Array_2 object at 0x01FCE620>
```

```python
x.ctypes.strides
```

```python
<numpy.core._internal.c_longlong_Array_2 object at 0x01F01300>
```

chararray.data

Python buffer object pointing to the start of the array’s data.

chararray.dtype

Data type of the array’s elements.

**Parameters**

None

**Returns**

d : numpy dtype object

**See also:**

numpy.dtype

**Examples**

```python
array([[0, 1],
       [2, 3]])
```

```python
x
```

```python
dtype('int32')
```

```python
type(x.dtype)
```

```python
'type 'numpy.dtype''
```

chararray.flags

Information about the memory layout of the array.

**Notes**

The flags object can be accessed dictionary-like (as in a.flags['WRITEABLE']), or by using lower-cased attribute names (as in a.flags.writeable). Short flag names are only supported in dictionary access.
Only the UPDATEIFCOPY, WRITEABLE, and ALIGNED flags can be changed by the user, via direct assignment to the attribute or dictionary entry, or by calling `ndarray.setflags`.

The array flags cannot be set arbitrarily:

- UPDATEIFCOPY can only be set to False.
- ALIGNED can only be set to True if the data is truly aligned.
- WRITEABLE can only be set to True if the array owns its own memory or the ultimate owner of the memory exposes a writeable buffer interface or is a string.

Arrays can be both C-style and Fortran-style contiguous simultaneously. This is clear for 1-dimensional arrays, but can also be true for higher dimensional arrays.

Even for contiguous arrays a stride for a given dimension `arr.strides[dim]` may be arbitrary if `arr.shape[dim] == 1` or the array has no elements. It does not generally hold that `self.strides[-1] == self.itemsize` for C-style contiguous arrays or `self.strides[0] == self.itemsize` for Fortran-style contiguous arrays is true.

### Attributes

<table>
<thead>
<tr>
<th>Flag</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_CONTIGUOUS</td>
<td>This data is in a single, C-style contiguous segment.</td>
</tr>
<tr>
<td>F_CONTIGUOUS</td>
<td>This data is in a single, Fortran-style contiguous segment.</td>
</tr>
<tr>
<td>OWNDATA</td>
<td>The array owns the memory it uses or borrows it from another object.</td>
</tr>
<tr>
<td>WRITEABLE</td>
<td>The data area can be written to. Setting this to False locks the data, making it read-only. A view (slice, etc.) inherits WRITEABLE from its base array at creation time, but a view of a writable array may be subsequently locked while the base array remains writeable. (The opposite is not true, in that a view of a locked array may not be made writable. However, currently, locking a base object does not lock any views that already reference it, so under that circumstance it is possible to alter the contents of a locked array via a previously created writable view onto it.) Attempting to change a non-writeable array raises a RuntimeError exception. The data and all elements are aligned appropriately for the hardware. This array is a copy of some other array. When this array is deallocated, the base array will be updated with the contents of this array.</td>
</tr>
<tr>
<td>ALIGNED</td>
<td>F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
<tr>
<td>DATEIFCOPY</td>
<td>F_CONTIGUOUS or C_CONTIGUOUS (one-segment test).</td>
</tr>
<tr>
<td>BEHAVED</td>
<td>ALIGNED and WRITEABLE.</td>
</tr>
<tr>
<td>FNC</td>
<td>BEHAVED and C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FORC</td>
<td>BEHAVED and F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
<tr>
<td>chararray.flat</td>
<td>A 1-D iterator over the array. This is a <code>numpy.flatiter</code> instance, which acts similarly to, but is not a subclass of, Python’s built-in iterator object.</td>
</tr>
</tbody>
</table>

See also:
**flatten**

Return a copy of the array collapsed into one dimension.

**flatiter**

**Examples**

```python
>>> x = np.arange(1, 7).reshape(2, 3)
>>> x
array([[1, 2, 3],
       [4, 5, 6]])
>>> x.flat[3]
4
>>> x.T
array([[1, 4],
       [2, 5],
       [3, 6]])
>>> x.T.flat[3]
5
>>> type(x.flat)
<type 'numpy.flatiter'>
```

An assignment example:

```python
>>> x.flat = 3; x
array([[3, 3, 3],
       [3, 3, 3]])
```

**chararray.imag**

The imaginary part of the array.

**Examples**

```python
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.imag
array([ 0. , 0.70710678])
>>> x.imag.dtype
dtype('float64')
```

**chararray.itemsize**

Length of one array element in bytes.

**Examples**

```python
>>> x = np.array([1,2,3], dtype=np.float64)
>>> x.itemsize
8
>>> x = np.array([1,2,3], dtype=np.complex128)
>>> x.itemsize
16
```

**chararray.nbytes**

Total bytes consumed by the elements of the array.

**Notes**

Does not include memory consumed by non-element attributes of the array object.
Examples

```python
>>> x = np.zeros((3,5,2), dtype=np.complex128)
>>> x.nbytes
480
>>> np.prod(x.shape) * x.itemsize
480
```

`chararray.ndim`
Number of array dimensions.

Examples

```python
>>> x = np.array([1, 2, 3])
>>> x.ndim
1
>>> y = np.zeros((2, 3, 4))
>>> y.ndim
3
```

`chararray.real`
The real part of the array.

See also:

`numpy.real`
equivalent function

Examples

```python
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.real
array([ 1. , 0.70710678])
>>> x.real.dtype
dtype('float64')
```

`chararray.shape`
Tuple of array dimensions.

Notes
May be used to “reshape” the array, as long as this would not require a change in the total number of elements

Examples

```python
>>> x = np.array([1, 2, 3, 4])
>>> x.shape
(4,)
>>> y = np.zeros((2, 3, 4))
>>> y.shape
(2, 3, 4)
>>> y.shape = (3, 8)
>>> y
array([[ 0., 0., 0., 0., 0., 0., 0., 0.],
       [ 0., 0., 0., 0., 0., 0., 0., 0.],
       [ 0., 0., 0., 0., 0., 0., 0., 0.]])
>>> y.shape = (3, 6)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
```
chararray.size

Number of elements in the array.

Equivalent to np.prod(a.shape), i.e., the product of the array’s dimensions.

Examples

```python
>>> x = np.zeros((3, 5, 2), dtype=np.complex128)
>>> x.size
30
>>> np.prod(x.shape)
30
```

chararray.strides

Tuple of bytes to step in each dimension when traversing an array.

The byte offset of element \((i[0], i[1], \ldots, i[n])\) in an array \(a\) is:

\[
\text{offset} = \sum (\text{np.array}(i) \times a.\text{strides})
\]

A more detailed explanation of strides can be found in the “ndarray.rst” file in the NumPy reference guide.

See also:

numpy.lib.stride_tricks.as_strided

Notes

Imagine an array of 32-bit integers (each 4 bytes):

```python
x = np.array([[0, 1, 2, 3, 4],
              [5, 6, 7, 8, 9]], dtype=np.int32)
```

This array is stored in memory as 40 bytes, one after the other (known as a contiguous block of memory). The strides of an array tell us how many bytes we have to skip in memory to move to the next position along a certain axis. For example, we have to skip 4 bytes (1 value) to move to the next column, but 20 bytes (5 values) to get to the same position in the next row. As such, the strides for the array \(x\) will be \((20, 4)\).

Examples

```python
>>> y = np.reshape(np.arange(2*3*4), (2,3,4))
>>> y
array([[[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]],
       [[12, 13, 14, 15],
        [16, 17, 18, 19],
        [20, 21, 22, 23]]])
>>> y.strides
(48, 16, 4)
```

17

```python
>>> offset=sum(y.strides * np.array((1,1,1)))
>>> offset/y.itemsize
17
```
Methods

- **astype**<sup>1</sup>(dtype[, order, casting, subok, copy])  
  Copy of the array, cast to a specified type.
- **copy**<sup>1</sup>(order)  
  Return a copy of the array.
- **count**(sub[, start, end])  
  Returns an array with the number of non-overlapping occurrences of substring sub in the array.
- **decode**<sup>1</sup>([encoding, errors])  
  Calls str.decode element-wise.
- **dump**(file)  
  Dump a pickle of the array to the specified file.
- **dumpst**<sup>1</sup>()  
  Returns the pickle of the array as a string.
- **encode**<sup>1</sup>([encoding, errors])  
  Calls str.encode element-wise.
- **endwith**(suffix[, start, end])  
  Returns a boolean array which is True where the string element in self ends with suffix.
- **expandtabs**([tabsize])  
  Fill the array with a scalar value.
- **fill**(value)  
  For each element, return the lowest index in the string where substring sub is found.
- **find**(sub[, start, end])  
  For each element, return the index of the elements that are non-zero.
- **flatten**(order)  
  Return a copy of the array collapsed into one dimension.
- **getfield**(dtype[, offset])  
  Returns a field of the given array as a certain type.
- **index**(sub[, start, end])  
  Like find, but raises ValueError when the substring is not found.
- **isalnum**()  
  Returns true for each element if all characters in the string are alphanumeric and there is at least one character.
- **isalpha**()  
  Returns true for each element if all characters in the string are alphabetic and there is at least one character.
- **isdecimal**()  
  Returns true for each element if all characters in the string are digits and there is at least one character.
- **isdigit**()  
  Returns true for each element if all characters in the string are digits and there is at least one character.
- **isspace**()  
  Returns true for each element if there are only whitespace characters in the string and there is at least one character.
- **isnumeric**()  
  Returns true for each element if there are only numeric characters in the element.
- **isupper**()  
  Returns true for each element if all characters in the string are uppercase and there is at least one character.
- **islower**()  
  Returns true for each element if all characters in the string are lowercase and there is at least one character.
- **isspace**()  
  Returns true for each element if there are only numeric characters in the element.
- **lower()**  
  For each element, return a copy with the leading characters removed.
- **lstrip**(chars)  
  Return a copy of the array where each string element in self has its leading characters removed.
- **nonzero**(order)  
  Return the indices of the elements that are non-zero.
- **put**(indices, values[, mode])  
  Set a.flat[n] = values[n] for all n in indices.
- **ravel**(order)  
  Return a flattened array.
- **repeat**(repeats[, axis])  
  Repeat elements of an array.
- **replace**(old, new[, count])  
  For each element in self, return a copy of the string with all occurrences of substring old replaced by new.
- **reshape**(shape[, order])  
  Returns an array containing the same data with a new shape.
- **resize**(new_shape[, refcheck])  
  Change shape and size of array in-place.
- **rfind**(sub[, start, end])  
  For each element in self, return the highest index in the string where substring sub is found.
- **rjust**(width[, fillchar])  
  For each element in self, return a copy with the trailing characters removed.
- **rpeate**(repeats[, axis])  
  Repeat elements of an array.
- **replace**(old, new[, count])  
  For each element in self, return a copy of the string with all occurrences of substring old replaced by new.
- **reshape**(shape[, order])  
  Returns an array containing the same data with a new shape.
- **resize**(new_shape[, refcheck])  
  Change shape and size of array in-place.
- **rfind**(sub[, start, end])  
  For each element in self, return the highest index in the string where substring sub is found.
- **rjust**(width[, fillchar])  
  For each element in self, return a copy with the trailing characters removed.
- **repeat**(repeats[, axis])  
  Repeat elements of an array.
- **replace**(old, new[, count])  
  For each element in self, return a copy of the string with all occurrences of substring old replaced by new.
- **reshape**(shape[, order])  
  Returns an array containing the same data with a new shape.
- **resize**(new_shape[, refcheck])  
  Change shape and size of array in-place.
- **rfind**(sub[, start, end])  
  For each element in self, return the highest index in the string where substring sub is found.
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>setfield(val, dtype[, offset])</code></td>
<td>Put a value into a specified place in a field defined by a data-type.</td>
</tr>
<tr>
<td><code>setflags([write, align, uic])</code></td>
<td>Set array flags WRITEABLE, ALIGNED, and UPDATEIFCOPY, respectively.</td>
</tr>
<tr>
<td><code>sort([axis, kind, order])</code></td>
<td>Sort an array, in-place.</td>
</tr>
<tr>
<td><code>split([sep, maxsplit])</code></td>
<td>For each element in <code>self</code>, return a list of the words in the string, using <code>sep</code> as the delimiter.</td>
</tr>
<tr>
<td><code>splitlines([keepends])</code></td>
<td>For each element in <code>self</code>, return a list of the lines in the element, breaking at line boundaries.</td>
</tr>
<tr>
<td><code>squeeze([axis])</code></td>
<td>Remove single-dimensional entries from the shape of <code>a</code>.</td>
</tr>
<tr>
<td><code>startswith(prefix[, start, end])</code></td>
<td>Returns a boolean array which is <code>True</code> where the string element in <code>self</code> starts with <code>prefix</code>, otherwise <code>False</code>.</td>
</tr>
<tr>
<td><code>strip([chars])</code></td>
<td>For each element in <code>self</code>, return a copy with the leading and trailing characters removed.</td>
</tr>
<tr>
<td><code>swapaxes(axis1, axis2)</code></td>
<td>For each element in <code>self</code>, return a copy with the axes transposed.</td>
</tr>
<tr>
<td><code>swapcase()</code></td>
<td>Return an array formed from the elements of <code>a</code> at the given indices.</td>
</tr>
<tr>
<td><code>take(indices[, axis, out, mode])</code></td>
<td>For each element in <code>self</code>, return a titlecased version of the string: words start with uppercase characters, all remaining cased characters are lowercase.</td>
</tr>
<tr>
<td><code>tolist()</code></td>
<td>Write array to a file as text or binary (default).</td>
</tr>
<tr>
<td><code>tofile(fid[, sep, format])</code></td>
<td>Construct Python bytes containing the raw data bytes in the array.</td>
</tr>
<tr>
<td><code>translate(table[, deletechars])</code></td>
<td>For each element in <code>self</code>, return a copy of the string where all characters occurring in <code>deletechars</code> are removed, and the remaining characters have been mapped through the given translation table.</td>
</tr>
<tr>
<td><code>transpose(*axes)</code></td>
<td>Return a view of the array with axes transposed.</td>
</tr>
<tr>
<td><code>upper()</code></td>
<td>Return an array with the elements of <code>self</code> converted to uppercase.</td>
</tr>
<tr>
<td><code>view([dtype, type])</code></td>
<td>New view of array with the same data.</td>
</tr>
<tr>
<td><code>zfill(width)</code></td>
<td>Return the numeric string left-filled with zeros in a string of length <code>width</code>.</td>
</tr>
</tbody>
</table>

**chararray.astype** *(dtype, order='K', casting='unsafe', subok=True, copy=True)*

Copy of the array, cast to a specified type.

**Parameters**

- **dtype** : str or dtype
  Typecode or data-type to which the array is cast.

- **order** : {'C', 'F', 'A', 'K'}, optional
  Controls the memory layout order of the result. 'C' means C order, 'F' means Fortran order, 'A' means 'F' order if all the arrays are Fortran contiguous, 'C' order otherwise, and 'K' means as close to the order the array elements appear in memory as possible. Default is 'K'.

- **casting** : {'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional
  Controls what kind of data casting may occur. Defaults to 'unsafe' for backwards compatibility.
  - 'no' means the data types should not be cast at all.
  - 'equiv' means only byte-order changes are allowed.
  - 'safe' means only casts which can preserve values are allowed.
  - 'same_kind' means only safe casts or casts within a kind, like float64 to float32, are allowed.
  - 'unsafe' means any data conversions may be done.

- **subok** : bool, optional
  If True, then sub-classes will be passed-through (default), otherwise the returned array will be forced to be a base-class array.

- **copy** : bool, optional
By default, astype always returns a newly allocated array. If this is set to false, and the
dtype, order, and subok requirements are satisfied, the input array is returned instead of
a copy.

Returns

arr_t : ndarray

Unless copy is False and the other conditions for returning the input array are satisfied
(see description for copy input paramter), arr_t is a new array of the same shape as the
input array, with dtype, order given by dtype, order.

Raises

ComplexWarning

When casting from complex to float or int. To avoid this, one should use
a.real.astype(t).

Notes

Starting in NumPy 1.9, astype method now returns an error if the string dtype to cast to is not long enough
in ‘safe’ casting mode to hold the max value of integer/float array that is being casted. Previously the
casting was allowed even if the result was truncated.

Examples

>>> x = np.array([1, 2, 2.5])

array([ 1. , 2. , 2.5])

>>> x.astype(int)

array([1, 2, 2])

cchararray.copy(order='C')

Return a copy of the array.

Parameters


Controls the memory layout of the copy. ‘C’ means C-order, ‘F’ means F-order, ‘A’
means ‘F’ if a is Fortran contiguous, ‘C’ otherwise, ‘K’ otherwise, ‘K’ means match the layout of a as
closely as possible. (Note that this function and :func:numpy.copy are very similar, but
have different default values for their order= arguments.)

See also:

numpy.copy, numpy.copyto

Examples

>>> x = np.array([[1,2,3],[4,5,6]], order='F')

>>> y = x.copy()

>>> x.fill(0)

>>> x

array([[0, 0, 0],
        [0, 0, 0]])
```python
>>> y
array([[1, 2, 3],
       [4, 5, 6]])

>>> y.flags['C_CONTIGUOUS']
True
```

```python
chararray.count(sub[, start, end])
```
Returns an array with the number of non-overlapping occurrences of substring `sub` in the range `[start, end]`.

**See also:**
char.count

```python
chararray.decode(encoding=None, errors=None)
```
Calls `str.decode` element-wise.

**See also:**
char.decode

```python
chararray.dump(file)
```
Dump a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

**Parameters**
- `file`: str
  - A string naming the dump file.

```python
chararray.dumps()
```
Returns the pickle of the array as a string. pickle.loads or numpy.loads will convert the string back to an array.

**Parameters**
- None

```python
chararray.encode(encoding=None, errors=None)
```
Calls `str.encode` element-wise.

**See also:**
char.encode

```python
chararray.endswith(suffix[, start, end])
```
Returns a boolean array which is `True` where the string element in `self` ends with `suffix`, otherwise `False`.

**See also:**
char.endswith

```python
chararray.expandtabs(tabsize=8)
```
Return a copy of each string element where all tab characters are replaced by one or more spaces.

**See also:**
char.expandtabs

```python
chararray.fill(value)
```
Fill the array with a scalar value.

**Parameters**
- `value`: scalar
  - All elements of `a` will be assigned this value.
Examples

```python
>>> a = np.array([1, 2])
>>> a.fill(0)
>>> a
array([0, 0])
>>> a = np.empty(2)
>>> a.fill(1)
>>> a
array([ 1., 1.])
```

`chararray.find(sub, start=0, end=None)`

For each element, return the lowest index in the string where substring `sub` is found.

See also:

`char.find`

`chararray.flatten(order='C')`

Return a copy of the array collapsed into one dimension.

**Parameters**

`order`: {'C', 'F', 'A'}, optional

Whether to flatten in C (row-major), Fortran (column-major) order, or preserve the C/Fortran ordering from `a`. The default is ‘C’.

**Returns**

`y`: ndarray

A copy of the input array, flattened to one dimension.

See also:

`ravel`

Return a flattened array.

`flat`

A 1-D flat iterator over the array.

Examples

```python
>>> a = np.array([[1,2], [3,4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])
```

`chararray.getfield(dtype, offset=0)`

Returns a field of the given array as a certain type.

A field is a view of the array data with a given data-type. The values in the view are determined by the given type and the offset into the current array in bytes. The offset needs to be such that the view dtype fits in the array dtype; for example an array of dtype complex128 has 16-byte elements. If taking a view with a 32-bit integer (4 bytes), the offset needs to be between 0 and 12 bytes.

**Parameters**

`dtype`: str or dtype

The data type of the view. The dtype size of the view can not be larger than that of the array itself.

`offset`: int
Number of bytes to skip before beginning the element view.

**Examples**

```python
>>> x = np.diag([1.+1.j]*2)
>>> x[1, 1] = 2 + 4.j
>>> x
array([[ 1.+1.j, 0.+0.j],
       [ 0.+0.j, 2.+4.j]])
```  
```python
>>> x.getfield(np.float64)
array([[ 1., 0.],
       [ 0., 2.]])
```

By choosing an offset of 8 bytes we can select the complex part of the array for our view:

```python
>>> x.getfield(np.float64, offset=8)
array([[ 1., 0.],
       [ 0., 4.]])
```

<table>
<thead>
<tr>
<th>chararray</th>
<th><code>.index(sub, start=0, end=None)</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>Like <code>find</code>, but raises <code>ValueError</code> when the substring is not found.</td>
<td></td>
</tr>
</tbody>
</table>

See also:
- `char.index`

<table>
<thead>
<tr>
<th>chararray</th>
<th><code>.isalnum()</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>Returns true for each element if all characters in the string are alphanumeric and there is at least one character, false otherwise.</td>
<td></td>
</tr>
</tbody>
</table>

See also:
- `char.isalnum`

<table>
<thead>
<tr>
<th>chararray</th>
<th><code>.isalpha()</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>Returns true for each element if all characters in the string are alphabetic and there is at least one character, false otherwise.</td>
<td></td>
</tr>
</tbody>
</table>

See also:
- `char.isalpha`

<table>
<thead>
<tr>
<th>chararray</th>
<th><code>.isdecimal()</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>For each element in <code>self</code>, return True if there are only decimal characters in the element.</td>
<td></td>
</tr>
</tbody>
</table>

See also:
- `char.isdecimal`

<table>
<thead>
<tr>
<th>chararray</th>
<th><code>.isdigit()</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>Returns true for each element if all characters in the string are digits and there is at least one character, false otherwise.</td>
<td></td>
</tr>
</tbody>
</table>

See also:
- `char.isdigit`

<table>
<thead>
<tr>
<th>chararray</th>
<th><code>.islower()</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>Returns true for each element if all cased characters in the string are lowercase and there is at least one cased character, false otherwise.</td>
<td></td>
</tr>
</tbody>
</table>

See also:
- `char.islower`
chararray.isnumeric()  
For each element in self, return True if there are only numeric characters in the element.

See also:  
char.isnumeric

chararray.isspace()  
Returns true for each element if there are only whitespace characters in the string and there is at least one character, false otherwise.

See also:  
char.isspace

chararray.istitle()  
Returns true for each element if the element is a titlecased string and there is at least one character, false otherwise.

See also:  
char.istitle

chararray.isupper()  
Returns true for each element if all cased characters in the string are uppercase and there is at least one character, false otherwise.

See also:  
char.isupper

cchararray.item(*args)  
Copy an element of an array to a standard Python scalar and return it.

Parameters  
*args: Arguments (variable number and type)

  • none: in this case, the method only works for arrays with one element (a.size == 1), which element is copied into a standard Python scalar object and returned.
  • int_type: this argument is interpreted as a flat index into the array, specifying which element to copy and return.
  • tuple of int_types: functions as does a single int_type argument, except that the argument is interpreted as an nd-index into the array.

Returns  
z: Standard Python scalar object
A copy of the specified element of the array as a suitable Python scalar

Notes  
When the data type of a is longdouble or clongdouble, item() returns a scalar array object because there is no available Python scalar that would not lose information. Void arrays return a buffer object for item(), unless fields are defined, in which case a tuple is returned.

item is very similar to [args], except, instead of an array scalar, a standard Python scalar is returned. This can be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using Python’s optimized math.
Examples

```python
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[3, 1, 7],
       [2, 8, 3],
       [8, 5, 3]])
>>> x.item(3)
2
>>> x.item(7)
5
>>> x.item((0, 1))
1
>>> x.item((2, 2))
3
```

cchararray.join(seq)

Return a string which is the concatenation of the strings in the sequence seq.

See also:

cchar.join
cchararray.ljust(width, fillchar=' ')

Return an array with the elements of self left-justified in a string of length width.

See also:

cchar.ljust
cchararray.lower()

Return an array with the elements of self converted to lowercase.

See also:

cchar.lower
cchararray.lstrip(chars=None)

For each element in self, return a copy with the leading characters removed.

See also:

cchar.lstrip
cchararray.nonzero()

Return the indices of the elements that are non-zero.

Refer to numpy.nonzero for full documentation.

See also:

numpy.nonzero
equivalent function
cchararray.put(indices, values, mode='raise')

Set a.flat[n] = values[n] for all n in indices.

Refer to numpy.put for full documentation.

See also:

numpy.put
equivalent function
chararray.ravel([order])
Return a flattened array.

Refer to numpy.ravel for full documentation.

See also:

numpy.ravel
equivalent function

ndarray.flat
a flat iterator on the array.

chararray.repeat(repeats, axis=None)
Repeat elements of an array.

Refer to numpy.repeat for full documentation.

See also:

numpy.repeat
equivalent function

chararray.replace(old, new, count=None)
For each element in self, return a copy of the string with all occurrences of substring old replaced by new.

See also:

char.replace

chararray.reshape(shape, order='C')
Returns an array containing the same data with a new shape.

Refer to numpy.reshape for full documentation.

See also:

numpy.reshape
equivalent function

chararray.resize(new_shape, refcheck=True)
Change shape and size of array in-place.

Parameters

new_shape : tuple of ints, or n ints
    Shape of resized array.

refcheck : bool, optional
    If False, reference count will not be checked. Default is True.

Returns

None

Raises

ValueError
    If a does not own its own data or references or views to it exist, and the data memory
    must be changed.

SystemError
If the order keyword argument is specified. This behaviour is a bug in NumPy.

See also:

\texttt{resize}

Return a new array with the specified shape.

\textbf{Notes}

This reallocates space for the data area if necessary.

Only contiguous arrays (data elements consecutive in memory) can be resized.

The purpose of the reference count check is to make sure you do not use this array as a buffer for another Python object and then reallocate the memory. However, reference counts can increase in other ways so if you are sure that you have not shared the memory for this array with another Python object, then you may safely set \texttt{refcheck} to False.

\textbf{Examples}

Shrinking an array: array is flattened (in the order that the data are stored in memory), resized, and reshaped:

\begin{verbatim}
>>> a = np.array([[0, 1], [2, 3]], order='C')
>>> a.resize((2, 1))
array([[0],
       [1]])

>>> a = np.array([[0, 1], [2, 3]], order='F')
>>> a.resize((2, 1))
array([[0],
       [2]])
\end{verbatim}

Enlarging an array: as above, but missing entries are filled with zeros:

\begin{verbatim}
>>> b = np.array([[0, 1], [2, 3]])
>>> b.resize(2, 3) \ # new_shape parameter doesn’t have to be a tuple
>>> b
array([[0, 1, 2],
       [3, 0, 0]])
\end{verbatim}

Referencing an array prevents resizing...

\begin{verbatim}
>>> c = a
>>> a.resize((1, 1))
Traceback (most recent call last):
 ... ValueError: cannot resize an array that has been referenced ...
>>> b
array([[0, 1, 2],
       [3, 0, 0]])
\end{verbatim}

Unless \texttt{refcheck} is False:

\begin{verbatim}
>>> a.resize((1, 1), refcheck=False)
>>> a
array([[0]])
>>> c
array([[0]])
\end{verbatim}
chararray.rfind \( (sub\), \text{start}=0, \text{end}=\text{None} \)
For each element in self, return the highest index in the string where substring sub is found, such that sub is contained within \([\text{start}, \text{end}]\).

See also:
- char.rfind

chararray.rindex \( (sub\), \text{start}=0, \text{end}=\text{None} \)
Like rfind, but raises ValueError when the substring sub is not found.

See also:
- char.rindex

chararray.rjust \( (width, \text{fillchar}=\text{'}\text{'}\text{')}) \)
Return an array with the elements of self right-justified in a string of length width.

See also:
- char.rjust

chararray.rsplit \( (sep=\text{None}, \text{maxsplit}=\text{None}) \)
For each element in self, return a list of the words in the string, using sep as the delimiter string.

See also:
- char.rsplit

chararray.rstrip \( (chars=\text{None}) \)
For each element in self, return a copy with the trailing characters removed.

See also:
- char.rstrip

chararray.searchsorted \( (v, \text{side}=\text{'}\text{left}', \text{sorter}=\text{None}) \)
Find indices where elements of v should be inserted in a to maintain order.
For full documentation, see numpy.searchsorted

See also:
- numpy.searchsorted

equivalent function

chararray.setfield \( (val\), \text{dtype}, \text{offset}=0 \)
Put a value into a specified place in a field defined by a data-type.
Place val into a’s field defined by dtype and beginning offset bytes into the field.

Parameters
- val : object
  Value to be placed in field.
- dtype : dtype object
  Data-type of the field in which to place val.
- offset : int, optional
  The number of bytes into the field at which to place val.

Returns
- None
See also:

ggetitem

Examples

```python
>>> x = np.eye(3)
>>> x.getfield(np.float64)
array([[ 1., 0., 0.],
       [ 0., 1., 0.],
       [ 0., 0., 1.]])
>>> x.setfield(3, np.int32)
>>> x.getfield(np.int32)
array([[3, 3, 3],
       [3, 3, 3],
       [3, 3, 3]])
>>> x
array([ 1.00000000e+000, 1.48219694e-323, 1.48219694e-323],
       [ 1.48219694e-323, 1.00000000e+000, 1.48219694e-323],
       [ 1.48219694e-323, 1.48219694e-323, 1.00000000e+000]])
>>> x.setfield(np.eye(3), np.int32)
>>> x
array([[ 1., 0., 0.],
       [ 0., 1., 0.],
       [ 0., 0., 1.]])
```

chararray. setflags (write=None, align=None, uic=None)

Set array flags WRITEABLE, ALIGNED, and UPDATEIFCOPY, respectively.

These Boolean-valued flags affect how numpy interprets the memory area used by a (see Notes below). The ALIGNED flag can only be set to True if the data is actually aligned according to the type. The UPDATEIFCOPY flag can never be set to True. The flag WRITEABLE can only be set to True if the array owns its own memory, or the ultimate owner of the memory exposes a writeable buffer interface, or is a string. (The exception for string is made so that unpickling can be done without copying memory.)

Parameters

write : bool, optional

Describes whether or not a can be written to.

align : bool, optional

Describes whether or not a is aligned properly for its type.

uic : bool, optional

Describes whether or not a is a copy of another “base” array.

Notes

Array flags provide information about how the memory area used for the array is to be interpreted. There are 6 Boolean flags in use, only three of which can be changed by the user: UPDATEIFCOPY, WRITEABLE, and ALIGNED.

WRITEABLE (W) the data area can be written to;

ALIGNED (A) the data and strides are aligned appropriately for the hardware (as determined by the compiler);

UPDATEIFCOPY (U) this array is a copy of some other array (referenced by .base). When this array is deallocated, the base array will be updated with the contents of this array.

All flags can be accessed using their first (upper case) letter as well as the full name.
Examples

```python
>>> y
array([[3, 1, 7],
       [2, 0, 0],
       [8, 5, 9]])
```

```python
>>> y.flags
C_CONTIGUOUS : True
F_CONTIGUOUS : False
OWNDATA : True
WRITEABLE : True
ALIGNED : True
UPDATEIFCOPY : False
```

```python
>>> y.setflags(write=0, align=0)
```

```python
>>> y.flags
C_CONTIGUOUS : True
F_CONTIGUOUS : False
OWNDATA : True
WRITEABLE : False
ALIGNED : False
UPDATEIFCOPY : False
```

```python
>>> y.setflags(uic=1)
```

```
File "<stdin>", line 1, in <module>
ValueError: cannot set UPDATEIFCOPY flag to True
```

```python
chararray.sort(axis=-1, kind='quicksort', order=None)
```

Sort an array, in-place.

Parameters

- **axis**: int, optional
  
  Axis along which to sort. Default is -1, which means sort along the last axis.

- **kind**: {'quicksort', 'mergesort', 'heapsort'}, optional
  
  Sorting algorithm. Default is 'quicksort'.

- **order**: list, optional
  
  When a is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

See also:

- **numpy.sort**
  
  Return a sorted copy of an array.

- **argsort**
  
  Indirect sort.

- **lexsort**
  
  Indirect stable sort on multiple keys.

- **searchsorted**
  
  Find elements in sorted array.

- **partition**
  
  Partial sort.
Notes
See sort for notes on the different sorting algorithms.

Examples

```python
>>> a = np.array([[1, 4], [3, 1]])
>>> a.sort(axis=1)
>>> a
array([[1, 4],
[3, 1]])
>>> a.sort(axis=0)
>>> a
array([[1, 3],
[4, 1]])
```

Use the order keyword to specify a field to use when sorting a structured array:

```python
>>> a = np.array([('a', 2), ('c', 1)], dtype=[('x', 'S1'), ('y', int)])
>>> a.sort(order='y')
>>> a
array([('c', 1), ('a', 2)],
      dtype=[('x', '|S1'), ('y', '<i4')])
```

chararray.split(sep=None, maxsplit=None)
For each element in self, return a list of the words in the string, using sep as the delimiter string.

See also:
char.split

chararray.splitlines(keepends=None)
For each element in self, return a list of the lines in the element, breaking at line boundaries.

See also:
char.splitlines

chararray.squeeze(axis=None)
Remove single-dimensional entries from the shape of a.

Refer to numpy.squeeze for full documentation.

See also:

numpy.squeeze
equivalent function

chararray.startswith(prefix, start=0, end=None)
Returns a boolean array which is True where the string element in self starts with prefix, otherwise False.

See also:
char.startswith

chararray.strip(chars=None)
For each element in self, return a copy with the leading and trailing characters removed.

See also:
char.strip
NumPy Reference, Release 1.9.2

chararray.swapaxes(axis1, axis2)
Return a view of the array with axis1 and axis2 interchanged.
Refer to numpy.swapaxes for full documentation.
See also:
numpy.swapaxes
equivalent function
chararray.swapcase()
For each element in self, return a copy of the string with uppercase characters converted to lowercase and
vice versa.
See also:
char.swapcase
chararray.take(indices, axis=None, out=None, mode=’raise’)
Return an array formed from the elements of a at the given indices.
Refer to numpy.take for full documentation.
See also:
numpy.take
equivalent function
chararray.title()
For each element in self, return a titlecased version of the string: words start with uppercase characters, all
remaining cased characters are lowercase.
See also:
char.title
chararray.tofile(fid, sep=”“, format=”%s”)
Write array to a file as text or binary (default).
Data is always written in ‘C’ order, independent of the order of a. The data produced by this method can
be recovered using the function fromfile().
Parameters
fid : file or str
An open file object, or a string containing a filename.
sep : str
Separator between array items for text output. If “” (empty), a binary file is written,
equivalent to file.write(a.tobytes()).
format : str
Format string for text file output. Each entry in the array is formatted to text by first
converting it to the closest Python type, and then using “format” % item.
Notes
This is a convenience function for quick storage of array data. Information on endianness and precision
is lost, so this method is not a good choice for files intended to archive data or transport data between
machines with different endianness. Some of these problems can be overcome by outputting the data as
text files, at the expense of speed and file size.

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Chapter 1. Array objects


chararray.tolist()
    Return the array as a (possibly nested) list.
    Return a copy of the array data as a (nested) Python list. Data items are converted to the nearest compatible
Pythom type.

Parameters
    none

Returns
    y : list
        The possibly nested list of array elements.

Notes
The array may be recreated, a = np.array(a.tolist()).

Examples
>>> a = np.array([1, 2])
>>> a.tolist()
[1, 2]
>>> a = np.array([[1, 2], [3, 4]])
>>> list(a)
[array([1, 2]), array([3, 4])]
>>> a.tolist()
[[1, 2], [3, 4]]

chararray.tostring(order='C')
Construct Python bytes containing the raw data bytes in the array.

Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object can be
produced in either 'C' or 'Fortran', or 'Any' order (the default is 'C'-order). 'Any' order means C-order
unless the F_CONTIGUOUS flag in the array is set, in which case it means 'Fortran' order.

This function is a compatibility alias for tobytes. Despite its name it returns bytes not strings.

Parameters
    order : {'C', 'F', None}, optional
        Order of the data for multidimensional arrays: C, Fortran, or the same as for the original
array.

Returns
    s : bytes
        Python bytes exhibiting a copy of a's raw data.

Examples
>>> x = np.array([[0, 1], [2, 3]])
>>> x.tobytes()
'b\x00\x00\x00\x00\x00\x01\x00\x00\x00\x02\x00\x00\x03\x00\x00\x00'
>>> x.tobytes('C') == x.tobytes()
True
>>> x.tobytes('F')
'b\x00\x00\x00\x00\x00\x02\x00\x00\x00\x01\x00\x00\x00\x03\x00\x00\x00\x00'

chararray.translate(table, deletechars=None)
    For each element in self, return a copy of the string where all characters occurring in the optional argument
*deletechars* are removed, and the remaining characters have been mapped through the given translation table.

**See also:**

char.translate

chararray.transpose(*axes*)

Returns a view of the array with axes transposed.

For a 1-D array, this has no effect. (To change between column and row vectors, first cast the 1-D array into a matrix object.) For a 2-D array, this is the usual matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided and `a.shape = (i[0], i[1], ... i[n-2], i[n-1])`, then `a.transpose().shape = (i[n-1], i[n-2], ... i[1], i[0])`.

**Parameters**

- **axes**: None, tuple of ints, or *n* ints
  
  - None or no argument: reverses the order of the axes.
  
  - tuple of ints: *i* in the *j*-th place in the tuple means *a*'s *i*-th axis becomes `a.transpose()`’s *j*-th axis.
  
  - *n* ints: same as an *n*-tuple of the same ints (this form is intended simply as a “convenience” alternative to the tuple form)

**Returns**

- **out**: ndarray
  
  View of `a`, with axes suitably permuted.

**See also:**

ndarray.T

Array property returning the array transposed.

**Examples**

```python
g = np.array([[1, 2], [3, 4]])
g a
g.array([[1, 2],
   [3, 4]])
g a.transpose()
g.array([[1, 2],
   [3, 4]])
g a.transpose((1, 0))
g.array([[1, 0],
   [2, 4]])
g a.transpose(1, 0)
g.array([[1, 0],
   [2, 4]])
```

- **chararray.upper()**
  
  Return an array with the elements of `self` converted to uppercase.

**See also:**

char.upper

- **chararray.view**(*dtype=None, type=None*)
  
  New view of array with the same data.
Parameters

dtype : data-type or ndarray sub-class, optional

Data-type descriptor of the returned view, e.g., float32 or int16. The default, None, results in the view having the same data-type as \( a \). This argument can also be specified as an ndarray sub-class, which then specifies the type of the returned object (this is equivalent to setting the type parameter).

type : Python type, optional

Type of the returned view, e.g., ndarray or matrix. Again, the default None results in type preservation.

Notes

\( a.view() \) is used two different ways:

\( a.view(some\_dtype) \) or \( a.view(dtype=some\_dtype) \) constructs a view of the array’s memory with a different data-type. This can cause a reinterpretation of the bytes of memory.

\( a.view(ndarray\_subclass) \) or \( a.view(type=ndarray\_subclass) \) just returns an instance of \( ndarray\_subclass \) that looks at the same array (same shape, dtype, etc.) This does not cause a reinterpretation of the memory.

For \( a.view(some\_dtype) \), if \( some\_dtype \) has a different number of bytes per entry than the previous dtype (for example, converting a regular array to a structured array), then the behavior of the view cannot be predicted just from the superficial appearance of \( a \) (shown by \( print(a) \)). It also depends on exactly how \( a \) is stored in memory. Therefore if \( a \) is C-ordered versus fortran-ordered, versus defined as a slice or transpose, etc., the view may give different results.

Examples

```python
>>> x = np.array([(1, 2)], dtype=[('a', np.int8), ('b', np.int8)])
Viewing array data using a different type and dtype:

>>> y = x.view(dtype=np.int16, type=np.matrix)
>>> y
matrix([[513]], dtype=int16)
>>> print type(y)
<class 'numpy.matrixlib.defmatrix.matrix'>

Creating a view on a structured array so it can be used in calculations

```python
>>> x = np.array([(1, 2), (3, 4)], dtype=[('a', np.int8), ('b', np.int8)])
>>> xv = x.view(dtype=np.int8).reshape(-1,2)
>>> xv
array([[ 1,  2],
       [ 3,  4]], dtype=int8)
>>> xv.mean(0)
array([ 2.,  3.])
```  
Making changes to the view changes the underlying array

```python
>>> xv[0,1] = 20
>>> print x
[(1, 20) (3, 4)]
```  
Using a view to convert an array to a record array:
>>> z = x.view(np.recarray)
>>> z.a
array([1], dtype=int8)

Views share data:

>>> x[0] = (9, 10)
>>> z[0]
(9, 10)

Views that change the dtype size (bytes per entry) should normally be avoided on arrays defined by slices, transposes, fortran-ordering, etc.:

>>> x = np.array([[1, 2, 3], [4, 5, 6]], dtype=np.int16)
>>> y = x[:, 0:2]
>>> y
array([[1, 2],
       [4, 5]], dtype=int16)

>>> y.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: new type not compatible with array.

>>> z = y.copy()
>>> z.view(dtype=[('width', np.int16), ('length', np.int16)])
array([[1, 2],
       [4, 5]], dtype=[('width', '<i2'), ('length', '<i2')])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: new type not compatible with array.

chararray.zfill(width)
Return the numeric string left-filled with zeros in a string of length width.

See also:
char.zfill

numpy.core.defchararray.array(obj, itemsize=None, copy=True, unicode=None, order=None)
Create a chararray.

Note: This class is provided for numarray backward-compatibility. New code (not concerned with numarray compatibility) should use arrays of type string_ or unicode_ and use the free functions in numpy.char for fast vectorized string operations instead.

Versus a regular Numpy array of type str or unicode, this class adds the following functionality:

1. values automatically have whitespace removed from the end when indexed
2. comparison operators automatically remove whitespace from the end when comparing values
3. vectorized string operations are provided as methods (e.g. str.endswith) and infix operators (e.g. +, *, %)

Parameters
obj : array of str or unicode-like
itemsize : int, optional
is the number of characters per scalar in the resulting array. If itemsize is None, and obj is an object array or a Python list, the itemsize will be automatically determined. If itemsize is provided and obj is of type str or unicode, then the obj string will be chunked into itemsize pieces.

**copy**: bool, optional

If true (default), then the object is copied. Otherwise, a copy will only be made if __array__ returns a copy, if obj is a nested sequence, or if a copy is needed to satisfy any of the other requirements (itemsize, unicode, order, etc.).

**unicode**: bool, optional

When true, the resulting chararray can contain Unicode characters, when false only 8-bit characters. If unicode is None and obj is one of the following:

- a chararray,
- an ndarray of type str or unicode
- a Python str or unicode object,

then the unicode setting of the output array will be automatically determined.

**order**: {'C', 'F', 'A'}, optional

Specify the order of the array. If order is ‘C’ (default), then the array will be in C-contiguous order (last-index varies the fastest). If order is ‘F’, then the returned array will be in Fortran-contiguous order (first-index varies the fastest). If order is ‘A’, then the returned array may be in any order (either C-, Fortran-contiguous, or even discontiguous).

Another difference with the standard ndarray of str data-type is that the chararray inherits the feature introduced by Numarray that white-space at the end of any element in the array will be ignored on item retrieval and comparison operations.

### 1.6.5 Record arrays (numpy.rec)

See also:

Creating record arrays (numpy.rec), Data type routines, Data type objects (dtype).

Numpy provides the recarray class which allows accessing the fields of a record/structured array as attributes, and a corresponding scalar data type object record.

```python
recarray = Construct an ndarray that allows field access using attributes.
record = A data-type scalar that allows field access as attribute lookup.
```

**class** numpy.recarray

Construct an ndarray that allows field access using attributes.

Arrays may have a data-types containing fields, analogous to columns in a spread sheet. An example is `[ (x, int), (y, float) ]`, where each entry in the array is a pair of `(int, float)`. Normally, these attributes are accessed using dictionary lookups such as `arr['x']` and `arr['y']`. Record arrays allow the fields to be accessed as members of the array, using `arr.x` and `arr.y`.

**Parameters**

- **shape**: tuple

  Shape of output array.
```python
dtype : data-type, optional

The desired data-type. By default, the data-type is determined from formats, names, titles, aligned and byteorder.

formats : list of data-types, optional

A list containing the data-types for the different columns, e.g. ['i4', 'f8', 'i4']. formats does not support the new convention of using types directly, i.e. (int, float, int). Note that formats must be a list, not a tuple. Given that formats is somewhat limited, we recommend specifying dtype instead.

names : tuple of str, optional

The name of each column, e.g. ('x', 'y', 'z').

buf : buffer, optional

By default, a new array is created of the given shape and data-type. If buf is specified and is an object exposing the buffer interface, the array will use the memory from the existing buffer. In this case, the offset and strides keywords are available.

Returns

rec : recarray

Empty array of the given shape and type.

Other Parameters

titles : tuple of str, optional

Aliases for column names. For example, if names were ('x', 'y', 'z') and titles is ('x_coordinate', 'y_coordinate', 'z_coordinate'), then arr['x'] is equivalent to both arr.x and arr.x_coordinate.

byteorder : {'<', '>', '='}, optional

Byte-order for all fields.

aligned : bool, optional

Align the fields in memory as the C-compiler would.

strides : tuple of ints, optional

Buffer (buf) is interpreted according to these strides (strides define how many bytes each array element, row, column, etc. occupy in memory).

offset : int, optional

Start reading buffer (buf) from this offset onwards.

order : {'C', 'F'}, optional

Row-major or column-major order.

See also:

rec.fromrecords
 Construct a record array from data.

record
 fundamental data-type for recarray.

format_parser
 determine a data-type from formats, names, titles.
```
Notes

This constructor can be compared to empty: it creates a new record array but does not fill it with data. To create a record array from data, use one of the following methods:

1. Create a standard ndarray and convert it to a record array, using arr.view(np.recarray)
2. Use the buf keyword.
3. Use np.rec.fromrecords.

Examples

Create an array with two fields, x and y:

```python
>>> x = np.array([(1.0, 2), (3.0, 4)], dtype=[('x', float), ('y', int)])
```

```python
>>> x
array([(1.0, 2), (3.0, 4)],
dtype=[('x', '<f8'), ('y', '<i4')])
```

```python
>>> x['x']
array([1., 3.])
```

View the array as a record array:

```python
>>> x = x.view(np.recarray)
```

```python
>>> x.x
array([1., 3.])
```

```python
>>> x.y
array([2, 4])
```

Create a new, empty record array:

```python
>>> np.recarray((2,)
... dtype=[('x', int), ('y', float), ('z', int)])
rec.array([-1073741821, 1.2249118382103472e-301, 24547520, (3471280, 1.2134086255804012e-316, 0)],
dtype=[('x', '<i4'), ('y', '<f8'), ('z', '<i4')])
```

Attributes

- T: Same as self.transpose(), except that self is returned if self.ndim < 2.
- base: Base object if memory is from some other object.
- ctypes: An object to simplify the interaction of the array with the ctypes module.
- data: Python buffer object pointing to the start of the array’s data.
- dtype: Data-type of the array’s elements.
- flags: Information about the memory layout of the array.
- flat: A 1-D iterator over the array.
- imag: The imaginary part of the array.
- itemsize: Length of one array element in bytes.
- nbytes: Total bytes consumed by the elements of the array.
- ndim: Number of array dimensions.
- real: The real part of the array.
- shape: Tuple of array dimensions.
- size: Number of elements in the array.
- strides: Tuple of bytes to step in each dimension when traversing an array.
recarray.T

Same as self.transpose(), except that self is returned if self.ndim < 2.

Examples

```python
>>> x = np.array([[1., 2.], [3., 4.]])
>>> x
array([[ 1.,  2.],
       [ 3.,  4.]])
>>> x.T
array([[ 1.,  3.],
       [ 2.,  4.]])
```

```
>>> x = np.array([1., 2., 3., 4.])
>>> x
array([1., 2., 3., 4.])
>>> x.T
array([1., 2., 3., 4.])
```

recarray.base

Base object if memory is from some other object.

Examples

The base of an array that owns its memory is None:

```python
>>> x = np.array([1,2,3,4])
>>> x.base is None
True
```

Slicing creates a view, whose memory is shared with x:

```python
>>> y = x[2:]
>>> y.base is x
True
```

recarray.ctypes

An object to simplify the interaction of the array with the ctypes module.

This attribute creates an object that makes it easier to use arrays when calling shared libraries with the ctypes module. The returned object has, among others, data, shape, and strides attributes (see Notes below) which themselves return ctypes objects that can be used as arguments to a shared library.

Parameters

None

Returns

c : Python object

Possessing attributes data, shape, strides, etc.

See also:

numpy.ctypeslib

Notes

Below are the public attributes of this object which were documented in “Guide to NumPy” (we have omitted undocumented public attributes, as well as documented private attributes):

*data: A pointer to the memory area of the array as a Python integer. This memory area may contain data that is not aligned, or not in correct byte-order. The memory area may not even be writeable. The array flags and data-type of this array should be respected when passing this attribute to arbitrary
C-code to avoid trouble that can include Python crashing. User Beware! The value of this attribute is exactly the same as self._array_interface_['data'][0].

•shape (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the C-integer corresponding to dtype('p') on this platform. This base-type could be c_int, c_long, or c_longlong depending on the platform. The c_intp type is defined accordingly in numpy.ctypeslib. The ctypes array contains the shape of the underlying array.

•strides (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the same as for the shape attribute. This ctypes array contains the strides information from the underlying array. This strides information is important for showing how many bytes must be jumped to get to the next element in the array.

•data_as(obj): Return the data pointer cast to a particular c-types object. For example, calling self.as_parameter_ is equivalent to self.data_as(ctypes.c_void_p). Perhaps you want to use the data as a pointer to a ctypes array of floating-point data: self.data_as(ctypes.POINTER(ctypes.c_double)).

•shape_as(obj): Return the shape tuple as an array of some other c-types type. For example: self.shape_as(ctypes.c_short).

•strides_as(obj): Return the strides tuple as an array of some other c-types type. For example: self.strides_as(ctypes.c_longlong).

Be careful using the ctypes attribute - especially on temporary arrays or arrays constructed on the fly. For example, calling (a+b).ctypes.data_as(ctypes.c_void_p) returns a pointer to memory that is invalid because the array created as (a+b) is deallocated before the next Python statement. You can avoid this problem using either c=a+b or ct=(a+b).ctypes. In the latter case, ct will hold a reference to the array until ct is deleted or re-assigned.

If the ctypes module is not available, then the ctypes attribute of array objects still returns something useful, but ctypes objects are not returned and errors may be raised instead. In particular, the object will still have the as parameter attribute which will return an integer equal to the data attribute.

Examples

```python
>>> import ctypes
>>> x
array([[0, 1],
       [2, 3]])
>>> x.ctypes.data
30439712
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_long))
<ctypes.LP_c_long object at 0x001F01300>
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_long)).contents
\n\n```

recarray.data
Python buffer object pointing to the start of the array’s data.
recarray.dtype
Data-type of the array’s elements.

Parameters
None

Returns

*d*: numpy dtype object

See also:
numpy.dtype

Examples

```python
gg> x = array([[0, 1],
[2, 3]])
gg> x.dtype
dtype('int32')
gg> type(x.dtype)
<type 'numpy.dtype'>
```

recarray.flags
Information about the memory layout of the array.

Notes
The **flags** object can be accessed dictionary-like (as in `a.flags['WRITEABLE']`), or by using lower-cased attribute names (as in `a.flags.writeable`). Short flag names are only supported in dictionary access.

Only the UPDATEIFCOPY, WRITEABLE, and ALIGNED flags can be changed by the user, via direct assignment to the attribute or dictionary entry, or by calling `ndarray.setflags`.

The array flags cannot be set arbitrarily:

- UPDATEIFCOPY can only be set `False`.
- ALIGNED can only be set `True` if the data is truly aligned.
- WRITEABLE can only be set `True` if the array owns its own memory or the ultimate owner of the memory exposes a writeable buffer interface or is a string.

Arrays can be both C-style and Fortran-style contiguous simultaneously. This is clear for 1-dimensional arrays, but can also be true for higher dimensional arrays.

Even for contiguous arrays a stride for a given dimension `arr.strides[dim]` may be arbitrary if `arr.shape[dim] == 1` or the array has no elements. It does not generally hold that `self.strides[-1] == self.itemsize` for C-style contiguous arrays or `self.strides[0] == self.itemsize` for Fortran-style contiguous arrays is true.
### Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_CONTIGUOUS</td>
<td>This data is in a single, C-style contiguous segment.</td>
</tr>
<tr>
<td>F_CONTIGUOUS</td>
<td>This data is in a single, Fortran-style contiguous segment.</td>
</tr>
<tr>
<td>OWN_DATA</td>
<td>The array owns the memory it uses or borrows it from another object.</td>
</tr>
<tr>
<td>WRITEABLE</td>
<td>The data area can be written to. Setting this to False locks the data, making it read-only. A view (slice, etc.) inherits WRITEABLE from its base array at creation time, but a view of a writeable array may be subsequently locked while the base array remains writeable. (The opposite is not true, in that a view of a locked array may not be made writeable. However, currently, locking a base object does not lock any views that already reference it, so under that circumstance it is possible to alter the contents of a locked array via a previously created writeable view onto it.) Attempting to change a non-writeable array raises a RuntimeError exception. The data and all elements are aligned appropriately for the hardware.</td>
</tr>
<tr>
<td>ALIGNED</td>
<td>This array is a copy of some other array. When this array is deallocated, the base array will be updated with the contents of this array.</td>
</tr>
<tr>
<td>FNC</td>
<td>F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FORC</td>
<td>F_CONTIGUOUS or C_CONTIGUOUS (one-segment test).</td>
</tr>
<tr>
<td>BEHAVED</td>
<td>ALIGNED and WRITEABLE.</td>
</tr>
<tr>
<td>CARRAY</td>
<td>BEHAVED and C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FARRAY</td>
<td>BEHAVED and F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
</tbody>
</table>

**recarray.flat**

A 1-D iterator over the array.

This is a *numpy.flatiter* instance, which acts similarly to, but is not a subclass of, Python’s built-in iterator object.

See also:

**flatten**

Return a copy of the array collapsed into one dimension.

**flatiter**

### Examples

```python
>>> x = np.arange(1, 7).reshape(2, 3)
>>> x
array([[1, 2, 3],
       [4, 5, 6]])
>>> x.flat[3]
4
>>> x.T
array([[1, 4],
       [2, 5],
       [3, 6]])
```
>>> x.T.flat[3]
5
>>> type(x.flat)
<type 'numpy.flatiter'>

An assignment example:

>>> x.flat = 3; x
array([[3, 3, 3],
       [3, 3, 3]])
>>> x.flat[[1,4]] = 1; x
array([[3, 1, 3],
       [3, 1, 3]])

recarray.imag
The imaginary part of the array.

Examples

>>> x = np.sqrt([1+0j, 0+1j])
>>> x.imag
array([0., 0.70710678])
>>> x.imag.dtype
dtype('float64')

recarray.itemsize
Length of one array element in bytes.

Examples

>>> x = np.array([1,2,3], dtype=np.float64)
>>> x.itemsize
8
>>> x = np.array([1,2,3], dtype=np.complex128)
>>> x.itemsize
16

recarray.nbytes
Total bytes consumed by the elements of the array.

Notes
Does not include memory consumed by non-element attributes of the array object.

Examples

>>> x = np.zeros((3,5,2), dtype=np.complex128)
>>> x.nbytes
480
>>> np.prod(x.shape) * x.itemsize
480

recarray.ndim
Number of array dimensions.

Examples

>>> x = np.array([1, 2, 3])
>>> x.ndim
1
```
>>> y = np.zeros((2, 3, 4))
>>> y.ndim
3
```

**recarray.real**

The real part of the array.

**See also:**

**numpy.real**

equivalent function

**Examples**

```
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.real
array([ 1. , 0.70710678])
>>> x.real.dtype
dtype('float64')
```

**recarray.shape**

Tuple of array dimensions.

**Notes**

May be used to “reshape” the array, as long as this would not require a change in the total number of elements

**Examples**

```
>>> x = np.array([1, 2, 3, 4])
>>> x.shape
(4,)
>>> y = np.zeros((2, 3, 4))
>>> y.shape
(2, 3, 4)
>>> y.shape = (3, 8)
>>> y
array([[ 0., 0., 0., 0., 0., 0., 0., 0.],
       [ 0., 0., 0., 0., 0., 0., 0., 0.],
       [ 0., 0., 0., 0., 0., 0., 0., 0.]])
>>> y.shape = (3, 6)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: total size of new array must be unchanged
```

**recarray.size**

Number of elements in the array.

Equivalent to `np.prod(a.shape)`, i.e., the product of the array’s dimensions.

**Examples**

```
>>> x = np.zeros((3, 5, 2), dtype=np.complex128)
>>> x.size
30
```
recarray.strides
Tuple of bytes to step in each dimension when traversing an array.

The byte offset of element \((i[0], i[1], \ldots, i[n])\) in an array \(a\) is:

\[
\text{offset} = \sum \text{np.array}(i) \times a.\text{strides}
\]

A more detailed explanation of strides can be found in the “ndarray.rst” file in the NumPy reference guide.

See also:

numpy.lib.stride_tricks.as_strided

Notes
Imagine an array of 32-bit integers (each 4 bytes):

\[
x = \text{np.array([[0, 1, 2, 3, 4],}
[5, 6, 7, 8, 9]], \text{dtype=np.int32})
\]

This array is stored in memory as 40 bytes, one after the other (known as a contiguous block of memory). The strides of an array tell us how many bytes we have to skip in memory to move to the next position along a certain axis. For example, we have to skip 4 bytes (1 value) to move to the next column, but 20 bytes (5 values) to get to the same position in the next row. As such, the strides for the array \(x\) will be \((20, 4)\).

Examples

\[
\begin{align*}
\text{array} & = \text{np.arange(2*3*4)} \\rightarrow \text{array} \rightarrow \text{array} \\
\text{y} & = \text{np.reshape} \left( \text{np.arange}(2*3*4), (2,3,4) \right) \\
\text{y} & = \text{array} \\
\text{y} & = \text{array} \\
\text{y} & = \text{array} \\
\text{y} & = \text{array} \\
\text{offset} & = \text{sum}(y.\text{strides} \times \text{np.array}\left( (1,1,1) \right)) \\
\text{offset} & = \text{y}.\text{itemsize} \\
\text{x} & = \text{np.reshape} \left( \text{np.arange}(5*6*7*8), (5,6,7,8) \right).\text{transpose}(2,3,1,0) \\
\text{x} & = \text{array} \\
\text{x} & = \text{array} \\
i & = \text{np.array}[3,5,2,2] \\
i & = \text{np.array}[3,5,2,2] \\
\text{offset} & = \text{sum}(i \times x.\text{strides}) \\
\text{offset} & = x.\text{itemsize} \\
\text{x} & = x.\text{itemsize} \\
\text{offset} & = x.\text{itemsize} \\
\text{x} & = x.\text{itemsize}
\end{align*}
\]

Methods
### Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>all()</code></td>
<td>Returns True if all elements evaluate to True.</td>
</tr>
<tr>
<td><code>any()</code></td>
<td>Returns True if any of the elements of <code>a</code> evaluate to True.</td>
</tr>
<tr>
<td><code>argmax()</code></td>
<td>Return indices of the maximum values along the given axis.</td>
</tr>
<tr>
<td><code>argmin()</code></td>
<td>Return indices of the minimum values along the given axis of <code>a</code>.</td>
</tr>
<tr>
<td><code>argpartition()</code></td>
<td>Returns the indices that would partition this array.</td>
</tr>
<tr>
<td><code>argsort()</code></td>
<td>Returns the indices that would sort this array.</td>
</tr>
<tr>
<td><code>astype()</code></td>
<td>Copy of the array, cast to a specified type.</td>
</tr>
<tr>
<td><code>byteswap()</code></td>
<td>Swap the bytes of the array elements. Toggle between low-endian and big-endian data representation by returning a byteswapped array, optionally swapped in-place.</td>
</tr>
<tr>
<td><code>choose()</code></td>
<td>Use an index array to construct a new array from a set of choices.</td>
</tr>
<tr>
<td><code>clip()</code></td>
<td>Return an array whose values are limited to <code>[a_min, a_max]</code>.</td>
</tr>
<tr>
<td><code>compress()</code></td>
<td>Return selected slices of this array along given axis.</td>
</tr>
<tr>
<td><code>conj()</code></td>
<td>Complex-conjugate all elements.</td>
</tr>
<tr>
<td><code>conjugate()</code></td>
<td>Return the complex conjugate, element-wise.</td>
</tr>
<tr>
<td><code>copy()</code></td>
<td>Return a copy of the array.</td>
</tr>
<tr>
<td><code>cumprod()</code></td>
<td>Return the cumulative product of the elements along the given axis.</td>
</tr>
<tr>
<td><code>cumsum()</code></td>
<td>Return the cumulative sum of the elements along the given axis.</td>
</tr>
<tr>
<td><code>diagonal()</code></td>
<td>Return specified diagonals.</td>
</tr>
<tr>
<td><code>dot()</code></td>
<td>Dot product of two arrays.</td>
</tr>
<tr>
<td><code>dump()</code></td>
<td>Dump a pickle of the array to the specified file.</td>
</tr>
<tr>
<td><code>dumps()</code></td>
<td>Returns the pickle of the array as a string.</td>
</tr>
<tr>
<td><code>field()</code></td>
<td>Return a field of the given array as a certain type.</td>
</tr>
<tr>
<td><code>fill()</code></td>
<td>Fill the array with a scalar value.</td>
</tr>
<tr>
<td><code>flatten()</code></td>
<td>Return a copy of the array collapsed into one dimension.</td>
</tr>
<tr>
<td><code>getfield()</code></td>
<td>Return a copy of the array collapsed into one dimension.</td>
</tr>
<tr>
<td><code>item()</code></td>
<td>Return a copy of the array collapsed into one dimension.</td>
</tr>
<tr>
<td><code>itemset()</code></td>
<td>Copy an element of an array to a standard Python scalar and return it.</td>
</tr>
<tr>
<td><code>max()</code></td>
<td>Return the maximum along a given axis.</td>
</tr>
<tr>
<td><code>mean()</code></td>
<td>Returns the average of the array elements along given axis.</td>
</tr>
<tr>
<td><code>min()</code></td>
<td>Return the minimum along a given axis.</td>
</tr>
<tr>
<td><code>newbyteorder()</code></td>
<td>Return the array with the same data viewed with a different byte order.</td>
</tr>
<tr>
<td><code>nonzero()</code></td>
<td>Return the indices of the elements of the array in a such that value of the element in <code>kth</code> position is True.</td>
</tr>
<tr>
<td><code>partition()</code></td>
<td>Rearranges the elements in the array in such a way that value of the element in <code>kth</code> position is in the correct position.</td>
</tr>
<tr>
<td><code>prod()</code></td>
<td>Return the product of the array elements over the given axis.</td>
</tr>
<tr>
<td><code>ptp()</code></td>
<td>Peak to peak (maximum - minimum) value along a given axis.</td>
</tr>
<tr>
<td><code>put()</code></td>
<td>Set <code>a.flat[n] = values[n]</code> for all <code>n</code> in indices.</td>
</tr>
<tr>
<td><code>ravel()</code></td>
<td>Return a flattened array.</td>
</tr>
<tr>
<td><code>repeat()</code></td>
<td>Repeat elements of an array.</td>
</tr>
<tr>
<td><code>reshape()</code></td>
<td>Returns an array containing the same data with a new shape.</td>
</tr>
<tr>
<td><code>resize()</code></td>
<td>Change shape and size of array in-place.</td>
</tr>
<tr>
<td><code>round()</code></td>
<td>Return a with each element rounded to the given number of decimals.</td>
</tr>
<tr>
<td><code>searchsorted()</code></td>
<td>Find indices where elements of <code>v</code> should be inserted in a to maintain order.</td>
</tr>
<tr>
<td><code>setfield()</code></td>
<td>Put a value into a specified place in a field defined by a data-type.</td>
</tr>
<tr>
<td><code>setflags()</code></td>
<td>Set array flags WRITEABLE, ALIGNED, and UPDATEIFCOPY, respectively.</td>
</tr>
<tr>
<td><code>sort()</code></td>
<td>Sort an array, in-place.</td>
</tr>
<tr>
<td><code>squeeze()</code></td>
<td>Remove single-dimensional entries from the shape of <code>a</code>.</td>
</tr>
<tr>
<td><code>std()</code></td>
<td>Returns the standard deviation of the array elements along given axis.</td>
</tr>
<tr>
<td><code>sum()</code></td>
<td>Return the sum of the array elements over the given axis.</td>
</tr>
<tr>
<td><code>swapaxes()</code></td>
<td>Return a view of the array with <code>axis1</code> and <code>axis2</code> interchanged.</td>
</tr>
<tr>
<td><code>take()</code></td>
<td>Return an array formed from the elements of <code>a</code> at the given indices.</td>
</tr>
<tr>
<td><code>tobytes()</code></td>
<td>Construct Python bytes containing the raw data bytes in the array.</td>
</tr>
<tr>
<td><code>tofile()</code></td>
<td>Write array to a file as text or binary (default).</td>
</tr>
<tr>
<td><code>tolist()</code></td>
<td>Return the array as a (possibly nested) list.</td>
</tr>
<tr>
<td>Function</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td><code>tostring(order)</code></td>
<td>Construct Python bytes containing the raw data bytes in the array.</td>
</tr>
<tr>
<td><code>trace(offset, axis1, axis2, dtype, out)</code></td>
<td>Return the sum along diagonals of the array.</td>
</tr>
<tr>
<td><code>transpose(*axes)</code></td>
<td>Returns a view of the array with axes transposed.</td>
</tr>
<tr>
<td><code>var(axis, dtype, out, ddof)</code></td>
<td>Returns the variance of the array elements, along given axis.</td>
</tr>
</tbody>
</table>

**recarray**

**`.all(axis=None, out=None)`**

Returns True if all elements evaluate to True.

Refer to `numpy.all` for full documentation.

See also:

- `numpy.all` equivalent function

**`.any(axis=None, out=None)`**

Returns True if any of the elements of `a` evaluate to True.

Refer to `numpy.any` for full documentation.

See also:

- `numpy.any` equivalent function

**`.argmax(axis=None, out=None)`**

Return indices of the maximum values along the given axis.

Refer to `numpy.argmax` for full documentation.

See also:

- `numpy.argmax` equivalent function

**`.argmin(axis=None, out=None)`**

Return indices of the minimum values along the given axis of `a`.

Refer to `numpy.argmin` for detailed documentation.

See also:

- `numpy.argmin` equivalent function

**`.argpartition(kth, axis=-1, kind='introselct', order=None)`**

Returns the indices that would partition this array.

Refer to `numpy.argpartition` for full documentation.

New in version 1.8.0.

See also:

- `numpy.argpartition` equivalent function
recarray.argsort

Returns the indices that would sort this array.

Refer to numpy.argsort for full documentation.

See also:

numpy.argsort
equivalent function

recarray.astype

Copy of the array, cast to a specified type.

Parameters

dtype : str or dtype
Typecode or data-type to which the array is cast.

order : {'C', 'F', 'A', 'K'}, optional
Controls the memory layout order of the result. ‘C’ means C order, ‘F’ means Fortran order, ‘A’ means ‘F’ order if all the arrays are Fortran contiguous, ‘C’ order otherwise, and ‘K’ means as close to the order the array elements appear in memory as possible. Default is ‘K’.

casting : {'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional
Controls what kind of data casting may occur. Defaults to ‘unsafe’ for backwards compatibility.

• ‘no’ means the data types should not be cast at all.
• ‘equiv’ means only byte-order changes are allowed.
• ‘safe’ means only casts which can preserve values are allowed.
• ‘same_kind’ means only safe casts or casts within a kind, like float64 to float32, are allowed.
• ‘unsafe’ means any data conversions may be done.

subok : bool, optional
If True, then sub-classes will be passed-through (default), otherwise the returned array will be forced to be a base-class array.

copy : bool, optional
By default, astype always returns a newly allocated array. If this is set to false, and the dtype, order, and subok requirements are satisfied, the input array is returned instead of a copy.

Returns

arr_t : ndarray
Unless copy is False and the other conditions for returning the input array are satisfied (see description for copy input paramter), arr_t is a new array of the same shape as the input array, with dtype, order given by dtype, order.

Raises

ComplexWarning

When casting from complex to float or int. To avoid this, one should use a.real.astype(t).
Notes
Starting in NumPy 1.9, astype method now returns an error if the string dtype to cast to is not long enough in ‘safe’ casting mode to hold the max value of integer/float array that is being casted. Previously the casting was allowed even if the result was truncated.

Examples

```python
>>> x = np.array([1, 2, 2.5])
>>> x
array([ 1. , 2. , 2.5])
>>> x.astype(int)
array([1, 2, 2])
```

recarray.**byteswap**(inplace)
Swap the bytes of the array elements
Toggle between low-endian and big-endian data representation by returning a byteswapped array, optionally swapped in-place.

**Parameters**

- inplace : bool, optional
  If True, swap bytes in-place, default is False.

**Returns**

- out : ndarray
  The byteswapped array. If inplace is True, this is a view to self.

Examples

```python
>>> A = np.array([1, 256, 8755], dtype=np.int16)
>>> map(hex, A)
['0x1', '0x100', '0x2233']
>>> A.byteswap(True)
array([ 256, 1, 13090], dtype=int16)
>>> map(hex, A)
['0x100', '0x1', '0x3322']
```

Arrays of strings are not swapped

```python
>>> A = np.array(['ceg', 'fac'])
>>> A.byteswap()
array(['ceg', 'fac'],
      dtype='|S3')
```

recarray.**choose**(choices, out=None, mode='raise')
Use an index array to construct a new array from a set of choices.
Refer to numpy.choose for full documentation.

See also:

- numpy.choose
equivalent function

recarray.**clip**(a_min, a_max, out=None)
Return an array whose values are limited to \([a_{\text{min}}, a_{\text{max}}]\).
Refer to numpy.clip for full documentation.
See also:

```
numpy.clip
```
equivalent function

```
recarray.compress(condition, axis=None, out=None)
```
Return selected slices of this array along given axis.
Refer to `numpy.compress` for full documentation.

See also:

```
numpy.compress
```
equivalent function

```
recarray.conj()
```
Complex-conjugate all elements.
Refer to `numpy.conjugate` for full documentation.

See also:

```
numpy.conjugate
```
equivalent function

```
recarray.conjugate()
```
Return the complex conjugate, element-wise.
Refer to `numpy.conjugate` for full documentation.

See also:

```
numpy.conjugate
```
equivalent function

```
recarray.copy(order='C')
```
Return a copy of the array.

Parameters
```
order : {'C', 'F', 'A', 'K'}, optional
```
Controls the memory layout of the copy. ‘C’ means C-order, ‘F’ means F-order, ‘A’ means ‘F’ if a is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of a as closely as possible. (Note that this function and :func:numpy.copy are very similar, but have different default values for their order= arguments.)

See also:

```
numpy.copy, numpy.copyto
```

Examples
```
>>> x = np.array([[1, 2, 3], [4, 5, 6]], order='F')

>>> y = x.copy()

>>> x.fill(0)
```
>>> x
array([[0, 0, 0],
       [0, 0, 0]])

>>> y
array([[1, 2, 3],
       [4, 5, 6]])

>>> y.flags['C_CONTIGUOUS']
True

recarray.cumprod (axis=None, dtype=None, out=None)
Return the cumulative product of the elements along the given axis.
Refer to numpy.cumprod for full documentation.

See also:

numpy.cumprod
 equivalent function

recarray.cumsum (axis=None, dtype=None, out=None)
Return the cumulative sum of the elements along the given axis.
Refer to numpy.cumsum for full documentation.

See also:

numpy.cumsum
 equivalent function

recarray.diagonal (offset=0, axis1=0, axis2=1)
Return specified diagonals. In NumPy 1.9 the returned array is a read-only view instead of a copy as in previous NumPy versions. In NumPy 1.10 the read-only restriction will be removed.
Refer to numpy.diagonal for full documentation.

See also:

numpy.diagonal
 equivalent function

recarray.dot (b, out=None)
Dot product of two arrays.
Refer to numpy.dot for full documentation.

See also:

numpy.dot
 equivalent function

Examples

>>> a = np.eye(2)
>>> b = np.ones((2, 2)) * 2
>>> a.dot(b)
array([[ 2.,  2.],
       [ 2.,  2.]])
This array method can be conveniently chained:

```python
>>> a.dot(b).dot(b)
array([[ 8.,  8.],
       [ 8.,  8.]])
```

*recarray.dump*(file)

Dump a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

**Parameters**
- **file**: str
  - A string naming the dump file.

*recarray.dumps()*

Returns the pickle of the array as a string. pickle.loads or numpy.loads will convert the string back to an array.

**Parameters**
- **None**

*recarray.field*(attr, val=None)*

Fill the array with a scalar value.

**Parameters**
- **value**: scalar
  - All elements of *a* will be assigned this value.

**Examples**

```python
>>> a = np.array([1, 2])
>>> a.fill(0)
```

```python
>>> a
array([0, 0])
```

```python
>>> a = np.empty(2)
>>> a.fill(1)
```

```python
>>> a
array([ 1., 1.])
```

*recarray.flatten*(order='C')

Return a copy of the array collapsed into one dimension.

**Parameters**
- **order**: {'C', 'F', 'A'}, optional
  - Whether to flatten in C (row-major), Fortran (column-major) order, or preserve the C/Fortran ordering from *a*. The default is ‘C’.

**Returns**
- **y**: ndarray
  - A copy of the input array, flattened to one dimension.

**See also:**

* ravel
  - Return a flattened array.
**flat**

A 1-D flat iterator over the array.

**Examples**

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])
```

**recarray.getfield**(dtype, offset=0)

Returns a field of the given array as a certain type.

A field is a view of the array data with a given data-type. The values in the view are determined by the given type and the offset into the current array in bytes. The offset needs to be such that the view dtype fits in the array dtype; for example an array of dtype complex128 has 16-byte elements. If taking a view with a 32-bit integer (4 bytes), the offset needs to be between 0 and 12 bytes.

**Parameters**

- **dtype**: str or dtype
  The data type of the view. The dtype size of the view can not be larger than that of the array itself.

- **offset**: int
  Number of bytes to skip before beginning the element view.

**Examples**

```python
>>> x = np.diag([1.+1.j]*2)
>>> x[1, 1] = 2 + 4.j
>>> x
array([[ 1.+1.j, 0.+0.j],
       [ 0.+0.j, 2.+4.j]])
>>> x.getfield(np.float64)
array([[ 1., 0.],
       [ 0., 2.]])
```

By choosing an offset of 8 bytes we can select the complex part of the array for our view:

```python
>>> x.getfield(np.float64, offset=8)
array([[ 1., 0.],
       [ 0., 4.]])
```

**recarray.item**(args)

Copy an element of an array to a standard Python scalar and return it.

**Parameters**

- **args**: Arguments (variable number and type)
  - none: in this case, the method only works for arrays with one element (a.size == 1), which element is copied into a standard Python scalar object and returned.
  - int_type: this argument is interpreted as a flat index into the array, specifying which element to copy and return.
  - tuple of int_types: functions as does a single int_type argument, except that the argument is interpreted as an nd-index into the array.
**Returns**

\[ z \]: Standard Python scalar object

A copy of the specified element of the array as a suitable Python scalar

**Notes**

When the data type of \( a \) is longdouble or clongdouble, item() returns a scalar array object because there is no available Python scalar that would not lose information. Void arrays return a buffer object for item(), unless fields are defined, in which case a tuple is returned.

item is very similar to \( a[args] \), except, instead of an array scalar, a standard Python scalar is returned. This can be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using Python’s optimized math.

**Examples**

```python
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[3, 1, 7],
       [2, 8, 3],
       [8, 5, 3]])
>>> x.item(3)
2
>>> x.item(7)
5
>>> x.item((0, 1))
1
>>> x.item((2, 2))
3
```

recarray.itemset(*args)

Insert scalar into an array (scalar is cast to array’s dtype, if possible)

There must be at least 1 argument, and define the last argument as item. Then, a.itemset(*args) is equivalent to but faster than \( a[args] = \) item. The item should be a scalar value and args must select a single item in the array \( a \).

**Parameters**

*args : Arguments

If one argument: a scalar, only used in case \( a \) is of size 1. If two arguments: the last argument is the value to be set and must be a scalar, the first argument specifies a single array element location. It is either an int or a tuple.

**Notes**

Compared to indexing syntax, itemset provides some speed increase for placing a scalar into a particular location in an ndarray, if you must do this. However, generally this is discouraged: among other problems, it complicates the appearance of the code. Also, when using itemset (and item) inside a loop, be sure to assign the methods to a local variable to avoid the attribute look-up at each loop iteration.

**Examples**

```python
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[3, 1, 7],
       [2, 8, 3],
       [8, 5, 3]])
>>> x.itemset(4, 0)
```

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Recall the maximum along a given axis.

Refer to :func:`numpy.amax` for full documentation.

See also:

.. code-block::

   numpy.amax

.. code-block::

   equivalent function

Recarray mean

.. code-block::

   recarray.mean (axis=None, dtype=None, out=None)

Returns the average of the array elements along given axis.

Refer to :func:`numpy.mean` for full documentation.

See also:

.. code-block::

   numpy.mean

.. code-block::

   equivalent function

Recarray min

.. code-block::

   recarray.min (axis=None, out=None)

Return the minimum along a given axis.

Refer to :func:`numpy.amin` for full documentation.

See also:

.. code-block::

   numpy.amin

.. code-block::

   equivalent function

Recarray newbyteorder

.. code-block::

   recarray.newbyteorder (new_order='S')

Return the array with the same data viewed with a different byte order.

Equivalent to:

.. code-block::

   arr.view(arr.dtype.newbytorder(new_order))

Changes are also made in all fields and sub-arrays of the array data type.

Parameters

**new_order** : string, optional

Byte order to force; a value from the byte order specifications above. :attr:`new_order` codes can be any of:

* ‘S’ - swap dtype from current to opposite endian
* ‘<’, ‘L’ - little endian
* ‘>’, ‘B’ - big endian
* ‘=’, ‘N’ - native order
* ‘|’, ‘I’ - ignore (no change to byte order)

The default value (‘S’) results in swapping the current byte order. The code does a case-insensitive check on the first letter of :attr:`new_order` for the alternatives above. For example, any of ‘B’ or ‘b’ or ‘biggish’ are valid to specify big-endian.
Returns

```
new_arr : array
```

New array object with the dtype reflecting given change to the byte order.

```
recarray.nonzero()
```

Return the indices of the elements that are non-zero.

Refer to `numpy.nonzero` for full documentation.

See also:

```
numpy.nonzero
```

Equivalent function

```
recarray.partition(kth, axis=-1, kind='introselect', order=None)
```

Rearranges the elements in the array in such a way that value of the element in kth position is in the position it would be in a sorted array. All elements smaller than the kth element are moved before this element and all equal or greater are moved behind it. The ordering of the elements in the two partitions is undefined.

New in version 1.8.0.

Parameters

- `kth` : int or sequence of ints
  Element index to partition by. The kth element value will be in its final sorted position and all smaller elements will be moved before it and all equal or greater elements behind it. The order all elements in the partitions is undefined. If provided with a sequence of kth it will partition all elements indexed by kth of them into their sorted position at once.

- `axis` : int, optional
  Axis along which to sort. Default is -1, which means sort along the last axis.

- `kind` : {'introselect'}, optional
  Selection algorithm. Default is ‘introselect’.

- `order` : list, optional
  When a is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

See also:

```
numpy.partition
```

Return a partitioned copy of an array.

```
argpartition
```

Indirect partition.

```
sort
```

Full sort.

Notes

See `np.partition` for notes on the different algorithms.
Examples

```python
>>> a = np.array([3, 4, 2, 1])
>>> a.partition(a, 3)
>>> a
array([2, 1, 3, 4])
```

```python
>>> a.partition((1, 3))
array([1, 2, 3, 4])
```

```python
recarray.prod(axis=None, dtype=None, out=None)
```
Return the product of the array elements over the given axis

Refer to `numpy.prod` for full documentation.

See also:

```python
numpy.prod
```
equivalent function

```python
recarray.ptp(axis=None, out=None)
```
Peak to peak (maximum - minimum) value along a given axis.

Refer to `numpy.ptp` for full documentation.

See also:

```python
numpy.ptp
```
equivalent function

```python
recarray.put(indices, values, mode='raise')
```
Set `a.flat[n] = values[n]` for all `n` in `indices`.

Refer to `numpy.put` for full documentation.

See also:

```python
numpy.put
```
equivalent function

```python
recarray.ravel(order=None)
```
Return a flattened array.

Refer to `numpy.ravel` for full documentation.

See also:

```python
numpy.ravel
```
equivalent function

```python
ndarray.flat
```
a flat iterator on the array.

```python
recarray.repeat(repeats, axis=None)
```
Repeat elements of an array.

Refer to `numpy.repeat` for full documentation.

See also:
**numpy.repeat**
equivalent function

**recarray.reshape**(shape, order='C')
Returns an array containing the same data with a new shape.

Refer to **numpy.reshape** for full documentation.

See also:

**numpy.reshape**
equivalent function

**recarray.resize**(new_shape, refcheck=True)
Change shape and size of array in-place.

**Parameters**

- **new_shape**: tuple of ints, or n ints
  Shape of resized array.
- **refcheck**: bool, optional
  If False, reference count will not be checked. Default is True.

**Returns**

None

**Raises**

- **ValueError**
  If a does not own its own data or references or views to it exist, and the data memory must be changed.

- **SystemError**
  If the order keyword argument is specified. This behaviour is a bug in NumPy.

See also:

**resize**
Return a new array with the specified shape.

**Notes**

This reallocates space for the data area if necessary.

Only contiguous arrays (data elements consecutive in memory) can be resized.

The purpose of the reference count check is to make sure you do not use this array as a buffer for another Python object and then reallocate the memory. However, reference counts can increase in other ways so if you are sure that you have not shared the memory for this array with another Python object, then you may safely set refcheck to False.

**Examples**

Shrinking an array: array is flattened (in the order that the data are stored in memory), resized, and reshaped:

```python
>>> a = np.array([[0, 1], [2, 3]], order='C')
>>> a.resize((2, 1))
>>> a
```

1.6. Standard array subclasses
array([[0],
       [1]]))

>>> a = np.array([[0, 1], [2, 3]], order='F')

>>> a.resize((2, 1))

array([[0],
       [2]])

Enlarging an array: as above, but missing entries are filled with zeros:

>>> b = np.array([[0, 1], [2, 3]])

>>> b.resize(2, 3) # new_shape parameter doesn’t have to be a tuple

array([[0, 1, 2],
       [3, 0, 0]])

Referencing an array prevents resizing...

>>> c = a

>>> a.resize((1, 1))

Traceback (most recent call last):
...
ValueError: cannot resize an array that has been referenced ...

Traceback (most recent call last):
...
ValueError: cannot resize an array that has been referenced ...

Unless refcheck is False:

>>> a.resize((1, 1), refcheck=False)

>>> a

array([[0]])

>>> c

array([[0]])

recarray.round(decimals=0, out=None)

Return a with each element rounded to the given number of decimals.

Refer to numpy.around for full documentation.

See also:

numpy.around

equivalent function

recarray.searchsorted(v, side='left', sorter=None)

Find indices where elements of v should be inserted in a to maintain order.

For full documentation, see numpy.searchsorted

See also:

numpy.searchsorted

equivalent function

recarray.setfield(val, dtype, offset=0)

Put a value into a specified place in a field defined by a data-type.

Place val into a’s field defined by dtype and beginning offset bytes into the field.
Parameters
val : object
Value to be placed in field.
dtype : dtype object
Data-type of the field in which to place val.
offset : int, optional
The number of bytes into the field at which to place val.

Returns
None

See also:
gffield

Examples
>>> x = np.eye(3)
>>> x.getfield(np.float64)
array([[ 1.,  0.,  0.],
       [ 0.,  1.,  0.],
       [ 0.,  0.,  1.]])
>>> x.setfield(3, np.int32)
>>> x.getfield(np.int32)
array([[3, 3, 3],
       [3, 3, 3],
       [3, 3, 3]])

recarray.setflags(write=None, align=None, uic=None)
Set array flags WRITEABLE, ALIGNED, and UPDATEIFCOPY, respectively.

These Boolean-valued flags affect how numpy interprets the memory area used by a (see Notes below).
The ALIGNED flag can only be set to True if the data is actually aligned according to the type. The
UPDATEIFCOPY flag can never be set to True. The flag WRITEABLE can only be set to True if the array
owns its own memory, or the ultimate owner of the memory exposes a writable buffer interface, or is a
string. (The exception for string is made so that unpickling can be done without copying memory.)

Parameters
write : bool, optional
Describes whether or not a can be written to.
align : bool, optional
Describes whether or not a is aligned properly for its type.
uic : bool, optional
Describes whether or not a is a copy of another “base” array.

1.6. Standard array subclasses
Notes

Array flags provide information about how the memory area used for the array is to be interpreted. There are 6 Boolean flags in use, only three of which can be changed by the user: UPDATEIFCOPY, WRITEABLE, and ALIGNED.

WRITEABLE (W) the data area can be written to;

ALIGNED (A) the data and strides are aligned appropriately for the hardware (as determined by the compiler);

UPDATEIFCOPY (U) this array is a copy of some other array (referenced by .base). When this array is deallocated, the base array will be updated with the contents of this array.

All flags can be accessed using their first (upper case) letter as well as the full name.

Examples

```python
>>> y
array([[3, 1, 7],
       [2, 0, 0],
       [8, 5, 9]])
>>> y.flags
    C_CONTIGUOUS : True
    F_CONTIGUOUS : False
    OWNDATA : True
    WRITEABLE : True
    ALIGNED : True
    UPDATEIFCOPY : False
>>> y.setflags(write=0, align=0)
>>> y.flags
    C_CONTIGUOUS : True
    F_CONTIGUOUS : False
    OWNDATA : True
    WRITEABLE : False
    ALIGNED : False
    UPDATEIFCOPY : False
>>> y.setflags(uic=1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: cannot set UPDATEIFCOPY flag to True
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: cannot set UPDATEIFCOPY flag to True
```

recarray.sort (axis=-1, kind='quicksort', order=None)

Sort an array, in-place.

Parameters

axis : int, optional

Axis along which to sort. Default is -1, which means sort along the last axis.

kind : {'quicksort', 'mergesort', 'heapsort'}, optional

Sorting algorithm. Default is ‘quicksort’.

order : list, optional

When a is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

See also:
numpy.sort
Return a sorted copy of an array.

argsort
Indirect sort.

lexsort
Indirect stable sort on multiple keys.

searchsorted
Find elements in sorted array.

partition
Partial sort.

Notes
See sort for notes on the different sorting algorithms.

Examples
>>> a = np.array([1,4], [3,1])
>>> a.sort(axis=1)
>>> a
array([[1, 4],
       [1, 3]])

Use the order keyword to specify a field to use when sorting a structured array:

>>> a = np.array([('a', 2), ('c', 1)], dtype=[('x', 'S1'), ('y', int)])
>>> a.sort(order='y')
>>> a
array([('c', 1), ('a', 2)],
      dtype=[('x', '|S1'), ('y', '<i4')])

recarray.squeeze (axis=None)
Remove single-dimensional entries from the shape of a.

Refer to numpy.squeeze for full documentation.

See also:

numpy.squeeze
equivalent function

recarray.std (axis=None, dtype=None, out=None, ddof=0)
Returns the standard deviation of the array elements along given axis.

Refer to numpy.std for full documentation.

See also:

numpy.std
equivalent function
recarray.sum (axis=None, dtype=None, out=None)
    Return the sum of the array elements over the given axis.
    Refer to numpy.sum for full documentation.
    See also:
    
    numpy.sum
        equivalent function

recarray.swapaxes (axis1, axis2)
    Return a view of the array with axis1 and axis2 interchanged.
    Refer to numpy.swapaxes for full documentation.
    See also:
    
    numpy.swapaxes
        equivalent function

recarray.take (indices, axis=None, out=None, mode='raise')
    Return an array formed from the elements of a at the given indices.
    Refer to numpy.take for full documentation.
    See also:
    
    numpy.take
        equivalent function

recarray.tobytes (order='C')
    Construct Python bytes containing the raw data bytes in the array.
    Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object can be
    produced in either ‘C’ or ‘Fortran’, or ‘Any’ order (the default is ‘C’-order). ‘Any’ order means C-order
    unless the F_CONTIGUOUS flag in the array is set, in which case it means ‘Fortran’ order.
    New in version 1.9.0.

    Parameters
        order : {‘C’, ‘F’, None}, optional
            Order of the data for multidimensional arrays: C, Fortran, or the same as for the original
            array.

    Returns
        s : bytes
            Python bytes exhibiting a copy of a’s raw data.

    Examples
    >>> x = np.array([[0, 1], [2, 3]])
    >>> x.tobytes()
    b'\x00\x00\x00\x00\x00\x00\x02\x00\x00\x00\x02\x00\x00\x00\x00\x00\x00\x00'
    >>> x.tobytes('C') == x.tobytes()
    True
    >>> x.tobytes('F')
    b'\x00\x00\x00\x00\x00\x00\x02\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00'
recarray.tofile(fid, sep="", format="%s")
Write array to a file as text or binary (default).

Data is always written in ‘C’ order, independent of the order of a. The data produced by this method can be recovered using the function fromfile().

Parameters
fid : file or str
An open file object, or a string containing a filename.
sep : str
Separator between array items for text output. If ‘’ (empty), a binary file is written, equivalent to file.write(a.tobytes()).
format : str
Format string for text file output. Each entry in the array is formatted to text by first converting it to the closest Python type, and then using “format” % item.

Notes
This is a convenience function for quick storage of array data. Information on endianness and precision is lost, so this method is not a good choice for files intended to archive data or transport data between machines with different endianness. Some of these problems can be overcome by outputting the data as text files, at the expense of speed and file size.

recarray.tolist()
Return the array as a (possibly nested) list.

Return a copy of the array data as a (nested) Python list. Data items are converted to the nearest compatible Python type.

Parameters
none

Returns
y : list
The possibly nested list of array elements.

Notes
The array may be recreated, a = np.array(a.tolist()).

Examples
>>> a = np.array([1, 2])
>>> a.tolist()
[1, 2]
>>> a = np.array([[1, 2], [3, 4]])
>>> list(a)
[array([1, 2]), array([3, 4])]
>>> a.tolist()
[[1, 2], [3, 4]]

recarray.tostring(order='C')
Construct Python bytes containing the raw data bytes in the array.

Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object can be produced in either ‘C’ or ‘Fortran’, or ‘Any’ order (the default is ‘C’-order). ‘Any’ order means C-order unless the F_CONTIGUOUS flag in the array is set, in which case it means ‘Fortran’ order.
This function is a compatibility alias for tobytes. Despite its name it returns bytes not strings.

**Parameters**
- order : {'C', 'F', None}, optional
  Order of the data for multidimensional arrays: C, Fortran, or the same as for the original array.

**Returns**
- s : bytes
  Python bytes exhibiting a copy of a’s raw data.

**Examples**
```python
>>> x = np.array([[0, 1], [2, 3]])
>>> x.tobytes()
b'\x00\x00\x00\x00\x01\x00\x00\x00\x02\x00\x00\x00\x03\x00\x00\x00\x00'
>>> x.tobytes('C') == x.tobytes()
True
>>> x.tobytes('F')
b'\x00\x00\x00\x00\x02\x00\x00\x00\x01\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00'
```

**recarray.trace**(offset=0, axis1=0, axis2=1, dtype=None, out=None)

Return the sum along diagonals of the array.

Refer to `numpy.trace` for full documentation.

See also:
- `numpy.trace`
equivalent function

**recarray.transpose(***axes**)

Returns a view of the array with axes transposed.

For a 1-D array, this has no effect. (To change between column and row vectors, first cast the 1-D array into a matrix object.) For a 2-D array, this is the usual matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided and a.shape = (i[0], i[1], ... i[n-2], i[n-1]), then a.transpose().shape = (i[n-1], i[n-2], ... i[1], i[0]).

**Parameters**
- axes : None, tuple of ints, or n ints
  - None or no argument: reverses the order of the axes.
  - tuple of ints: i in the j-th place in the tuple means a’s i-th axis becomes a.transpose()’s j-th axis.
  - n ints: same as an n-tuple of the same ints (this form is intended simply as a “convenience” alternative to the tuple form)

**Returns**
- out : ndarray
  View of a, with axes suitably permuted.

See also:
- `ndarray.T`
  Array property returning the array transposed.
Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])
```

```python
recarray.var(axis=None, dtype=None, out=None, ddof=0)
```
Returns the variance of the array elements, along given axis.

Refer to `numpy.var` for full documentation.

See also:

```python
numpy.var
```
equivalent function

```python
recarray.view(dtype=None, type=None)
```

class `numpy.record`
A data-type scalar that allows field access as attribute lookup.

Attributes

```
T           transpose
base        base object
data        pointer to start of data
dtype       dtype object
flags       integer value of flags
flat        a 1-d view of scalar
imag        imaginary part of scalar
itemsize    length of one element in bytes
 nbytes      length of item in bytes
 ndim        number of array dimensions
 real        real part of scalar
 shape       tuple of array dimensions
 size        number of elements in the gentype
 strides     tuple of bytes steps in each dimension
```

```python
record.T
``` transpose

```python
record.base
``` base object

```python
record.data
``` pointer to start of data
record.dtype
   dtype object
record.flags
   integer value of flags
record.flat
   a 1-d view of scalar
record.imag
   imaginary part of scalar
record.itemsize
   length of one element in bytes
record.nbytes
   length of item in bytes
record.ndim
   number of array dimensions
record.real
   real part of scalar
record.shape
   tuple of array dimensions
record.size
   number of elements in the gentype
record.strides
   tuple of bytes steps in each dimension

Methods

all
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po any
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po argmax
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po argmin
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po argsort
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po astype
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po byteswap
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po choose
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po clip
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po compress
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po conj
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po conjugate
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po copy
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po cumprod
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po cums
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po diagonal
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po dump
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po dumps
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po fill
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po flatten
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po getfield
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po item
   Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and po itemset
Not implemented (virtual attribute) Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
The

record.all()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
The

record.any()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
The

record.argmax()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

1.6. Standard array subclasses
See also:

The

`record.argmin()`
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

`record.argsort()`
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

`record.astype()`
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

`record.byteswap()`
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

`record.choose()`
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

`record.clip()`
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

`record.compress()`
Not implemented (virtual attribute)
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

record.\texttt{conj}()

\texttt{record.conjugate}()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

record.\texttt{copy}()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

record.\texttt{cumprod}()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

record.\texttt{cumsum}()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

record.\texttt{diagonal}()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

record.\texttt{dump}()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:
The

```
record.dumps()
```

Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

```
record.fill()
```

Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

```
record.flatten()
```

Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

```
record.getfield()
```

```
record.item()
```

Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

```
record.itemset()
```

Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

```
record.max()
```

Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The
record.mean()
    Not implemented (virtual attribute)

    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

    See also:

    The

record.min()
    Not implemented (virtual attribute)

    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

    See also:

    The

record.newbyteorder(new_order='S')
    Return a new dtype with a different byte order.

    Changes are also made in all fields and sub-arrays of the data type.

    The new_order code can be any from the following:
    • {'<', 'L'} - little endian
    • {'>', 'B'} - big endian
    • {'=', 'N'} - native order
    • 'S' - swap dtype from current to opposite endian
    • {'I', 'I'} - ignore (no change to byte order)

    Parameters
    new_order : str, optional
        Byte order to force; a value from the byte order specifications above. The default value ('S') results in swapping the current byte order. The code does a case-insensitive check on the first letter of new_order for the alternatives above. For example, any of 'B' or 'b' or 'biggish' are valid to specify big-endian.

    Returns
    new_dtype : dtype
        New dtype object with the given change to the byte order.

record.nonzero()
    Not implemented (virtual attribute)

    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

    See also:

    The

record.pprint()
    Pretty-print all fields.
record.\texttt{prod}()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

    \textbf{See also:}
    
The

record.\texttt{ptp}()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

    \textbf{See also:}
    
The

record.\texttt{put}()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

    \textbf{See also:}
    
The

record.\texttt{ravel}()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

    \textbf{See also:}
    
The

record.\texttt{repeat}()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

    \textbf{See also:}
    
The

record.\texttt{reshape}()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

    \textbf{See also:}
    
The

record.\texttt{resize}()
    Not implemented (virtual attribute)
    Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

    \textbf{See also:}
The

**record.round**()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

**record.searchsorted**()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

**record.setfield**()

**record.setflags**()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

**record.sort**()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

**record.squeeze**()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

**record.std**()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

1.6. Standard array subclasses
record.sum()

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

record.swapaxes()

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

record.take()

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

record.tobytes()

record.tofile()

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

record.tolist()

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

record.tostring()

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

record.trace()
Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

record.transpose()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

record.var()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

record.view()
Not implemented (virtual attribute)

Class generic exists solely to derive numpy scalars from, and possesses, albeit unimplemented, all the attributes of the ndarray class so as to provide a uniform API.

See also:

The

1.6.6 Masked arrays (numpy.ma)

See also:

Masked arrays

1.6.7 Standard container class

For backward compatibility and as a standard “container” class, the UserArray from Numeric has been brought over to NumPy and named numpy.lib.user_array.container The container class is a Python class whose self.array attribute is an ndarray. Multiple inheritance is probably easier with numpy.lib.user_array.container than with the ndarray itself and so it is included by default. It is not documented here beyond mentioning its existence because you are encouraged to use the ndarray class directly if you can.

numpy.lib.user_array.container(data[, ...])

class numpy.lib.user_array.container (data, dtype=None, copy=True)

Methods

Continued on next page
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<table>
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<tr>
<th>Method</th>
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<td>astype(typecode)</td>
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<td>byteswap()</td>
</tr>
<tr>
<td>copy()</td>
</tr>
<tr>
<td>tostring()</td>
</tr>
</tbody>
</table>

container.astype(typecode)

container.byteswap()

container.copy()

container.tostring()

1.6.8 Array Iterators

Iterators are a powerful concept for array processing. Essentially, iterators implement a generalized for-loop. If myiter is an iterator object, then the Python code:

```python
for val in myiter:
    ...
    some code involving val
    ...
```

calls `val = myiter.next()` repeatedly until `StopIteration` is raised by the iterator. There are several ways to iterate over an array that may be useful: default iteration, flat iteration, and $N$-dimensional enumeration.

**Default iteration**

The default iterator of an ndarray object is the default Python iterator of a sequence type. Thus, when the array object itself is used as an iterator. The default behavior is equivalent to:

```python
for i in range(arr.shape[0]):
    val = arr[i]
```

This default iterator selects a sub-array of dimension $N - 1$ from the array. This can be a useful construct for defining recursive algorithms. To loop over the entire array requires $N$ for-loops.

```python
>>> a = arange(24).reshape(3,2,4)+10
>>> for val in a:
...    print 'item:', val
item: [[10 11 12 13]
     [14 15 16 17]]
item: [[18 19 20 21]
     [22 23 24 25]]
item: [[26 27 28 29]
     [30 31 32 33]]
```

**Flat iteration**
**ndarray.flat**
A 1-D iterator over the array.

This is a `numpy.flatiter` instance, which acts similarly to, but is not a subclass of, Python’s built-in iterator object.

**See also:**

`flatten`
Return a copy of the array collapsed into one dimension.

**flatiter**

**Examples**

```python
>>> x = np.arange(1, 7).reshape(2, 3)
>>> x
array([[1, 2, 3],
       [4, 5, 6]])
>>> x.flat[3]
4
>>> x.T
array([[1, 4],
       [2, 5],
       [3, 6]])
>>> x.T.flat[3]
5
>>> type(x.flat)
<type 'numpy.flatiter'>
```

An assignment example:

```python
>>> x.flat = 3; x
array([[3, 3, 3],
       [3, 3, 3]])
>>> x.flat[[1,4]] = 1; x
array([[3, 1, 3],
       [3, 1, 3]])
```

As mentioned previously, the flat attribute of ndarray objects returns an iterator that will cycle over the entire array in C-style contiguous order.

```python
>>> for i, val in enumerate(x.flat):
...     if i%5 == 0: print i, val
0 10
5 15
10 20
15 25
20 30
```

Here, I’ve used the built-in enumerate iterator to return the iterator index as well as the value.

**N-dimensional enumeration**
class numpy.ndenumerate(arr)

Multidimensional index iterator.

Return an iterator yielding pairs of array coordinates and values.

Parameters

a : ndarray

Input array.

See also:

ndindex, flatiter

Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> for index, x in np.ndenumerate(a):
...     print(index, x)
(0, 0) 1
(0, 1) 2
(1, 0) 3
(1, 1) 4
```

Methods

next() Standard iterator method, returns the index tuple and array value.

```
nndenumerate.next()

Standard iterator method, returns the index tuple and array value.

Returns

coords : tuple of ints

The indices of the current iteration.

val : scalar

The array element of the current iteration.

Sometimes it may be useful to get the N-dimensional index while iterating. The ndenumerate iterator can achieve this.

```python
>>> for i, val in ndenumerate(a):
...     if sum(i)%5 == 0: print i, val
(0, 0, 0) 10
(1, 1, 3) 25
(2, 0, 3) 29
(2, 1, 2) 32
```

Iterator for broadcasting

```
broadcast Produce an object that mimics broadcasting.
```

240 Chapter 1. Array objects
class `numpy.broadcast`

Produce an object that mimics broadcasting.

**Parameters**

`in1, in2, ... : array_like`

Input parameters.

**Returns**

`b : broadcast object`

Broadcast the input parameters against one another, and return an object that encapsulates the result. Amongst others, it has `shape` and `nd` properties, and may be used as an iterator.

**Examples**

Manually adding two vectors, using broadcasting:

```python
def add_vectors(x, y):
    out = np.empty(b.shape)
    out.flat = [u+v for (u,v) in b]
    return out
```

```python
>>> x = np.array([[1], [2], [3]])
>>> y = np.array([4, 5, 6])
>>> b = np.broadcast(x, y)

>>> out = add_vectors(x, y)
array([[ 5., 6., 7.],
       [ 6., 7., 8.],
       [ 7., 8., 9.]])
```

Compare against built-in broadcasting:

```python
>>> x + y
array([[ 5, 6, 7],
       [ 6, 7, 8],
       [ 7, 8, 9]])
```

**Attributes**

- `index : current index in broadcasted result`
- `iters : tuple of iterators along self's “components.”`
- `shape : Shape of broadcasted result.`
- `size : Total size of broadcasted result.`

**Examples**

```python
>>> x = np.array([[1], [2], [3]])
>>> y = np.array([4, 5, 6])
>>> b = np.broadcast(x, y)

>>> b.index
0
>>> b.next(), b.next(), b.next()((1, 4), (1, 5), (1, 6))
>>> b.index
3
```
broadcast.\texttt{iters}

tuple of iterators along \texttt{self}'s “components.”

Returns a tuple of \texttt{numpy.flatiter} objects, one for each “component” of \texttt{self}.

See also:

\texttt{numpy.flatiter}

\textbf{Examples}

\begin{verbatim}
>>> x = np.array([1, 2, 3])
>>> y = np.array([[4], [5], [6]])
>>> b = np.broadcast(x, y)
>>> row, col = b.iters
>>> row.next(), col.next()
(1, 4)
\end{verbatim}

broadcast.\texttt{shape}

Shape of broadcasted result.

\textbf{Examples}

\begin{verbatim}
>>> x = np.array([1, 2, 3])
>>> y = np.array([[4], [5], [6]])
>>> b = np.broadcast(x, y)
>>> b.shape
(3, 3)
\end{verbatim}

broadcast.\texttt{size}

Total size of broadcasted result.

\textbf{Examples}

\begin{verbatim}
>>> x = np.array([1, 2, 3])
>>> y = np.array([[4], [5], [6]])
>>> b = np.broadcast(x, y)
>>> b.size
9
\end{verbatim}

\textbf{Methods}

\begin{verbatim}
next          x.next() -> the next value, or raise StopIteration
reset()      Reset the broadcasted result’s iterator(s).
\end{verbatim}

broadcast.\texttt{next}

\texttt{x.next()} -> the next value, or raise \texttt{StopIteration}

broadcast.\texttt{reset()}

Reset the broadcasted result’s iterator(s).

\textbf{Parameters}

None

\textbf{Returns}

None
Examples

```python
>>> x = np.array([1, 2, 3])
>>> y = np.array([[4], [5], [6]])
>>> b = np.broadcast(x, y)
>>> b.index
0
>>> b.next(), b.next(), b.next()
((1, 4), (2, 4), (3, 4))
>>> b.index
3
>>> b.reset()
>>> b.index
0
```

The general concept of broadcasting is also available from Python using the `broadcast` iterator. This object takes \( N \) objects as inputs and returns an iterator that returns tuples providing each of the input sequence elements in the broadcasted result.

```python
>>> for val in broadcast([[1,0],[2,3]],[0,1]):
...  print(val)
(1, 0)
(0, 1)
(2, 0)
(3, 1)
```

1.7 Masked arrays

Masked arrays are arrays that may have missing or invalid entries. The `numpy.ma` module provides a nearly work-alike replacement for `numpy` that supports data arrays with masks.

1.7.1 The `numpy.ma` module

Rationale

Masked arrays are arrays that may have missing or invalid entries. The `numpy.ma` module provides a nearly work-alike replacement for `numpy` that supports data arrays with masks.

What is a masked array?

In many circumstances, datasets can be incomplete or tainted by the presence of invalid data. For example, a sensor may have failed to record a data, or recorded an invalid value. The `numpy.ma` module provides a convenient way to address this issue, by introducing masked arrays.

A masked array is the combination of a standard `numpy.ndarray` and a mask. A mask is either `nomask`, indicating that no value of the associated array is invalid, or an array of booleans that determines for each element of the associated array whether the value is valid or not. When an element of the mask is `False`, the corresponding element of the associated array is valid and is said to be unmasked. When an element of the mask is `True`, the corresponding element of the associated array is said to be masked (invalid).

The package ensures that masked entries are not used in computations.

As an illustration, let’s consider the following dataset:
We wish to mark the fourth entry as invalid. The easiest is to create a masked array:

```python
>>> mx = ma.masked_array(x, mask=[0, 0, 0, 1, 0])
```

We can now compute the mean of the dataset, without taking the invalid data into account:

```python
>>> mx.mean()
2.75
```

### The `numpy.ma` module

The main feature of the `numpy.ma` module is the `MaskedArray` class, which is a subclass of `numpy.ndarray`. The class, its attributes and methods are described in more details in the `MaskedArray class` section.

The `numpy.ma` module can be used as an addition to `numpy`:

```python
>>> import numpy as np
>>> import numpy.ma as ma
```

To create an array with the second element invalid, we would do:

```python
>>> y = ma.array([1, 2, 3], mask=[0, 1, 0])
```

To create a masked array where all values close to 1.e20 are invalid, we would do:

```python
>>> z = masked_values([1.0, 1.e20, 3.0, 4.0], 1.e20)
```

For a complete discussion of creation methods for masked arrays please see section `Constructing masked arrays`.

### 1.7.2 Using `numpy.ma`

#### Constructing masked arrays

There are several ways to construct a masked array.

- A first possibility is to directly invoke the `MaskedArray` class.
- A second possibility is to use the two masked array constructors, `array` and `masked_array`.

```python
array(data[, dtype, copy, order, mask, ...]) An array class with possibly masked values.
masked_array An array class with possibly masked values.
```

```python
numpy.ma.array(data, dtype=None, copy=False, order=False, mask=False, fill_value=None, keep_mask=True, hard_mask=None, shrink=True, subok=True, ndmin=0)
```

An array class with possibly masked values.

Masked values of True exclude the corresponding element from any computation.

Construction:

```python
x = MaskedArray(data, mask=nomask, dtype=None, 
                 copy=False, subok=True, ndmin=0, fill_value=None, 
                 keep_mask=True, hard_mask=False, shrink=True)
```
Parameters

**data** : array_like

Input data.

**mask** : sequence, optional

Mask. Must be convertible to an array of booleans with the same shape as `data`. True indicates a masked (i.e. invalid) data.

**dtype** : dtype, optional

Data type of the output. If `dtype` is None, the type of the data argument (`data.dtype`) is used. If `dtype` is not None and different from `data.dtype`, a copy is performed.

**copy** : bool, optional

Whether to copy the input data (True), or to use a reference instead. Default is False.

**subok** : bool, optional

Whether to return a subclass of `MaskedArray` if possible (True) or a plain `MaskedArray`. Default is True.

**ndmin** : int, optional

Minimum number of dimensions. Default is 0.

**fill_value** : scalar, optional

Value used to fill in the masked values when necessary. If None, a default based on the data-type is used.

**keep_mask** : bool, optional

Whether to combine `mask` with the mask of the input data, if any (True), or to use only `mask` for the output (False). Default is True.

**hard_mask** : bool, optional

Whether to use a hard mask or not. With a hard mask, masked values cannot be un-masked. Default is False.

**shrink** : bool, optional

Whether to force compression of an empty mask. Default is True.

```python
numpy.ma.masked_array
alias of MaskedArray
```

- A third option is to take the view of an existing array. In that case, the mask of the view is set to `nomask` if the array has no named fields, or an array of boolean with the same structure as the array otherwise.

```python
>>> x = np.array([1, 2, 3])
>>> x.view(ma.MaskedArray)
masked_array(data = [1 2 3],
             mask = False,
             fill_value = 999999)
>>> x = np.array([(1, 1.), (2, 2.)], dtype=[('a',int), ('b', float)])
>>> x.view(ma.MaskedArray)
masked_array(data = [(1, 1.0) (2, 2.0)],
             mask = [(False, False) (False, False)],
             fill_value = (999999, 1e+20),
             dtype = [('a', '<i4'), ('b', '<f8')])
```
• Yet another possibility is to use any of the following functions:

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```python
numpy.ma.asarray(a, dtype=None, order=None)
```

Convert the input to a masked array of the given data-type.

No copy is performed if the input is already an `ndarray`. If `a` is a subclass of `MaskedArray`, a base class `MaskedArray` is returned.

**Parameters**

- **a** : array_like
  Input data, in any form that can be converted to a masked array. This includes lists, lists of tuples, tuples of tuples, tuples of lists, ndarrays and masked arrays.

- **dtype** : dtype, optional
  By default, the data-type is inferred from the input data.

- **order** : {'C', 'F'}, optional
  Whether to use row-major ('C') or column-major ('FORTRAN') memory representation. Default is 'C'.

**Returns**

- **out** : MaskedArray
  Masked array interpretation of `a`.

See also:

- **asanyarray**
  Similar to `asarray`, but conserves subclasses.

**Examples**

```python
>>> x = np.arange(10.).reshape(2, 5)
>>> x
array([[ 0.,  1.,  2.,  3.,  4.],
       [ 5.,  6.,  7.,  8.,  9.]])
>>> np.ma.asarray(x)
masked_array(data =
             [[ 0.  1.  2.  3.  4.]
              [ 5.  6.  7.  8.  9.]],
       mask = [False False False False False],      
       fill_value=999999)  
```
mask = False,
    fill_value = 1e+20)
>>> type(np.ma.asarray(x))
<class 'numpy.ma.core.MaskedArray'>

calnumpy.ma.asanyarray (a, dtype=None)
Convert the input to a masked array, conserving subclasses.

If a is a subclass of MaskedArray, its class is conserved. No copy is performed if the input is already an ndarray.

Parameters

- **a**: array_like
  Input data, in any form that can be converted to an array.

- **dtype**: dtype, optional
  By default, the data-type is inferred from the input data.

- **order**: {'C', 'F'}, optional
  Whether to use row-major ('C') or column-major ('FORTRAN') memory representation. Default is 'C'.

Returns

- **out**: MaskedArray
  MaskedArray interpretation of a.

See also:

- **asarray**
  Similar to asanyarray, but does not conserve subclass.

Examples

```python
>>> x = np.arange(10.).reshape(2, 5)
>>> x
array([[ 0.,  1.,  2.,  3.,  4.],
       [ 5.,  6.,  7.,  8.,  9.]])
>>> np.ma.asanyarray(x)
masked_array(data =
    [[ 0.  1.  2.  3.  4.]
     [ 5.  6.  7.  8.  9.]],
    mask =
    False,
    fill_value = 1e+20)
>>> type(np.ma.asanyarray(x))
<class 'numpy.ma.core.MaskedArray'>
```

numpy.ma.fix_invalid (a, mask=False, copy=True, fill_value=None)
Return input with invalid data masked and replaced by a fill value.

Invalid data means values of nan, inf, etc.

Parameters

- **a**: array_like
  Input array, a (subclass of) ndarray.

- **copy**: bool, optional

Whether to use a copy of \( a \) (True) or to fix \( a \) in place (False). Default is True.

**fill_value**: scalar, optional

Value used for fixing invalid data. Default is None, in which case the \( a.fill_value \) is used.

**Returns**

- \( b \): MaskedArray

  The input array with invalid entries fixed.

**Notes**

A copy is performed by default.

**Examples**

```python
>>> x = np.ma.array([1., -1, np.nan, np.inf], mask=[1] + [0]*3)
>>> x
masked_array(data = [-- -1.0 nan inf],
              mask = [ True False False False],
              fill_value = 1e+20)
>>> np.ma.fix_invalid(x)
masked_array(data = [-- -1.0 -- --],
              mask = [ True False True True],
              fill_value = 1e+20)
>>> fixed = np.ma.fix_invalid(x)
>>> fixed.data
array([ 1.00000000e+00, -1.00000000e+00, 1.00000000e+20, 1.00000000e+20])
>>> x.data
array([ 1., -1., NaN, Inf])
```

**numpy.ma.masked_equal\( (x, value, copy=True) \)**

Mask an array where equal to a given value.

This function is a shortcut to \texttt{masked_where}, with \texttt{condition} = \( (x == value) \). For floating point arrays, consider using \texttt{masked_values(x, value)}.

**See also:**

- \texttt{masked_where} Mask where a condition is met.
- \texttt{masked_values} Mask using floating point equality.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_equal(a, 2)
masked_array(data = [0 1 -- 3],
              mask = [False False True False],
              fill_value=999999)
```
**numpy.ma.masked_greater** *(x, value, copy=True)*

Mask an array where greater than a given value.

This function is a shortcut to *masked_where*, with `condition = (x > value)`.

See also:

**masked.where**

Mask where a condition is met.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_greater(a, 2)
masked_array(data = [0 1 2 --],
             mask = [False False False True],
             fill_value=999999)
```

**numpy.ma.masked_greater_equal** *(x, value, copy=True)*

Mask an array where greater than or equal to a given value.

This function is a shortcut to *masked_where*, with `condition = (x >= value)`.

See also:

**masked.where**

Mask where a condition is met.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_greater_equal(a, 2)
masked_array(data = [0 1 -- --],
              mask = [False False True True],
              fill_value=999999)
```

**numpy.ma.masked_inside** *(x, v1, v2, copy=True)*

Mask an array inside a given interval.

Shortcut to *masked_where*, where `condition` is True for `x` inside the interval `[v1,v2]` (`v1 <= x <= v2`). The boundaries `v1` and `v2` can be given in either order.

See also:

**masked.where**

Mask where a condition is met.

**Notes**

The array `x` is prefilled with its filling value.
Examples

```python
code
>>> import numpy.ma as ma
>>> x = [0.31, 1.2, 0.01, 0.2, -0.4, -1.1]
>>> ma.masked_inside(x, -0.3, 0.3)
masked_array(data = [0.31 1.2 -- -- -0.4 -1.1],
             mask = [False False True True False False],
             fill_value=1e+20)
```

The order of `vl` and `v2` doesn’t matter.

```python
code
>>> ma.masked_inside(x, 0.3, -0.3)
mapped_array(data = [0.31 1.2 -- -- -0.4 -1.1],
             mask = [False False True True False False],
             fill_value=1e+20)
```

```
numpy.ma.masked_invalid(a, copy=True)
Mask an array where invalid values occur (NaNs or infs).

This function is a shortcut to masked_where, with condition = ~(np.isfinite(a)). Any pre-existing mask is conserved. Only applies to arrays with a dtype where NaNs or infs make sense (i.e. floating point types), but accepts any array_like object.

See also:

masked_where
Mask where a condition is met.
```

```
Examples

```python
code
>>> import numpy.ma as ma
>>> a = np.arange(5, dtype=np.float)
>>> a[2] = np.NaN
>>> a[3] = np.PINF
>>> a
array([ 0., 1., nan, inf, 4.])
>>> ma.masked_invalid(a)
mapped_array(data = [0.0 1.0 -- -- 4.0],
             mask = [False False True True False],
             fill_value=1e+20)
```

```
numpy.ma.masked_less(x, value, copy=True)
Mask an array where less than a given value.

This function is a shortcut to masked_where, with condition = (x < value).

See also:

masked_where
Mask where a condition is met.
```

```
Examples

```python
code
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_less(a, 2)
mapped_array(data = [-- -- 2 3],
```
numpy.ma.masked_less_equal(x, value, copy=True)

Mask an array where less than or equal to a given value.

This function is a shortcut to masked_where, with condition = (x <= value).

See also:

masked_where

Mask where a condition is met.

Examples

>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_less_equal(a, 2)
masked_array(data = [-- -- -- 3],
             mask = [ True  True  True False],
             fill_value=999999)

numpy.ma.masked_not_equal(x, value, copy=True)

Mask an array where not equal to a given value.

This function is a shortcut to masked_where, with condition = (x != value).

See also:

masked_where

Mask where a condition is met.

Examples

>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_not_equal(a, 2)
masked_array(data = [-- -- 2 --],
             mask = [ True  True False True],
             fill_value=999999)

numpy.ma.masked_object(x, value, copy=True, shrink=True)

Mask the array x where the data are exactly equal to value.

This function is similar to masked_values, but only suitable for object arrays: for floating point, use masked_values instead.

Parameters

x : array_like
    Array to mask

value : object
    Comparison value

copy : {True, False}, optional
Whether to return a copy of \( x \).

**shrink**: {True, False}, optional

Whether to collapse a mask full of False to nomask

**Returns**

**result**: MaskedArray

The result of masking \( x \) where equal to \( value \).

**See also:**

**masked_where**

Mask where a condition is met.

**masked_equal**

Mask where equal to a given value (integers).

**masked_values**

Mask using floating point equality.

**Examples**

```python
>>> import numpy.ma as ma
>>> food = np.array(['green_eggs', 'ham'], dtype=object)
>>> # don't eat spoiled food
>>> eat = ma.masked_object(food, 'green_eggs')
>>> print eat
[ham]
>>> # plain ol' ham is boring
>>> fresh_food = np.array(['cheese', 'ham', 'pineapple'], dtype=object)
>>> eat = ma.masked_object(fresh_food, 'green_eggs')
>>> print eat
[cheese ham pineapple]
```

Note that \( mask \) is set to \( nomask \) if possible.

```python
>>> eat
masked_array(data = [cheese ham pineapple],
             mask = False,
             fill_value=?)
```

**NumPy**. \( . masked \_outside \) \((x, v1, v2, copy=True)\)

Mask an array outside a given interval.

Shortcut to \( masked \_where \), where \( condition \) is True for \( x \) outside the interval \([v1,v2] (x < v1)|(x > v2)\). The boundaries \( v1 \) and \( v2 \) can be given in either order.

**See also:**

**masked_where**

Mask where a condition is met.

**Notes**

The array \( x \) is prefilled with its filling value.
Examples

```python
>>> import numpy.ma as ma
>>> x = [0.31, 1.2, 0.01, 0.2, -0.4, -1.1]
>>> ma.masked_outside(x, -0.3, 0.3)
masked_array(data = [-- -- 0.01 0.2 -- --],
             mask = [ True True False False True True],
              fill_value=1e+20)
```

The order of v1 and v2 doesn’t matter.

```python
>>> ma.masked_outside(x, 0.3, -0.3)
masked_array(data = [-- -- 0.01 0.2 -- --],
             mask = [ True True False False True True],
              fill_value=1e+20)
```

```python
numpy.ma.masked_values(x, value, rtol=1e-05, atol=1e-08, copy=True, shrink=True)
```

Mask using floating point equality.

Return a MaskedArray, masked where the data in array `x` are approximately equal to `value`, i.e. where the following condition is True

\[(\text{abs}(x - \text{value}) \leq \text{atol} + \text{rtol} \times \text{abs(value)})\]

The fill_value is set to `value` and the mask is set to `nomask` if possible. For integers, consider using `masked_equal`.

**Parameters**

- `x` : array_like
  Array to mask.
- `value` : float
  Masking value.
- `rtol` : float, optional
  Tolerance parameter.
- `atol` : float, optional
  Tolerance parameter (1e-8).
- `copy` : bool, optional
  Whether to return a copy of `x`.
- `shrink` : bool, optional
  Whether to collapse a mask full of False to `nomask`.

**Returns**

- `result` : MaskedArray
  The result of masking `x` where approximately equal to `value`.

**See also:**

- `masked_where`
  Mask where a condition is met.
- `masked_equal`
  Mask where equal to a given value (integers).
Examples

```python
>>> import numpy.ma as ma
>>> x = np.array([1, 1.1, 2, 1.1, 3])
>>> ma.masked_values(x, 1.1)
masked_array(data = [1.0 -- 2.0 -- 3.0],
             mask = [False True False True False],
             fill_value=1.1)

Note that mask is set to nomask if possible.

>>> ma.masked_values(x, 1.5)
masked_array(data = [ 1. 1.1 2. 1.1 3. ],
             mask = False,
             fill_value=1.5)
```

For integers, the fill value will be different in general to the result of `masked_equal`.

```python
>>> x = np.arange(5)
>>> x
array([0, 1, 2, 3, 4])
>>> ma.masked_values(x, 2)
masked_array(data = [0 1 -- 3 4],
             mask = [False False True False False],
             fill_value=2)
>>> ma.masked_equal(x, 2)
masked_array(data = [0 1 -- 3 4],
             mask = [False False True False False],
             fill_value=999999)
```

`numpy.ma.masked_where(condition, a, copy=True)`

Mask an array where a condition is met.

Return `a` as an array masked where `condition` is True. Any masked values of `a` or `condition` are also masked in the output.

**Parameters**

- `condition`: array_like
  
  Masking condition. When `condition` tests floating point values for equality, consider using `masked_values` instead.

- `a`: array_like
  
  Array to mask.

- `copy`: bool
  
  If True (default) make a copy of `a` in the result. If False modify `a` in place and return a view.

**Returns**

- `result`: MaskedArray
  
  The result of masking `a` where `condition` is True.

See also:

- `masked_values`
  
  Mask using floating point equality.

- `masked_equal`
  
  Mask where equal to a given value.
masked_not_equal
   Mask where not equal to a given value.

masked_less_equal
   Mask where less than or equal to a given value.

masked_greater_equal
   Mask where greater than or equal to a given value.

masked_less
   Mask where less than a given value.

masked_greater
   Mask where greater than a given value.

masked_inside
   Mask inside a given interval.

masked_outside
   Mask outside a given interval.

masked_invalid
   Mask invalid values (NaNs or infs).

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_where(a <= 2, a)
masked_array(data = [-- -- -- 3],
             mask = [ True True True False],
            fill_value=999999)
```

Mask array `b` conditional on `a`.

```python
>>> b = ['a', 'b', 'c', 'd']
>>> ma.masked_where(a == 2, b)
masked_array(data = [a b -- d],
             mask = [False False True False],
            fill_value=N/A)
```

Effect of the `copy` argument.

```python
>>> c = ma.masked_where(a <= 2, a)
>>> c
masked_array(data = [-- -- -- 3],
             mask = [ True True True False],
            fill_value=999999)
>>> c[0] = 99
>>> c
masked_array(data = [99 -- -- 3],
             mask = [False False True False],
            fill_value=999999)
>>> a
array([0, 1, 2, 3])
>>> c = ma.masked_where(a <= 2, a, copy=False)
>>> c[0] = 99
>>> c
masked_array(data = [99 -- -- 3],
             mask = [False False True False],
            fill_value=999999)
```
mask = [False True True False],
      fill_value=999999)
>>> a
array([99,  1,  2,  3])

When condition or a contain masked values.

>>> a = np.arange(4)
>>> a = ma.masked_where(a == 2, a)
>>> a
masked_array(data = [0 1 -- 3],
      mask = [False False True False],
      fill_value=999999)
>>> b = np.arange(4)
>>> b = ma.masked_where(b == 0, b)
>>> b
masked_array(data = [-- 1 2 3],
      mask = [ True False False False],
      fill_value=999999)

Accessing the data

The underlying data of a masked array can be accessed in several ways:

• through the data attribute. The output is a view of the array as a numpy.ndarray or one of its subclasses, depending on the type of the underlying data at the masked array creation.

• through the __array__ method. The output is then a numpy.ndarray.

• by directly taking a view of the masked array as a numpy.ndarray or one of its subclass (which is actually what using the data attribute does).

• by using the getdata function.

None of these methods is completely satisfactory if some entries have been marked as invalid. As a general rule, where a representation of the array is required without any masked entries, it is recommended to fill the array with the filled method.

Accessing the mask

The mask of a masked array is accessible through its mask attribute. We must keep in mind that a True entry in the mask indicates an invalid data.

Another possibility is to use the getmask and getmaskarray functions. getmask(x) outputs the mask of x if x is a masked array, and the special value nomask otherwise. getmaskarray(x) outputs the mask of x if x is a masked array. If x has no invalid entry or is not a masked array, the function outputs a boolean array of False with as many elements as x.

Accessing only the valid entries

To retrieve only the valid entries, we can use the inverse of the mask as an index. The inverse of the mask can be calculated with the numpy.logical_not function or simply with the ~ operator:
```python
>>> x = ma.array([[1, 2], [3, 4]], mask=[[0, 1], [1, 0]])
>>> x[-x.mask]
masked_array(data = [1 4],
    mask = [False False],
    fill_value = 999999)
```

Another way to retrieve the valid data is to use the `compressed` method, which returns a one-dimensional `ndarray` (or one of its subclasses, depending on the value of the `baseclass` attribute):

```python
>>> x.compressed()
array([1, 4])
```

Note that the output of `compressed` is always 1D.

### Modifying the mask

#### Masking an entry

The recommended way to mark one or several specific entries of a masked array as invalid is to assign the special value `masked` to them:

```python
>>> x = ma.array([1, 2, 3])
>>> x[0] = ma.masked
>>> x
masked_array(data = [- -- 2]
    mask = [ True False False],
    fill_value = 999999)
```

```python
>>> y = ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])
>>> y[(0, 1, 2), (1, 2, 0)] = ma.masked
>>> y
masked_array(data =
[[- -- 3]
 [4 5 --]
[-- 8 9]],
    mask =
[[False True False]
 [False False True]
 [ True False False]],
    fill_value = 999999)
```

```python
>>> z = ma.array([1, 2, 3, 4])
>>> z[:-2] = ma.masked
>>> z
masked_array(data = [-- -- 3 4],
    mask = [ True True False False],
    fill_value = 999999)
```

A second possibility is to modify the `mask` directly, but this usage is discouraged.

---

**Note:** When creating a new masked array with a simple, non-structured datatype, the mask is initially set to the special value `nomask`, that corresponds roughly to the boolean `False`. Trying to set an element of `nomask` will fail with a `TypeError` exception, as a boolean does not support item assignment.

All the entries of an array can be masked at once by assigning `True` to the mask:

```python
>>> x = ma.array([1, 2, 3], mask=[0, 0, 1])
>>> x.mask = True
>>> x
```
masked_array(data = [-- -- --],
    mask = [ True True True],
    fill_value = 999999)

Finally, specific entries can be masked and/or unmasked by assigning to the mask a sequence of booleans:

```python
>>> x = ma.array([1, 2, 3])
>>> x.mask = [0, 1, 0]
>>> x
masked_array(data = [1 -- 3],
    mask = [False True False],
    fill_value = 999999)
```

Unmasking an entry

To unmask one or several specific entries, we can just assign one or several new valid values to them:

```python
>>> x = ma.array([1, 2, 3], mask=[0, 0, 1])
>>> x
masked_array(data = [1 2 --],
    mask = [False False True],
    fill_value = 999999)
```

```python
>>> x[-1] = 5
>>> x
masked_array(data = [1 2 5],
    mask = [False False False],
    fill_value = 999999)
```

Note: Unmasking an entry by direct assignment will silently fail if the masked array has a hard mask, as shown by the hardmask attribute. This feature was introduced to prevent overwriting the mask. To force the unmasking of an entry where the array has a hard mask, the mask must first to be softened using the soften_mask method before the allocation. It can be re-hardened with harden_mask:

```python
>>> x = ma.array([1, 2, 3], mask=[0, 0, 1], hard_mask=True)
>>> x
masked_array(data = [1 2 --],
    mask = [False False True],
    fill_value = 999999)
```

```python
>>> x[-1] = 5
>>> x
masked_array(data = [1 2 --],
    mask = [False False True],
    fill_value = 999999)
```

```python
>>> x.soften_mask()
>>> x[-1] = 5
>>> x
masked_array(data = [1 2 5],
    mask = [False False False],
    fill_value = 999999)
```

```python
>>> x.harden_mask()
```

To unmask all masked entries of a masked array (provided the mask isn’t a hard mask), the simplest solution is to assign the constant nomask to the mask:

```python
>>> x = ma.array([1, 2, 3], mask=[0, 0, 1])
>>> x
masked_array(data = [1 2 --],
    mask = [False False True],
    fill_value = 999999)
fill_value = 999999)

>>> x.mask = ma.nomask
>>> x

masked_array(data = [1 2 3],
    mask = [False False False],
    fill_value = 999999)

Indexing and slicing

As a MaskedArray is a subclass of numpy.ndarray, it inherits its mechanisms for indexing and slicing.

When accessing a single entry of a masked array with no named fields, the output is either a scalar (if the corresponding entry of the mask is False) or the special value masked (if the corresponding entry of the mask is True):

```python
>>> x = ma.array([1, 2, 3], mask=[0, 0, 1])
>>> x[0]
1
>>> x[-1]
masked_array(data = --,
    mask = True,
    fill_value = 1e+20)
>>> x[-1] is ma.masked
True
```

If the masked array has named fields, accessing a single entry returns a numpy.void object if none of the fields are masked, or a 0d masked array with the same dtype as the initial array if at least one of the fields is masked.

```python
>>> y = ma.masked_array(
...     [(1,2), (3, 4)],
...     mask=[(0, 0), (0, 1)],
...     dtype=[('a', int), ('b', int)])
>>> y[0]
(1, 2)
>>> y[-1]
masked_array(data = (3, --),
    mask = (False, True),
    fill_value = (999999, 999999),
    dtype = [('a', '<i4'), ('b', '<i4')])
```

When accessing a slice, the output is a masked array whose data attribute is a view of the original data, and whose mask is either nomask (if there was no invalid entries in the original array) or a copy of the corresponding slice of the original mask. The copy is required to avoid propagation of any modification of the mask to the original.

```python
>>> x = ma.array([1, 2, 3, 4, 5], mask=[0, 1, 0, 0, 1])
>>> mx = x[:3]
>>> mx
masked_array(data = [1 -- 3],
    mask = [False True False],
    fill_value = 999999)
>>> mx[1] = -1
>>> mx
masked_array(data = [1 -1 3],
    mask = [False True False],
    fill_value = 999999)
>>> x.mask
array([False, True, False, False, True], dtype=bool)
>>> x.data
array([1, -1, 3, 4, 5])
```
Accessing a field of a masked array with structured datatype returns a `MaskedArray`.

**Operations on masked arrays**

Arithmetic and comparison operations are supported by masked arrays. As much as possible, invalid entries of a masked array are not processed, meaning that the corresponding `data` entries *should* be the same before and after the operation.

**Warning:** We need to stress that this behavior may not be systematic, that masked data may be affected by the operation in some cases and therefore users should not rely on this data remaining unchanged.

The `numpy.ma` module comes with a specific implementation of most ufuncs. Unary and binary functions that have a validity domain (such as `log` or `divide`) return the `masked` constant whenever the input is masked or falls outside the validity domain:

```python
>>> ma.log([-1, 0, 1, 2])
masked_array(data = [-- -- 0.0 0.69314718056],
            mask = [ True True False False],
            fill_value = 1e+20)
```

Masked arrays also support standard numpy ufuncs. The output is then a masked array. The result of a unary ufunc is masked wherever the input is masked. The result of a binary ufunc is masked wherever any of the input is masked. If the ufunc also returns the optional context output (a 3-element tuple containing the name of the ufunc, its arguments and its domain), the context is processed and entries of the output masked array are masked wherever the corresponding input fall outside the validity domain:

```python
>>> x = ma.array([-1, 1, 0, 2, 3], mask=[0, 0, 0, 0, 1])
>>> np.log(x)
masked_array(data = [-- -- 0.0 0.69314718056 --],
            mask = [ True True False False True],
            fill_value = 1e+20)
```

### 1.7.3 Examples

**Data with a given value representing missing data**

Let's consider a list of elements, `x`, where values of -9999. represent missing data. We wish to compute the average value of the data and the vector of anomalies (deviations from the average):

```python
>>> import numpy.ma as ma
>>> x = [0., 1., -9999., 3., 4.]
>>> mx = ma.masked_values(x, -9999.)
>>> print mx.mean()
2.0
>>> print mx - mx.mean()
[-2.0 -1.0 -- 1.0 2.0]
>>> print mx.anom()
[-2.0 -1.0 -- 1.0 2.0]
```

**Filling in the missing data**

Suppose now that we wish to print that same data, but with the missing values replaced by the average value.
>>> print mx.filled(mx.mean())
[ 0.  1.  2.  3.  4.]

Numerical operations

Numerical operations can be easily performed without worrying about missing values, dividing by zero, square roots of negative numbers, etc.:

>>> import numpy as np, numpy.ma as ma
>>> x = ma.array([1., -1., 3., 4., 5., 6.], mask=[0,0,0,0,1,0])
>>> y = ma.array([1., 2., 0., 4., 5., 6.], mask=[0,0,0,0,0,1])
>>> print np.sqrt(x/y)
[1.0 -- -- 1.0 -- --]

Four values of the output are invalid: the first one comes from taking the square root of a negative number, the second from the division by zero, and the last two where the inputs were masked.

Ignoring extreme values

Let’s consider an array d of random floats between 0 and 1. We wish to compute the average of the values of d while ignoring any data outside the range [0.1, 0.9]:

>>> print ma.masked_outside(d, 0.1, 0.9).mean()

1.7.4 Constants of the numpy.ma module

In addition to the MaskedArray class, the numpy.ma module defines several constants.

numpy.ma.masked
   The masked constant is a special case of MaskedArray, with a float datatype and a null shape. It is used to test whether a specific entry of a masked array is masked, or to mask one or several entries of a masked array:

   >>> x = ma.array([1, 2, 3], mask=[0, 1, 0])
   >>> x[1] is ma.masked
   True
   >>> x[-1] = ma.masked
   >>> x
   masked_array(data = [1 -- --],
                mask = [False True True],
                fill_value = 999999)

numpy.ma.nomask
   Value indicating that a masked array has no invalid entry. nomask is used internally to speed up computations when the mask is not needed.

numpy.ma.masked_print_options
   String used in lieu of missing data when a masked array is printed. By default, this string is ‘--’.

1.7.5 The MaskedArray class

class numpy.ma.MaskedArray

A subclass of ndarray designed to manipulate numerical arrays with missing data.
An instance of MaskedArray can be thought as the combination of several elements:

- The data, as a regular numpy.ndarray of any shape or datatype (the data).
- A boolean mask with the same shape as the data, where a True value indicates that the corresponding element of the data is invalid. The special value nomask is also acceptable for arrays without named fields, and indicates that no data is invalid.
- A fill_value, a value that may be used to replace the invalid entries in order to return a standard numpy.ndarray.

Attributes and properties of masked arrays

See also:

Array Attributes

MaskedArray.data
Returns the underlying data, as a view of the masked array. If the underlying data is a subclass of numpy.ndarray, it is returned as such.

```python
>>> x = ma.array(np.matrix([[1, 2], [3, 4]]), mask=[[0, 1], [1, 0]])
>>> x.data
matrix([[1, 2],
        [3, 4]])
```

The type of the data can be accessed through the baseclass attribute.

MaskedArray.mask
Returns the underlying mask, as an array with the same shape and structure as the data, but where all fields are atomically booleans. A value of True indicates an invalid entry.

MaskedArray.recordmask
Returns the mask of the array if it has no named fields. For structured arrays, returns a ndarray of booleans where entries are True if all the fields are masked, False otherwise:

```python
>>> x = ma.array(((1, 1), (2, 2), (3, 3), (4, 4), (5, 5)),
               mask=((0, 0), (1, 0), (1, 1), (0, 1), (0, 0)),
               dtype=[('a', int), ('b', int)])
>>> x.recordmask
array([False, False, True, False, False], dtype=bool)
```

MaskedArray.fill_value
Returns the value used to fill the invalid entries of a masked array. The value is either a scalar (if the masked array has no named fields), or a 0-D array with the same dtype as the masked array if it has named fields.

The default filling value depends on the datatype of the array:

<table>
<thead>
<tr>
<th>datatype</th>
<th>default</th>
</tr>
</thead>
<tbody>
<tr>
<td>bool</td>
<td>True</td>
</tr>
<tr>
<td>int</td>
<td>999999</td>
</tr>
<tr>
<td>float</td>
<td>1.2e20</td>
</tr>
<tr>
<td>complex</td>
<td>1.2e20+0j</td>
</tr>
<tr>
<td>object</td>
<td>‘?’</td>
</tr>
<tr>
<td>string</td>
<td>‘N/A’</td>
</tr>
</tbody>
</table>

MaskedArray.baseclass
Returns the class of the underlying data.
>>> x = ma.array(np.matrix([[1, 2], [3, 4]]), mask=[[0, 0], [1, 0]])
>>> x.baseclass
<class 'numpy.matrixlib.defmatrix.matrix'>

MaskedArray.sharedmask

Returns whether the mask of the array is shared between several masked arrays. If this is the case, any modification to the mask of one array will be propagated to the others.

MaskedArray.hardmask

Returns whether the mask is hard (True) or soft (False). When the mask is hard, masked entries cannot be unmasked.

As MaskedArray is a subclass of ndarray, a masked array also inherits all the attributes and properties of an ndarray instance.

<table>
<thead>
<tr>
<th>MaskedArray.attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MaskedArray.base</td>
<td>Base object if memory is from some other object.</td>
</tr>
<tr>
<td>MaskedArray.ctypes</td>
<td>An object to simplify the interaction of the array with the ctypes module.</td>
</tr>
<tr>
<td>MaskedArray.dtype</td>
<td>Data-type of the array’s elements.</td>
</tr>
<tr>
<td>MaskedArray.flags</td>
<td>Information about the memory layout of the array.</td>
</tr>
<tr>
<td>MaskedArray.itemsize</td>
<td>Length of one array element in bytes.</td>
</tr>
<tr>
<td>MaskedArray.nbytes</td>
<td>Total bytes consumed by the elements of the array.</td>
</tr>
<tr>
<td>MaskedArray.ndim</td>
<td>Number of array dimensions.</td>
</tr>
<tr>
<td>MaskedArray.shape</td>
<td>Tuple of array dimensions.</td>
</tr>
<tr>
<td>MaskedArray.size</td>
<td>Number of elements in the array.</td>
</tr>
<tr>
<td>MaskedArray.strides</td>
<td>Tuple of bytes to step in each dimension when traversing an array.</td>
</tr>
<tr>
<td>MaskedArray.imag</td>
<td>Imaginary part.</td>
</tr>
<tr>
<td>MaskedArray.real</td>
<td>Real part</td>
</tr>
<tr>
<td>MaskedArray.flat</td>
<td>Flat version of the array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>array_priority</strong></td>
<td>int(x=0) -&gt; int or long</td>
</tr>
</tbody>
</table>

MaskedArray.base

Base object if memory is from some other object.

**Examples**

The base of an array that owns its memory is None:

```python
>>> x = np.array([1, 2, 3, 4])
>>> x.base is None
True
```

Slicing creates a view, whose memory is shared with x:

```python
>>> y = x[2:]
>>> y.base is x
True
```

MaskedArray.ctypes

An object to simplify the interaction of the array with the ctypes module.

This attribute creates an object that makes it easier to use arrays when calling shared libraries with the ctypes module. The returned object has, among others, data, shape, and strides attributes (see Notes below) which themselves return ctypes objects that can be used as arguments to a shared library.

**Parameters**

None
Returns

c : Python object

Possessing attributes data, shape, strides, etc.

See also:

numpy.ctypeslib

Notes

Below are the public attributes of this object which were documented in “Guide to NumPy” (we have omitted undocumented public attributes, as well as documented private attributes):

• data: A pointer to the memory area of the array as a Python integer. This memory area may contain data that is not aligned, or not in correct byte-order. The memory area may not even be writeable. The array flags and data-type of this array should be respected when passing this attribute to arbitrary C-code to avoid trouble that can include Python crashing. User Beware! The value of this attribute is exactly the same as self._array_interface_['data'][0].

• shape (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the C-integer corresponding to dtype('p') on this platform. This base-type could be c_int, c_long, or c_longlong depending on the platform. The c_intp type is defined accordingly in numpy.ctypeslib. The ctypes array contains the shape of the underlying array.

• strides (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the same as for the shape attribute. This ctypes array contains the strides information from the underlying array. This strides information is important for showing how many bytes must be jumped to get to the next element in the array.

• data_as(obj): Return the data pointer cast to a particular c-types object. For example, calling self._as_parameter_ is equivalent to self.data_as(ctypes.c_void_p). Perhaps you want to use the data as a pointer to a ctypes array of floating-point data: self.data_as(ctypes.POINTER(ctypes.c_double)).

• shape_as(obj): Return the shape tuple as an array of some other c-types type. For example: self.shape_as(ctypes.c_short).

• strides_as(obj): Return the strides tuple as an array of some other c-types type. For example: self.strides_as(ctypes.c_longlong).

Be careful using the ctypes attribute - especially on temporary arrays or arrays constructed on the fly. For example, calling (a+b).ctypes.data_as(ctypes.c_void_p) returns a pointer to memory that is invalid because the array created as (a+b) is deallocated before the next Python statement. You can avoid this problem using either c=a+b or ct=(a+b).ctypes. In the latter case, ct will hold a reference to the array until ct is deleted or re-assigned.

If the ctypes module is not available, then the ctypes attribute of array objects still returns something useful, but ctypes objects are not returned and errors may be raised instead. In particular, the object will still have the as parameter attribute which will return an integer equal to the data attribute.

Examples

```python
>>> import ctypes
>>> x
array([[0, 1],
       [2, 3]])
>>> x.ctypes.data
30439712
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_long))
<ctypes.c_long object at 0x01F01300>
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_long)).contents
```
```
c_long(0)
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_longlong)).contents
  c_longlong(4294967296L)
>>> x.ctypes.shape
  <numpy.core._internal.c_long_Array_2 object at 0x01FFD580>
>>> x.ctypes.shape_as(ctypes.c_long)
  <numpy.core._internal.c_long_Array_2 object at 0x01FCE620>
>>> x.ctypes.strides
  <numpy.core._internal.c_long_Array_2 object at 0x01FCE620>
>>> x.ctypes.strides_as(ctypes.c_longlong)
  <numpy.core._internal.c_longlong_Array_2 object at 0x01F01300>
```

**MaskedArray.dtype**

Data-type of the array’s elements.

**Parameters**

None

**Returns**

- **d** : numpy dtype object

**See also:**

numpy.dtype

**Examples**

```python
>>> x
  array([[0, 1],
          [2, 3]])
>>> x.dtype
  dtype('int32')
>>> type(x.dtype)
  <type 'numpy.dtype'>
```

**MaskedArray.flags**

Information about the memory layout of the array.

**Notes**

The `flags` object can be accessed dictionary-like (as in `a.flags[‘WRITEABLE’]`), or by using lowercased attribute names (as in `a.flags.writeable`). Short flag names are only supported in dictionary access.

Only the UPDATEIFCOPY, WRITEABLE, and ALIGNED flags can be changed by the user, via direct assignment to the attribute or dictionary entry, or by calling `ndarray.setflags`.

The array flags cannot be set arbitrarily:

- UPDATEIFCOPY can only be set False.
- ALIGNED can only be set True if the data is truly aligned.
- WRITEABLE can only be set True if the array owns its own memory or the ultimate owner of the memory exposes a writeable buffer interface or is a string.

Arrays can be both C-style and Fortran-style contiguous simultaneously. This is clear for 1-dimensional arrays, but can also be true for higher dimensional arrays.

Even for contiguous arrays a stride for a given dimension `arr.strides[dim]` may be arbitrary if `arr.shape[dim]` == 1 or the array has no elements. It does not generally hold that `self.strides[-1] == self.itemsize` for C-style contiguous arrays or `self.strides[0] == self.itemsize` for Fortran-style contiguous arrays is true.
Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_CONTIGUOUS</td>
<td>The data is in a single, C-style contiguous segment.</td>
</tr>
<tr>
<td>F_CONTIGUOUS</td>
<td>The data is in a single, Fortran-style contiguous segment.</td>
</tr>
<tr>
<td>OWNDATA</td>
<td>The array owns the memory it uses or borrows it from another object.</td>
</tr>
<tr>
<td>WRITEABLE</td>
<td>The data area can be written to. Setting this to False locks the data, making it read-only. A view (slice, etc.) inherits WRITEABLE from its base array at creation time, but a view of a writeable array may be subsequently locked while the base array remains writeable. (The opposite is not true, in that a view of a locked array may not be made writeable. However, currently, locking a base object does not lock any views that already reference it, so under that circumstance it is possible to alter the contents of a locked array via a previously created writeable view onto it.) Attempting to change a non-writeable array raises a RuntimeError exception.</td>
</tr>
<tr>
<td>ALIGNED</td>
<td>The data and all elements are aligned appropriately for the hardware.</td>
</tr>
<tr>
<td>UPDATEIFCOPY</td>
<td>This array is a copy of some other array. When this array is deallocated, the base array will be updated with the contents of this array.</td>
</tr>
<tr>
<td>FNC</td>
<td>F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FORC</td>
<td>F_CONTIGUOUS or C_CONTIGUOUS (one-segment test).</td>
</tr>
<tr>
<td>BEHAVED</td>
<td>ALIGNED and WRITEABLE.</td>
</tr>
<tr>
<td>CARRAY</td>
<td>BEHAVED and C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FARRAY</td>
<td>BEHAVED and F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
</tbody>
</table>

MaskedArray.itemsize

Length of one array element in bytes.

Examples

```python
>>> x = np.array([1,2,3], dtype=np.float64)
>>> x.itemsize
8
>>> x = np.array([1,2,3], dtype=np.complex128)
>>> x.itemsize
16
```

MaskedArray.nbytes

Total bytes consumed by the elements of the array.

Notes

Does not include memory consumed by non-element attributes of the array object.

Examples

```python
>>> x = np.zeros((3,5,2), dtype=np.complex128)
>>> x.nbytes
480
>>> np.prod(x.shape) * x.itemsize
480
```
MaskedArray.\texttt{ndim}
Number of array dimensions.

\textbf{Examples}

\begin{verbatim}
>>> x = np.array([1, 2, 3])
>>> x.ndim
1
>>> y = np.zeros((2, 3, 4))
>>> y.ndim
3
\end{verbatim}

MaskedArray.\texttt{shape}
Tuple of array dimensions.

\textbf{Notes}
May be used to “reshape” the array, as long as this would not require a change in the total number of elements.

\textbf{Examples}

\begin{verbatim}
>>> x = np.array([1, 2, 3, 4])
>>> x.shape
(4,)
>>> y = np.zeros((2, 3, 4))
>>> y.shape
(2, 3, 4)
>>> y.shape = (3, 8)
>>> y
array([[ 0., 0., 0., 0., 0., 0., 0., 0.],
       [ 0., 0., 0., 0., 0., 0., 0., 0.],
       [ 0., 0., 0., 0., 0., 0., 0., 0.]])
>>> y.shape = (3, 6)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: total size of new array must be unchanged
\end{verbatim}

MaskedArray.\texttt{size}
Number of elements in the array.

Equivalent to \texttt{np.prod(a.shape)}, i.e., the product of the array’s dimensions.

\textbf{Examples}

\begin{verbatim}
>>> x = np.zeros((3, 5, 2), dtype=np.complex128)
>>> x.size
30
>>> np.prod(x.shape)
30
\end{verbatim}

MaskedArray.\texttt{strides}
Tuple of bytes to step in each dimension when traversing an array.

The byte offset of element \(i[0], i[1], \ldots, i[n]\) in an array \(a\) is:

\[
\text{offset} = \sum (\text{np.array}(i) \times a.\text{strides})
\]

A more detailed explanation of strides can be found in the “ndarray.rst” file in the NumPy reference guide.
See also:

numpy.lib.stride_tricks.as_strided

Notes
Imagine an array of 32-bit integers (each 4 bytes):

```python
dx = np.array([[0, 1, 2, 3, 4],
               [5, 6, 7, 8, 9]], dtype=np.int32)
```

This array is stored in memory as 40 bytes, one after the other (known as a contiguous block of memory). The strides of an array tell us how many bytes we have to skip in memory to move to the next position along a certain axis. For example, we have to skip 4 bytes (1 value) to move to the next column, but 20 bytes (5 values) to get to the same position in the next row. As such, the strides for the array `x` will be `(20, 4)`.

Examples

```python
>>> y = np.reshape(np.arange(2*3*4), (2,3,4))
>>> y
array(
    [[[ 0,  1,  2,  3],
      [ 4,  5,  6,  7],
      [ 8,  9, 10, 11]],
     [[12, 13, 14, 15],
      [16, 17, 18, 19],
      [20, 21, 22, 23]])
>>> y.strides
(48, 16, 4)
>>> y[1,1,1]
17
>>> offset = sum(y.strides * np.array((1,1,1)))
>>> offset / y.itemsize
17

>>> x = np.reshape(np.arange(5*6*7*8), (5,6,7,8)).transpose(2,3,1,0)
>>> x.strides
(32, 4, 224, 1344)
>>> i = np.array([3, 5, 2, 2])
>>> offset = sum(i * x.strides)
>>> x[3,5,2,2]
813
>>> offset / x.itemsize
813
```

MaskedArray.imag
Imaginary part.

MaskedArray.real
Real part.

MaskedArray.flat
Flat version of the array.

MaskedArray.__array_priority__ = 15

1.7.6 MaskedArray methods

See also:
Array methods

Conversion

MaskedArray.__float__()  Convert to float.
MaskedArray.__hex__()  "===> hex(x)
MaskedArray.__int__()  Convert to int.
MaskedArray.__long__()  "===> long(x)
MaskedArray.__oct__()  "===> oct(x)

MaskedArray.view([dtype, type])  New view of array with the same data.
MaskedArray.astype(newtype)  Returns a copy of the MaskedArray cast to given newtype.
MaskedArray.byteswap(inplace)  Swap the bytes of the array elements Toggle between low-endian and big-endian data representations.
MaskedArray.compressed()  Return all the non-masked data as a 1-D array.
MaskedArray.filled([fill_value])  Save a masked array to a file in binary format.
MaskedArray.toflex()  Transforms a masked array into a flexible-type array.
MaskedArray.tolist([fill_value])  Return the data portion of the masked array as a hierarchical Python list.
MaskedArray.torecords()  This function is a compatibility alias for tobytes.
MaskedArray.tobytes([fill_value, order])  Return the array data as a string containing the raw bytes in the array.

MaskedArray.__float__()  Convert to float.

MaskedArray.__hex__()  "===> hex(x)

MaskedArray.__int__()  Convert to int.

MaskedArray.__long__()  "===> long(x)

MaskedArray.__oct__()  "===> oct(x)

MaskedArray.view(dtype=None, type=None)  New view of array with the same data.

Parameters

dtype : data-type or ndarray sub-class, optional

Data-type descriptor of the returned view, e.g., float32 or int16. The default, None, results in the view having the same data-type as a. This argument can also be specified as an ndarray sub-class, which then specifies the type of the returned object (this is equivalent to setting the type parameter).

type : Python type, optional

Type of the returned view, e.g., ndarray or matrix. Again, the default None results in type preservation.

Notes

a.view() is used two different ways:
a.view(some_dtype) or a.view(dtype=some_dtype) constructs a view of the array’s memory with a different data-type. This can cause a reinterpretation of the bytes of memory.

1.7. Masked arrays
a.view(ndarray_subclass) or a.view(type=ndarray_subclass) just returns an instance of ndarray_subclass that looks at the same array (same shape, dtype, etc.) This does not cause a reinterpretation of the memory.

For a.view(some_dtype), if some_dtype has a different number of bytes per entry than the previous dtype (for example, converting a regular array to a structured array), then the behavior of the view cannot be predicted just from the superficial appearance of a (shown by print(a)). It also depends on exactly how a is stored in memory. Therefore if a is C-ordered versus fortran-ordered, versus defined as a slice or transpose, etc., the view may give different results.

Examples

>>> x = np.array([[1, 2]], dtype=[('a', np.int8), ('b', np.int8)])

Viewing array data using a different type and dtype:

>>> y = x.view(dtype=np.int16, type=np.matrix)

>>> y
matrix([[513]], dtype=int16)

>>> print type(y)
<class 'numpy.matrixlib.defmatrix.matrix'>

Creating a view on a structured array so it can be used in calculations

>>> x = np.array([[1, 2], (3, 4)], dtype=[('a', np.int8), ('b', np.int8)])

>>> xv = x.view(dtype=np.int8).reshape(-1, 2)

>>> xv
array([[1, 2],
       [3, 4]], dtype=int8)

>>> xv.mean(0)
array([ 2., 3.])

Making changes to the view changes the underlying array

>>> xv[0,1] = 20

>>> print x
[(1, 20) (3, 4)]

Using a view to convert an array to a record array:

>>> z = x.view(np.recarray)

>>> z.a
array([1], dtype=int8)

Views share data:

>>> x[0] = (9, 10)

>>> z[0]
(9, 10)

Views that change the dtype size (bytes per entry) should normally be avoided on arrays defined by slices, transposes, fortran-ordering, etc.: 

>>> x = np.array([[1, 2, 3], [4, 5, 6]], dtype=np.int16)

>>> y = x[:, 0:2]

>>> y
array([[1, 2],
       [4, 5]], dtype=int16)

>>> y.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
MaskedArray.nlargest(n)

Returns an array of the n largest values in masked array a.

Parameters

- n: int, optional
  The number of largest elements to return.

Returns

- nlargest: MaskedArray
  A 1-D masked array of the n largest elements in a. Since the number of unique
  elements is smaller than n, nlargest is shorter than n.

Examples

```python
c = np.ma.array([1, 2, 3, 4, 5])
c.nlargest(3)  # returns MaskedArray([5, 4, 3], mask=[False, False, False, True, False], fill_value=9)
```

MaskedArray.nsmallest(n)

Returns an array of the n smallest values in masked array a.

Parameters

- n: int, optional
  The number of smallest elements to return.

Returns

- nsmallest: MaskedArray
  A 1-D masked array of the n smallest elements in a. Since the number of unique
  elements is smaller than n, nsmallest is shorter than n.

Examples

```python
c = np.ma.array([1, 2, 3, 4, 5])
c.nsmallest(3)  # returns MaskedArray([1, 2, 3], mask=[True, True, True, False, False], fill_value=9)
```
array(['ceg', 'fac'],
      dtype='|S3')

MaskedArray.compressed()

Return all the non-masked data as a 1-D array.

Returns

data : ndarray

A new ndarray holding the non-masked data is returned.

Notes

The result is not a MaskedArray!

Examples

>>> x = np.ma.array(np.arange(5), mask=[0]*2 + [1]*3)
>>> x.compressed()
array([0, 1])
>>> type(x.compressed())
<type 'numpy.ndarray'>

MaskedArray.filled(fill_value=None)

Return a copy of self, with masked values filled with a given value.

Parameters

fill_value : scalar, optional

The value to use for invalid entries (None by default). If None, the fill_value attribute of the array is used instead.

Returns

filled_array : ndarray

A copy of self with invalid entries replaced by fill_value (be it the function argument or the attribute of self).

Notes

The result is not a MaskedArray!

Examples

>>> x = np.ma.array([1,2,3,4,5], mask=[0,0,1,0,1], fill_value=-999)
>>> x.filled()
array([1, 2, -999, 4, -999])
>>> type(x.filled())
<type 'numpy.ndarray'>

Subclassing is preserved. This means that if the data part of the masked array is a matrix, filled returns a matrix:

>>> x = np.ma.array(np.matrix([[1, 2], [3, 4]]), mask=[[0, 1], [1, 0]])
>>> x.filled()
matrix([[ 1, 999999],
        [999999, 4]])

MaskedArray.tofile(fid, sep='', format='%s')

Save a masked array to a file in binary format.
Warning: This function is not implemented yet.

Raises
NotImplementedError
When `tofile` is called.

MaskedArray.toflex()
Transforms a masked array into a flexible-type array.

The flexible type array that is returned will have two fields:

- the _data field stores the _data part of the array.
- the _mask field stores the _mask part of the array.

Parameters
None

Returns
record : ndarray
A new flexible-type ndarray with two fields: the first element containing a value, the second element containing the corresponding mask boolean. The returned record shape matches self.shape.

Notes
A side-effect of transforming a masked array into a flexible ndarray is that meta information (fill_value, ...) will be lost.

Examples

```python
>>> x = np.ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]], mask=[0] + [1, 0]*4)
>>> print x
[ [1 -- 3]
  [-- 5 --]
  [7 -- 9]]
>>> print x.toflex()
[[(1, False) (2, True) (3, False)]
 [(4, True) (5, False) (6, True)]
 [(7, False) (8, True) (9, False)]]
```

MaskedArray.tolist(fill_value=None)
Return the data portion of the masked array as a hierarchical Python list.

Data items are converted to the nearest compatible Python type. Masked values are converted to `fill_value`. If `fill_value` is None, the corresponding entries in the output list will be None.

Parameters
fill_value : scalar, optional
The value to use for invalid entries. Default is None.

Returns
result : list
The Python list representation of the masked array.
Examples

```python
>>> x = np.ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]], mask=[0] + [1, 0]*4)
>>> x.tolist()  # Default filling
[[1, None, 3], [None, 5, None], [7, None, 9]]

>>> x.tolist(-999)  # Filling with -999
[[1, -999, 3], [-999, 5, -999], [7, -999, 9]]
```

**MaskedArray.torecords()**

Transforms a masked array into a flexible-type array.

The flexible type array that is returned will have two fields:

- the `_data` field stores the `_data` part of the array.
- the `_mask` field stores the `_mask` part of the array.

**Parameters**

None

**Returns**

`record`: ndarray

A new flexible-type `ndarray` with two fields: the first element containing a value, the second element containing the corresponding mask boolean. The returned record shape matches self.shape.

**Notes**

A side-effect of transforming a masked array into a flexible `ndarray` is that meta information (fill_value, ...) will be lost.

**Examples**

```python
>>> x = np.ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]], mask=[0] + [1, 0]*4)
>>> print x
[[1 -- 3]
 [-5 --]
 [7 -- 9]]

>>> print x.toflex()
[[(1, False) (2, True) (3, False)]
 [(4, True) (5, False) (6, True)]
 [(7, False) (8, True) (9, False)]]
```

**MaskedArray.tostring**

This function is a compatibility alias for tobytes. Despite its name it returns bytes not strings.

**MaskedArray.tobytes**

Return the array data as a string containing the raw bytes in the array.

The array is filled with a fill value before the string conversion.

New in version 1.9.0.

**Parameters**

- `fill_value`: scalar, optional
  
  Value used to fill in the masked values. Default is None, in which case `MaskedArray.fill_value` is used.

- `order`: {'C', 'F', 'A'}, optional
  
  Order of the data item in the copy. Default is 'C'.
• 'C' – C order (row major).
• 'F' – Fortran order (column major).
• 'A' – Any, current order of array.
• None – Same as ‘A’.

See also:

ndarray.tobytes, tolist, tofile

Notes
As for ndarray.tobytes, information about the shape, dtype, etc., but also about fill_value, will be lost.

Examples
>>> x = np.ma.array(np.array([[1, 2], [3, 4]]), mask=[[0, 1], [1, 0]])
>>> x.tobytes()
'\x01\x00\x00\x00?B\x0f\x00?B\x0f\x00\x04\x00\x00\x00'

Shape manipulation

For reshape, resize, and transpose, the single tuple argument may be replaced with n integers which will be interpreted as an n-tuple.

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MaskedArray.flatten(order='C')

Return a copy of the array collapsed into one dimension.

Parameters

order : {'C', 'F', 'A'}, optional

Whether to flatten in C (row-major), Fortran (column-major) order, or preserve the C/Fortran ordering from a. The default is ‘C’.

Returns

y : ndarray

A copy of the input array, flattened to one dimension.

See also:

ravel

Return a flattened array.

flat

A 1-D flat iterator over the array.
Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])
```

MaskedArray.ravel()

Returns a 1D version of self, as a view.

Returns

MaskedArray

Output view is of shape (self.size,) (or (np.ma.product(self.shape),)).

Examples

```python
>>> x = np.ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]], mask=[0] + [1, 0]*4)
>>> print x
[[1 -- 3]
 [-- 5 --]
 [7 -- 9]]
>>> print x.ravel()
[1 -- 3 -- 5 -- 7 -- 9]
```

MaskedArray.reshape(*s, **kwargs)

Give a new shape to the array without changing its data.

Returns a masked array containing the same data, but with a new shape. The result is a view on the original array; if this is not possible, a ValueError is raised.

Parameters

- `shape` : int or tuple of ints
  
The new shape should be compatible with the original shape. If an integer is supplied, then the result will be a 1-D array of that length.

- `order` : {'C', 'F'}, optional
  
  Determines whether the array data should be viewed as in C (row-major) or FORTRAN (column-major) order.

Returns

reshaped_array : array

A new view on the array.

See also:

- `reshape`
  
  Equivalent function in the masked array module.

- `numpy.ndarray.reshape`
  
  Equivalent method on ndarray object.

- `numpy.reshape`
  
  Equivalent function in the NumPy module.
Notes

The reshaping operation cannot guarantee that a copy will not be made, to modify the shape in place, use `a.shape = s`

Examples

```python
>>> x = np.ma.array([[1,2], [3,4]], mask=[1,0,0,1])
>>> print x
[-- 2]
[3 --]
>>> x = x.reshape((4,1))
>>> print x
[--]
[2]
[3]
[--]
```

```
MaskedArray.resize(newshape, refcheck=True, order=False)
```

Warning: This method does nothing, except raise a ValueError exception. A masked array does not own its data and therefore cannot safely be resized in place. Use the `numpy.ma.resize` function instead.

This method is difficult to implement safely and may be deprecated in future releases of NumPy.

```
MaskedArray.squeeze(axis=None)
```

Remove single-dimensional entries from the shape of `a`.

Refer to `numpy.squeeze` for full documentation.

See also:

```
numpy.squeeze
equivalent function
```

```
MaskedArray.swapaxes(axis1, axis2)
```

Return a view of the array with `axis1` and `axis2` interchanged.

Refer to `numpy.swapaxes` for full documentation.

See also:

```
numpy.swapaxes
equivalent function
```

```
MaskedArray.transpose(*axes)
```

Returns a view of the array with axes transposed.

For a 1-D array, this has no effect. (To change between column and row vectors, first cast the 1-D array into a matrix object.) For a 2-D array, this is the usual matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided and `a.shape = (i[0], i[1], ... i[n-2], i[n-1])`, then `a.transpose().shape = (i[n-1], i[n-2], ... i[1], i[0])`.

Parameters

axes : None, tuple of ints, or n ints

- None or no argument: reverses the order of the axes.
- tuple of ints: `i` in the `j`-th place in the tuple means `a`'s `i`-th axis becomes `a.transpose()`'s `j`-th axis.
• \( n \) ints: same as an \( n \)-tuple of the same ints (this form is intended simply as a “convenience” alternative to the tuple form)

**Returns**

- **out**: ndarray

  View of \( a \), with axes suitably permuted.

**See also:**

- `ndarray.T`

  Array property returning the array transposed.

**Examples**

```python
g = np.array((1, 2, 3, 4))
g
```

```
array([1, 2, 3, 4])
```

```
g.transpose()   # default, equivalent to None
```

```
array([[1, 3],
       [2, 4]])
```

```
g.transpose((1, 0))
```

```
array([[1, 3],
       [2, 4]])
```

```
g.transpose(1, 0)
```

```
array([[1, 3],
       [2, 4]])
```

**Item selection and manipulation**

For array methods that take an `axis` keyword, it defaults to `None`. If `axis` is `None`, then the array is treated as a 1-D array. Any other value for `axis` represents the dimension along which the operation should proceed.

- `MaskedArray.argmax(axis=None, fill_value=None, out=None)`

  Returns array of indices of the maximum values along the given axis.

- `MaskedArray.argmin(axis=None, fill_value=None, out=None)`

  Return array of indices to the minimum values along the given axis.

- `MaskedArray.argsort(axis=None, kind=None, order=None)`

  Return an ndaray of indices that sort the array along the specified axis.

- `MaskedArray.choose(choices, out=None, mode='clip')`

  Use an index array to construct a new array from a set of choices.

- `MaskedArray.compress(condition, axis=None, out=None)`

  Return \( a \) where condition is True.

- `MaskedArray.diagonal(offset=0, axis1=0, axis2=1)`

  Return specified diagonals.

- `MaskedArray.fill(value)`

  Fill the array with a scalar value.

- `MaskedArray.item(*args)`

  Copy an element of an array to a standard Python scalar and return it.

- `MaskedArray.nonzero()`

  Return the indices of unmasked elements that are not zero.

- `MaskedArray.put(indices, values, mode='raise')`

  Set storage-indexed locations to corresponding values.

- `MaskedArray.repeat(repeats, axis=None)`

  Repeat elements of an array.

- `MaskedArray.searchsorted(v, side='left', sorter=None)`

  Find indices where elements of \( v \) should be inserted in \( a \) to maintain order.

- `MaskedArray.sort(axis=None, kind='quicksort', order=None)`

  Sort the array, in-place.

  **Parameters:**

  - `a` : array_like
    - Array to be sorted.

**MaskedArray.argmax(axis=None, fill_value=None, out=None)**

Returns array of indices of the maximum values along the given axis. Masked values are treated as if they had the value fill_value.
Parameters

- **axis**: {None, integer}
  
  If None, the index is into the flattened array, otherwise along the specified axis

- **fill_value**: {var}, optional
  
  Value used to fill in the masked values. If None, the output of `maximum_fill_value(self._data)` is used instead.

- **out**: {None, array}, optional
  
  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

Returns

- **index_array**: {integer_array}

Examples

```python
>>> a = np.arange(6).reshape(2,3)
>>> a.argmax()
5
>>> a.argmax(0)
array([1, 1, 1])
>>> a.argmax(1)
array([2, 2])
```

```python
MaskedArray.argmin(axis=None, fill_value=None, out=None)
```

Return array of indices to the minimum values along the given axis.

Parameters

- **axis**: {None, integer}
  
  If None, the index is into the flattened array, otherwise along the specified axis

- **fill_value**: {var}, optional
  
  Value used to fill in the masked values. If None, the output of `minimum_fill_value(self._data)` is used instead.

- **out**: {None, array}, optional
  
  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

Returns

- **index_array**: {integer_array, scalar}

Examples

```python
>>> x = np.ma.array(arange(4), mask=[1,1,0,0])
>>> x.shape = (2,2)
>>> print x
[[-- --]
 [2 3]]
>>> print x.argmin(axis=0, fill_value=-1)
[0 0]
```

1.7. Masked arrays
MaskedArray.\texttt{argmin}(axis=0, fill\_value=9)

\begin{verbatim}
[1 1]
\end{verbatim}

MaskedArray.\texttt{argsort}(axis=None, kind='quicksort', order=None, fill\_value=None)

Return an ndarray of indices that sort the array along the specified axis. Masked values are filled beforehand to fill\_value.

**Parameters**
- \texttt{axis} : int, optional
  - Axis along which to sort. The default is -1 (last axis). If None, the flattened array is used.
- \texttt{fill\_value} : var, optional
  - Value used to fill the array before sorting. The default is the fill\_value attribute of the input array.
- \texttt{kind} : {'quicksort', 'mergesort', 'heapsort'}, optional
  - Sorting algorithm.
- \texttt{order} : list, optional
  - When \(a\) is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

**Returns**
- \texttt{index\_array} : ndarray, int
  - Array of indices that sort \(a\) along the specified axis. In other words, \(a[\text{index\_array}]\) yields a sorted \(a\).

**See also:**
- \texttt{sort}
  - Describes sorting algorithms used.
- \texttt{lexsort}
  - Indirect stable sort with multiple keys.
- \texttt{ndarray.sort}
  - Inplace sort.

**Notes**
See \texttt{sort} for notes on the different sorting algorithms.

**Examples**

\begin{verbatim}
>>> a = np.ma.array([[3, 2], [4, 1]], mask=[[False, False], [True, False]])
>>> a
masked_array(data = [3 2 --],
    mask = [False False True],
    fill_value = 999999)
>>> a.argsort()
array([1, 0, 2])
\end{verbatim}

MaskedArray.\texttt{choose}(choices, out=None, mode='raise')

Use an index array to construct a new array from a set of choices.

Refer to numpy.\texttt{choose} for full documentation.
See also:

numpy.choose
  equivalent function

MaskedArray.compress(condition, axis=None, out=None)
Return a where condition is True.

If condition is a MaskedArray, missing values are considered as False.

Parameters
  condition : var
    Boolean 1-d array selecting which entries to return. If len(condition) is less than the
    size of a along the axis, then output is truncated to length of condition array.
  axis : {None, int}, optional
    Axis along which the operation must be performed.
  out : {None, ndarray}, optional
    Alternative output array in which to place the result. It must have the same shape as the
    expected output but the type will be cast if necessary.

Returns
  result : MaskedArray
    A MaskedArray object.

Notes
Please note the difference with compressed! The output of compress has a mask, the output of
compressed does not.

Examples
>>> x = np.ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]], mask=[0] + [1, 0]*4)
>>> print x
[1 -- 3]
[-- 5 --]
[7 -- 9]]
>>> x.compress([1, 0, 1])
masked_array(data = [1 3],
  mask = [False False],
  fill_value=999999)
>>> x.compress([1, 0, 1], axis=1)
masked_array(data =
  [[1 3]
   [7 9]],
  mask =
  [[False False]
   [True True]
   [False False]],
  fill_value=999999)

MaskedArray.diagonal(offset=0, axis1=0, axis2=1)
Return specified diagonals. In NumPy 1.9 the returned array is a read-only view instead of a copy as in previous
NumPy versions. In NumPy 1.10 the read-only restriction will be removed.
Refer to `numpy.diagonal` for full documentation.

**See also:**

`numpy.diagonal` equivalent function

**MaskedArray.fill(value)**

Fill the array with a scalar value.

**Parameters**

- **value**: scalar

  All elements of `a` will be assigned this value.

**Examples**

```python
g >> a = np.array([1, 2])
g >> a.fill(0)
g >> a
array([0, 0])
g >> a = np.empty(2)
g >> a.fill(1)
g >> a
array([ 1., 1.])
```

**MaskedArray.item(*args)**

Copy an element of an array to a standard Python scalar and return it.

**Parameters**

- **args**: Arguments (variable number and type)
  - none: in this case, the method only works for arrays with one element (`a.size == 1`), which element is copied into a standard Python scalar object and returned.
  - int_type: this argument is interpreted as a flat index into the array, specifying which element to copy and return.
  - tuple of int_types: functions as does a single int_type argument, except that the argument is interpreted as an nd-index into the array.

**Returns**

- **z**: Standard Python scalar object

  A copy of the specified element of the array as a suitable Python scalar

**Notes**

When the data type of `a` is longdouble or clongdouble, item() returns a scalar array object because there is no available Python scalar that would not lose information. Void arrays return a buffer object for item(), unless fields are defined, in which case a tuple is returned.

item is very similar to a[ args ], except, instead of an array scalar, a standard Python scalar is returned. This can be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using Python’s optimized math.

**Examples**

```python
g >> x = np.random.randint(9, size=(3, 3))
g >> x
array([[3, 1, 7],
```

Chapter 1. Array objects
>>> x.item(3)
2
>>> x.item(7)
5
>>> x.item((0, 1))
1
>>> x.item((2, 2))
3

MaskedArray.nonzero()

Return the indices of unmasked elements that are not zero.

Returns a tuple of arrays, one for each dimension, containing the indices of the non-zero elements in that dimension. The corresponding non-zero values can be obtained with:

```
a[a.nonzero()]
```

To group the indices by element, rather than dimension, use instead:

```
np.transpose(a.nonzero())
```

The result of this is always a 2d array, with a row for each non-zero element.

Parameters

None

Returns
tuple_of_arrays : tuple

Indices of elements that are non-zero.

See also:
numpy.nonzero

Function operating on ndarrays.

flatnonzero

Return indices that are non-zero in the flattened version of the input array.

ndarray.nonzero

Equivalent ndarray method.

count_nonzero

Counts the number of non-zero elements in the input array.

Examples

```python
>>> import numpy.ma as ma
>>> x = ma.array(np.eye(3))
>>> x
masked_array(data =
[[ 1.  0.  0.]
 [ 0.  1.  0.]
 [ 0.  0.  1.]],
mask =
False,
fill_value=1e+20)
>>> x.nonzero()
(array([0, 1, 2]), array([0, 1, 2]))
```
Masked elements are ignored.

```python
>>> x[1, 1] = ma.masked
>>> x
masked_array(data =
[[ 1.0  0.0  0.0]
 [ 0.0  --  0.0]
 [ 0.0  0.0  1.0]],
 mask =
[[ False False False]
 [ True  True False]
 [False False False]],
 fill_value=1e+20)
>>> x.nonzero()
(array([0, 2]), array([0, 2]))
```

Indices can also be grouped by element.

```python
>>> np.transpose(x.nonzero())
array([[0, 0],
       [2, 2]])
```

A common use for `nonzero` is to find the indices of an array, where a condition is True. Given an array `a`, the condition `a > 3` is a boolean array and since False is interpreted as 0, `ma.nonzero(a > 3)` yields the indices of the `a` where the condition is true.

```python
>>> a = ma.array([[1,2,3],[4,5,6],[7,8,9]])
>>> a > 3
masked_array(data =
[[False False False]
 [ True  True  True]
 [ True  True  True]],
 mask =
False,
 fill_value=999999)
>>> ma.nonzero(a > 3)
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

The `nonzero` method of the condition array can also be called.

```python
>>> (a > 3).nonzero()
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

MaskedArray.put(indices, values, mode='raise')

Set storage-indexed locations to corresponding values.

Sets self._data.flat[n] = values[n] for each n in indices. If values is shorter than indices then it will repeat. If values has some masked values, the initial mask is updated in consequence, else the corresponding values are unmasked.

**Parameters**

- **indices**: 1-D array_like
  
  Target indices, interpreted as integers.

- **values**: array_like
  
  Values to place in self._data copy at target indices.

- **mode**: {'raise', 'wrap', 'clip'}, optional
Specifies how out-of-bounds indices will behave. ‘raise’ : raise an error. ‘wrap’ : wrap around. ‘clip’ : clip to the range.

Notes
values can be a scalar or length 1 array.

Examples

```python
>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)
>>> print x
[[1 -- 3]
 [-- 5 --]
 [7 -- 9]]
>>> x.put([0,4,8],[10,20,30])
>>> print x
[[10 -- 3]
 [20 --]
 [7 -- 30]]
>>> x.put(4,999)
>>> print x
[[10 -- 3]
 [999 --]
 [7 -- 30]]
```

MaskedArray.repeat (repeats, axis=None)
Repeat elements of an array.

Refer to numpy.repeat for full documentation.

See also:

numpy.repeat
equivalent function

MaskedArray.searchsorted (v, side='left', sorter=None)
Find indices where elements of v should be inserted in a to maintain order.

For full documentation, see numpy.searchsorted

See also:

numpy.searchsorted
equivalent function

MaskedArray.sort (axis=-1, kind='quicksort', order=None, endwith=True, fill_value=None)
Sort the array, in-place

Parameters
a : array_like
Array to be sorted.
axis : int, optional
Axis along which to sort. If None, the array is flattened before sorting. The default is -1, which sorts along the last axis.
kind : {'quicksort', 'mergesort', 'heapsort'}, optional
Sorting algorithm. Default is ‘quicksort’.
order : list, optional

When \( a \) is a structured array, this argument specifies which fields to compare first, second, and so on. This list does not need to include all of the fields.

dewith : \{True, False\}, optional

Whether missing values (if any) should be forced in the upper indices (at the end of the array) (True) or lower indices (at the beginning). When the array contains unmasked values of the largest (or smallest if False) representable value of the datatype the ordering of these values and the masked values is undefined. To enforce the masked values are at the end (beginning) in this case one must sort the mask.

fill_value : \{var\}, optional

Value used internally for the masked values. If fill_value is not None, it supersedes endwith.

Returns

sorted_array : ndarray

Array of the same type and shape as \( a \).

See also:

ndarray.sort

Method to sort an array in-place.

argsort

Indirect sort.

lexsort

Indirect stable sort on multiple keys.

searchsorted

Find elements in a sorted array.

Notes

See sort for notes on the different sorting algorithms.

Examples

```python
>>> a = ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # Default
>>> a.sort()
>>> print a
[1 3 5 -- --]

>>> a = ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # Put missing values in the front
>>> a.sort(endwith=False)
>>> print a
[-- -- 1 3 5]

>>> a = ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # fill_value takes over endwith
>>> a.sort(endwith=False, fill_value=3)
>>> print a
[1 -- -- 3 5]
```
MaskedArray.\texttt{take}(indices, axis=None, out=None, mode='raise')

**Pickling and copy**

- **MaskedArray.\texttt{copy}(order)**: Return a copy of the array.
- **MaskedArray.\texttt{dump}(file)**: Dump a pickle of the array to the specified file.
- **MaskedArray.\texttt{dumps}()**: Returns the pickle of the array as a string.

MaskedArray.\texttt{copy}(order='C')
Return a copy of the array.

**Parameters**

- **order**: {'C', 'F', 'A', 'K'}, optional
  Controls the memory layout of the copy. ‘C’ means C-order, ‘F’ means F-order, ‘A’ means ‘F’ if \( a \) is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of \( a \) as closely as possible. (Note that this function and :func:numpy.copy are very similar, but have different default values for their order= arguments.)

**See also:**

numpy.copy, numpy.copyto

**Examples**

```python
>>> x = np.array([[1,2,3],[4,5,6]], order='F')

>>> y = x.copy()

>>> x.fill(0)

>>> x
array([[0, 0, 0],
       [0, 0, 0]])

>>> y
array([[1, 2, 3],
       [4, 5, 6]])

>>> y.flags['C_CONTIGUOUS']
True
```

MaskedArray.\texttt{dump}(file)
Dump a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

**Parameters**

- **file**: str
  A string naming the dump file.

MaskedArray.\texttt{dumps}()
Returns the pickle of the array as a string. pickle.loads or numpy.loads will convert the string back to an array.

**Parameters**

- **None**
### MaskedArray.all

Check if all of the elements of \( a \) are true.

**Parameters**

- **axis** : \{None, integer\}
  
  Axis to perform the operation over. If None, perform over flattened array.

- **out** : \{None, array\}, optional
  
  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**Examples**

```python
gnp.ma.array([1, 2, 3]).all()
True
```
Parameters

axis : int, optional

Axis over which the anomalies are taken. The default is to use the mean of the flattened array as reference.

dtype : dtype, optional

Type to use in computing the variance. For arrays of integer type the default is float32; for arrays of float types it is the same as the array type.

See also:

mean
Compute the mean of the array.

Examples

>>> a = np.ma.array([1,2,3])
>>> a.anom()
masked_array(data = [-1. 0. 1.],
             mask = False,
             fill_value = 1e+20)

MaskedArray.any( axis=None, out=None )
Check if any of the elements of a are true.

Performs a logical_or over the given axis and returns the result. Masked values are considered as False during computation.

Parameters

axis : {None, integer}

Axis to perform the operation over. If None, perform over flattened array and return a scalar.

out : {None, array}, optional

Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

See also:

any
equivalent function

MaskedArray.clip( a_min, a_max, out=None )
Return an array whose values are limited to [a_min, a_max].

Refer to numpy.clip for full documentation.

See also:

numpy.clip
equivalent function

MaskedArray.conj()
Complex-conjugate all elements.

Refer to numpy.conjugate for full documentation.

See also:
```
    numpy.conjugate
    equivalent function

MaskedArray.conjugate()
    Return the complex conjugate, element-wise.
    Refer to numpy.conjugate for full documentation.

See also:

    numpy.conjugate
    equivalent function

MaskedArray.cumprod(axis=None, dtype=None, out=None)
    Return the cumulative product of the elements along the given axis. The cumulative product is taken over
    the flattened array by default, otherwise over the specified axis.
    Masked values are set to 1 internally during the computation. However, their position is saved, and the result
    will be masked at the same locations.

    Parameters
    axis : {None, -1, int}, optional
        Axis along which the product is computed. The default (axis = None) is to compute
        over the flattened array.
    dtype : {None, dtype}, optional
        Determines the type of the returned array and of the accumulator where the elements
        are multiplied. If dtype has the value None and the type of a is an integer type
        of precision less than the default platform integer, then the default platform integer
        precision is used. Otherwise, the dtype is the same as that of a.
    out : ndarray, optional
        Alternative output array in which to place the result. It must have the same shape and
        buffer length as the expected output but the type will be cast if necessary.

    Returns
    cumprod : ndarray
        A new array holding the result is returned unless out is specified, in which case a refer-
        ence to out is returned.

Notes
    The mask is lost if out is not a valid MaskedArray !
    Arithmetic is modular when using integer types, and no error is raised on overflow.

MaskedArray.cumsum(axis=None, dtype=None, out=None)
    Return the cumulative sum of the elements along the given axis. The cumulative sum is calculated over
    the flattened array by default, otherwise over the specified axis.
    Masked values are set to 0 internally during the computation. However, their position is saved, and the result
    will be masked at the same locations.

    Parameters
    axis : {None, -1, int}, optional
```
Axis along which the sum is computed. The default (\texttt{axis = None}) is to compute over the flattened array. \texttt{axis} may be negative, in which case it counts from the last to the first axis.

\textbf{dtype} : {\texttt{None, dtype}}, \texttt{optional}

Type of the returned array and of the accumulator in which the elements are summed. If \texttt{dtype} is not specified, it defaults to the dtype of \texttt{a}, unless \texttt{a} has an integer dtype with a precision less than that of the default platform integer. In that case, the default platform integer is used.

\textbf{out} : \texttt{ndarray, optional}

Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

\textbf{Returns}

\textbf{cumsum} : \texttt{ndarray}.

A new array holding the result is returned unless \texttt{out} is specified, in which case a reference to \texttt{out} is returned.

\textbf{Notes}

The mask is lost if \texttt{out} is not a valid \texttt{MaskedArray}!

Arithmetic is modular when using integer types, and no error is raised on overflow.

\textbf{Examples}

\begin{verbatim}
>>> marr = np.ma.array(np.arange(10), mask=[0,0,0,1,1,1,0,0,0,0])
>>> print marr.cumsum()
[ 0  1  3 -- -- --  9 16 24 33]
\end{verbatim}

\texttt{MaskedArray.max} (\texttt{axis=None, out=None, fill_value=None})

Return the maximum along a given axis.

\textbf{Parameters}

\texttt{axis} : {\texttt{None, int}}, \texttt{optional}

Axis along which to operate. By default, \texttt{axis} is \texttt{None} and the flattened input is used.

\texttt{out} : \texttt{array_like, optional}

Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output.

\texttt{fill_value} : {\texttt{var}}, \texttt{optional}

Value used to fill in the masked values. If None, use the output of maximum_fill_value().

\textbf{Returns}

\texttt{amax} : \texttt{array_like}

New array holding the result. If \texttt{out} was specified, \texttt{out} is returned.

\textbf{See also:}

maximum_fill_value

Returns the maximum filling value for a given datatype.
MaskedArray.mean (axis=None, dtype=None, out=None)

Returns the average of the array elements.

Masked entries are ignored. The average is taken over the flattened array by default, otherwise over the specified axis. Refer to numpy.mean for the full documentation.

Parameters

a : array_like
    Array containing numbers whose mean is desired. If a is not an array, a conversion is attempted.

axis : int, optional
    Axis along which the means are computed. The default is to compute the mean of the flattened array.

dtype : dtype, optional
    Type to use in computing the mean. For integer inputs, the default is float64; for floating point, inputs it is the same as the input dtype.

out : ndarray, optional
    Alternative output array in which to place the result. It must have the same shape as the expected output but the type will be cast if necessary.

Returns

mean : ndarray, see dtype parameter above
    If out=None, returns a new array containing the mean values, otherwise a reference to the output array is returned.

See also:

numpy.ma.mean
    Equivalent function.

numpy.mean
    Equivalent function on non-masked arrays.

numpy.ma.average
    Weighted average.

Examples

>>> a = np.ma.array([1, 2, 3], mask=[False, False, True])
>>> a
masked_array(data = [1 2 --],
    mask = [False False True],
    fill_value = 999999)
>>> a.mean()
1.5

MaskedArray.min (axis=None, out=None, fill_value=None)

Return the minimum along a given axis.

Parameters

axis : {None, int}, optional
    Axis along which to operate. By default, axis is None and the flattened input is used.

out : array_like, optional

Alternative output array in which to place the result. Must be of the same shape and
buffer length as the expected output.

fill_value : {var}, optional

Value used to fill in the masked values. If None, use the output of
minimum_fill_value.

Returns

amin : array_like

New array holding the result. If out was specified, out is returned.

See also:

minimum_fill_value

Returns the minimum filling value for a given datatype.

MaskedArray.prod(axis=None, dtype=None, out=None)

Return the product of the array elements over the given axis. Masked elements are set to 1 internally for
computation.

Parameters

axis : {None, int}, optional

Axis over which the product is taken. If None is used, then the product is over all the
array elements.

dtype : {None, dtype}, optional

Determines the type of the returned array and of the accumulator where the elements are
multiplied. If dtype has the value None and the type of a is an integer type of precision
less than the default platform integer, then the default platform integer precision is used.
Otherwise, the dtype is the same as that of a.

out : {None, array}, optional

Alternative output array in which to place the result. It must have the same shape as the
expected output but the type will be cast if necessary.

Returns

product_along_axis : {array, scalar}, see dtype parameter above.

Returns an array whose shape is the same as a with the specified axis removed. Returns
a 0d array when a is 1d or axis=None. Returns a reference to the specified output array
if specified.

See also:

prod
equivalent function

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

>>> np.prod([1.,2.])
2.0
>>> np.prod([1.,2.], dtype=np.int32)
2
>>> np.prod([[1.,2.],[3.,4.]]
24.0
>>> np.prod([[1.,2.],[3.,4.]], axis=1)
array([ 2., 12.])

MaskedArray.product (axis=None, dtype=None, out=None)
Return the product of the array elements over the given axis. Masked elements are set to 1 internally for computation.

Parameters
axis : {None, int}, optional
Axis over which the product is taken. If None is used, then the product is over all the array elements.
dtype : {None, dtype}, optional
Determines the type of the returned array and of the accumulator where the elements are multiplied. If dtype has the value None and the type of a is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of a.
out : {None, array}, optional
Alternative output array in which to place the result. It must have the same shape as the expected output but the type will be cast if necessary.

Returns
product_along_axis : {array, scalar}, see dtype parameter above.
Returns an array whose shape is the same as a with the specified axis removed. Returns a 0d array when a is 1d or axis=None. Returns a reference to the specified output array if specified.

See also:
prod equivalent function

Notes
Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples
>>> np.prod([1.,2.])
2.0
>>> np.prod([1.,2.], dtype=np.int32)
2
>>> np.prod([[1.,2.],[3.,4.]])
24.0
>>> np.prod([[1.,2.],[3.,4.]], axis=1)
array([ 2., 12.])

MaskedArray.ptp (axis=None, out=None, fill_value=None)
Return (maximum - minimum) along the the given dimension (i.e. peak-to-peak value).

Parameters
axis : {None, int}, optional
Axis along which to find the peaks. If None (default) the flattened array is used.
out : {None, array_like}, optional
   Alternative output array in which to place the result. It must have the same shape and
   buffer length as the expected output but the type will be cast if necessary.

fill_value : {var}, optional
   Value used to fill in the masked values.

Returns
   ptp : ndarray.
      A new array holding the result, unless out was specified, in which case a reference to
      out is returned.

MaskedArray.round (decimals=0, out=None)
   Return a with each element rounded to the given number of decimals.
   Refer to numpy.around for full documentation.

See also:
   numpy.around equivalent function

MaskedArray.std (axis=None, dtype=None, out=None, ddof=0)
   Compute the standard deviation along the specified axis.

   Returns the standard deviation, a measure of the spread of a distribution, of the array elements. The standard
deviation is computed for the flattened array by default, otherwise over the specified axis.

Parameters
   a : array_like
      Calculate the standard deviation of these values.

   axis : int, optional
      Axis along which the standard deviation is computed. The default is to compute the
      standard deviation of the flattened array.

   dtype : dtype, optional
      Type to use in computing the standard deviation. For arrays of integer type the default
      is float64, for arrays of float types it is the same as the array type.

   out : ndarray, optional
      Alternative output array in which to place the result. It must have the same shape as the
      expected output but the type (of the calculated values) will be cast if necessary.

   ddof : int, optional
      Means Delta Degrees of Freedom. The divisor used in calculations is N − ddof,
      where N represents the number of elements. By default ddof is zero.

   keepdims : bool, optional
      If this is set to True, the axes which are reduced are left in the result as dimensions with
      size one. With this option, the result will broadcast correctly against the original arr.

Returns
   standard_deviation : ndarray, see dtype parameter above.
If `out` is None, return a new array containing the standard deviation, otherwise return a reference to the output array.

See also:

`var`, `mean`, `nanmean`, `nanstd`, `nanvar`

`numpy.doc.ufuncs`

Section “Output arguments”

Notes

The standard deviation is the square root of the average of the squared deviations from the mean, i.e., \( \text{std} = \sqrt{\text{mean}(abs(x - \text{mean}())**2)} \).

The average squared deviation is normally calculated as \( x.\text{sum()} / N \), where \( N = \text{len}(x) \). If, however, \( \text{ddof} \) is specified, the divisor \( N - \text{ddof} \) is used instead. In standard statistical practice, \( \text{ddof}=1 \) provides an unbiased estimator of the variance of the infinite population. \( \text{ddof}=0 \) provides a maximum likelihood estimate of the variance for normally distributed variables. The standard deviation computed in this function is the square root of the estimated variance, so even with \( \text{ddof}=1 \), it will not be an unbiased estimate of the standard deviation per se.

Note that, for complex numbers, `std` takes the absolute value before squaring, so that the result is always real and nonnegative.

For floating-point input, the `std` is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the `dtype` keyword can alleviate this issue.

Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> np.std(a)
1.1180339887498949
>>> np.std(a, axis=0)
array([ 1., 1.])
>>> np.std(a, axis=1)
array([[ 0.5, 0.5]])
```

In single precision, `std()` can be inaccurate:

```python
>>> a = np.zeros((2,512*512), dtype=np.float32)
>>> a[0, :] = 1.0
>>> a[1, :] = 0.1
>>> np.std(a)
0.45172946707416706
```

Computing the standard deviation in float64 is more accurate:

```python
>>> np.std(a, dtype=np.float64)
0.44999999925552653
```

`MaskedArray.sum(axis=None, dtype=None, out=None)`

Return the sum of the array elements over the given axis. Masked elements are set to 0 internally.

Parameters

- `axis` : [None, -1, int], optional
  - Axis along which the sum is computed. The default (`axis` = None) is to compute over the flattened array.
- `dtype` : [None, dtype], optional
Determines the type of the returned array and of the accumulator where the elements are summed. If dtype has the value None and the type of a is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of a.

out : {None, ndarray}, optional

Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

Returns

sum_along_axis : MaskedArray or scalar

An array with the same shape as self, with the specified axis removed. If self is a 0-d array, or if axis is None, a scalar is returned. If an output array is specified, a reference to out is returned.

Examples

```python
g = np.ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]], mask=[0] + [1, 0] * 4)
g.sum()  # 25
```
Type to use in computing the variance. For arrays of integer type the default is `float32`; for arrays of float types it is the same as the array type.

**out** : ndarray, optional

Alternate output array in which to place the result. It must have the same shape as the expected output, but the type is cast if necessary.

**ddof** : int, optional

“Delta Degrees of Freedom”: the divisor used in the calculation is \(N - ddof\), where \(N\) represents the number of elements. By default \(ddof\) is zero.

**keepdims** : bool, optional

If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original \(arr\).

**Returns**

**variance** : ndarray, see dtype parameter above

If out=None, returns a new array containing the variance; otherwise, a reference to the output array is returned.

**See also:**

`std`, `mean`, `nanmean`, `nanstd`, `nanvar`

`numpy.doc.ufuncs`

Section “Output arguments”

**Notes**

The variance is the average of the squared deviations from the mean, i.e., \(\text{var} = \text{mean}(\text{abs}(x - x.\text{mean})^2)\).

The mean is normally calculated as \(x.\text{sum}() / N\), where \(N = \text{len}(x)\). If, however, \(ddof\) is specified, the divisor \(N - ddof\) is used instead. In standard statistical practice, \(ddof=1\) provides an unbiased estimator of the variance of a hypothetical infinite population. \(ddof=0\) provides a maximum likelihood estimate of the variance for normally distributed variables.

Note that for complex numbers, the absolute value is taken before squaring, so that the result is always real and nonnegative.

For floating-point input, the variance is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for \(float32\) (see example below). Specifying a higher-accuracy accumulator using the \(\text{dtype}\) keyword can alleviate this issue.

**Examples**

```python
>>> a = np.array([[1,2],[3,4]])
>>> np.var(a)
1.25
>>> np.var(a, axis=0)
array([ 1., 1.])
>>> np.var(a, axis=1)
array([ 0.25, 0.25])
```

In single precision, \(\text{var()}\) can be inaccurate:

```python
>>> a = np.zeros((2,512*512), dtype=np.float32)
>>> a[0,:] = 1.0
>>> a[1,:] = 0.1
```
Computing the variance in float64 is more accurate:

```python
>>> np.var(a, dtype=np.float64)
0.20249999932997387
```

```python
>>> ((1-0.55)**2 + (0.1-0.55)**2)/2
0.20250000000000001
```

### Arithmetic and comparison operations

**Comparison operators:**

- `x.__lt__(y)`  
  `x < y`
- `x.__le__(y)`  
  `x <= y`
- `x.__gt__(y)`  
  `x > y`
- `x.__ge__(y)`  
  `x >= y`
- `x.__eq__(other)`  
  Check whether `other` equals `self` elementwise
- `x.__ne__(other)`  
  Check whether `other` doesn’t equal `self` elementwise

**Truth value of an array (bool):**

- `x.__nonzero__()`  
  `x != 0`

**Arithmetic:**

- `x.__abs__()`  
  `abs(x)`
- `x.__add__(other)`  
  Add other to `self`, and return a new masked array.
- `x.__radd__(other)`  
  Add `other` to `self`, and return a new masked array.
- `x.__sub__(other)`  
  Subtract `other` from `self`, and return a new masked array.
- `x.__rsub__(other)`  
  Subtract `self` from `other`, and return a new masked array.
- `x.__mul__(other)`  
  Multiply `other` by `self`, and return a new masked array.

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<td>MaskedArray.<strong>rmul</strong>(other)</td>
<td>Multiply other by self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>div</strong>(other)</td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>rdiv</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>truediv</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>rtruediv</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>floordiv</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>rfloordiv</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>mod</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>rmod</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>truediv</strong>(y)</td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>rtruediv</strong>(y)</td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>pow</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>rpow</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>lshift</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>rlshift</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>rshift</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>rrshift</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>and</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>rand</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>or</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>ror</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>xor</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
<tr>
<td>MaskedArray.<strong>rxor</strong></td>
<td>Divide other into self, and return a new masked array.</td>
</tr>
</tbody>
</table>

MaskedArray.__abs__() => abs(x)

MaskedArray.__add__(other)  
Add other to self, and return a new masked array.

MaskedArray.__radd__(other)  
Add other to self, and return a new masked array.

MaskedArray.__sub__(other)  
Subtract other from self, and return a new masked array.

MaskedArray.__rsub__(other)  
Subtract other from self, and return a new masked array.

MaskedArray.__mul__(other)  
Multiply other by self, and return a new masked array.

MaskedArray.__rmul__(other)  
Multiply other by self, and return a new masked array.

MaskedArray.__div__(other)  
Divide other into self, and return a new masked array.

MaskedArray.__rdiv__(y)  
x.__rdiv__(y) <=> y/x

MaskedArray.__truediv__(other)  
Divide other into self, and return a new masked array.

MaskedArray.__rtruediv__(other)  
Divide other into self, and return a new masked array.
MaskedArray.__floordiv__(other)
    Divide other into self, and return a new masked array.

MaskedArray.__rfloordiv__(other)
    Divide other into self, and return a new masked array.

MaskedArray.__mod__
    x.__mod__(y) <=> x%y

MaskedArray.__rmod__
    x.__rmod__(y) <=> y%x

MaskedArray.__divmod__
    (y) <=> divmod(x, y)

MaskedArray.__rdivmod__
    (y) <=> divmod(y, x)

MaskedArray.__pow__(other)
    Raise self to the power other, masking the potential NaNs/Infs

MaskedArray.__rpow__(other)
    Raise self to the power other, masking the potential NaNs/Infs

MaskedArray.__lshift__
    x.__lshift__(y) <=> x<<y

MaskedArray.__rlshift__
    x.__rlshift__(y) <=> y<<x

MaskedArray.__rshift__
    x.__rshift__(y) <=> x>>y

MaskedArray.__rrshift__
    x.__rrshift__(y) <=> y>>x

MaskedArray.__and__
    x.__and__(y) <=> x&y

MaskedArray.__rand__
    x.__rand__(y) <=> y&x

MaskedArray.__or__
    x.__or__(y) <=> x|y

MaskedArray.__ror__
    x.__ror__(y) <=> y|x

MaskedArray.__xor__
    x.__xor__(y) <=> x^y

MaskedArray.__rxor__
    x.__rxor__(y) <=> y^x

**Arithmetic, in-place:**

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<thead>
<tr>
<th>Method</th>
<th>Description</th>
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<tbody>
<tr>
<td>MaskedArray.<strong>iadd</strong>(other)</td>
<td>Add other to self in-place.</td>
</tr>
<tr>
<td>MaskedArray.<strong>isub</strong>(other)</td>
<td>Subtract other from self in-place.</td>
</tr>
<tr>
<td>MaskedArray.<strong>imul</strong>(other)</td>
<td>Multiply self by other in-place.</td>
</tr>
<tr>
<td>MaskedArray.<strong>idiv</strong>(other)</td>
<td>Divide self by other in-place.</td>
</tr>
<tr>
<td>MaskedArray.<strong>itruediv</strong>(other)</td>
<td>True divide self by other in-place.</td>
</tr>
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<tr>
<th>Method</th>
<th>Description</th>
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<tbody>
<tr>
<td>MaskedArray.<strong>ifloordiv</strong>(other)</td>
<td>Floor divide by other in-place.</td>
</tr>
<tr>
<td>MaskedArray.<strong>imod</strong></td>
<td>x.<strong>imod</strong>(y) &lt;==&gt; x%=y</td>
</tr>
<tr>
<td>MaskedArray.<strong>ipow</strong>(other)</td>
<td>Raise self to the power other, in place.</td>
</tr>
<tr>
<td>MaskedArray.<strong>ilshift</strong></td>
<td>x.<strong>ilshift</strong>(y) &lt;==&gt; x&lt;&lt;=y</td>
</tr>
<tr>
<td>MaskedArray.<strong>irshift</strong></td>
<td>x.<strong>irshift</strong>(y) &lt;==&gt; x&gt;&gt;=y</td>
</tr>
<tr>
<td>MaskedArray.<strong>iand</strong></td>
<td>x.<strong>iand</strong>(y) &lt;==&gt; x&amp;=y</td>
</tr>
<tr>
<td>MaskedArray.<strong>ior</strong></td>
<td>x.<strong>ior</strong>(y) &lt;==&gt; x</td>
</tr>
<tr>
<td>MaskedArray.<strong>ixor</strong></td>
<td>x.<strong>ixor</strong>(y) &lt;==&gt; x^=y</td>
</tr>
</tbody>
</table>

Representation

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
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<tbody>
<tr>
<td>MaskedArray.<strong>repr</strong>()</td>
<td>Literal string representation.</td>
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<tr>
<td>MaskedArray.<strong>str</strong>()</td>
<td>String representation.</td>
</tr>
<tr>
<td>MaskedArray.ids()</td>
<td>Return the addresses of the data and mask areas.</td>
</tr>
<tr>
<td>MaskedArray.iscontiguous()</td>
<td>Return a boolean indicating whether the data is contiguos.</td>
</tr>
</tbody>
</table>
MaskedArray.__repr__()
    Literal string representation.

MaskedArray.__str__()
    String representation.

MaskedArray.ids()
    Return the addresses of the data and mask areas.

    Parameters
      None

    Examples
      >>> x = np.ma.array([1, 2, 3], mask=[0, 1, 1])
      >>> x.ids()
      (166670640, 166659832)

      If the array has no mask, the address of nomask is returned. This address is typically not close to the data in memory:
      >>> x = np.ma.array([1, 2, 3])
      >>> x.ids()
      (166691080, 3083169284L)

MaskedArray.iscontiguous()
    Return a boolean indicating whether the data is contiguous.

    Parameters
      None

    Examples
      >>> x = np.ma.array([1, 2, 3])
      >>> x.iscontiguous()
      True

      iscontiguous returns one of the flags of the masked array:
      >>> x.flags
      C_CONTIGUOUS : True
      F_CONTIGUOUS : True
      OWNDATA : False
      WRITEABLE : True
      ALIGNED : True
      UPDATEIFCOPY : False

Special methods

For standard library functions:

MaskedArray.__copy__([order])  Return a copy of the array.
MaskedArray.__deepcopy__([memo])  Return the internal state of the masked array, for pickling purposes.
MaskedArray._getstate__()  Return a 3-tuple for pickling a MaskedArray.
MaskedArray._reduce__()  Restore the internal state of the masked array, for pickling purposes.

MaskedArray.__copy__([order])

1.7. Masked arrays
Return a copy of the array.

**Parameters**

- `order`: `{ 'C', 'F', 'A' }`, optional
  If order is ‘C’ (False) then the result is contiguous (default). If order is ‘Fortran’ (True) then the result has fortran order. If order is ‘Any’ (None) then the result has fortran order only if the array already is in fortran order.

MaskedArray.__deepcopy__(memo=None)

MaskedArray.__getstate__()

Return the internal state of the masked array, for pickling purposes.

MaskedArray.__reduce__()

Return a 3-tuple for pickling a MaskedArray.

MaskedArray.__setstate__(state)

Restore the internal state of the masked array, for pickling purposes. *state* is typically the output of the __getstate__ output, and is a 5-tuple:

- class name
- a tuple giving the shape of the data
- a typecode for the data
- a binary string for the data
- a binary string for the mask.

Basic customization:

- **MaskedArray.__new__([data, mask, dtype, ...])** Create a new masked array from scratch.
- **MaskedArray.__array__(...)** Returns either a new reference to self if dtype is not given or a new array of provided data type if dtype is different from the current dtype of the array.
- **MaskedArray.__array_wrap__(obj[, context])** Special hook for ufuncs.

```
static MaskedArray.__new__(data=None, mask=False, dtype=None, copy=False, subok=True, ndmin=0, fill_value=None, keep_mask=True, hard_mask=None, shrink=True, **options)
```

Create a new masked array from scratch.

**Notes**

A masked array can also be created by taking a .view(MaskedArray).

```
MaskedArray.__array__(dtype) → reference if type unchanged, copy otherwise.
```

Returns either a new reference to self if dtype is not given or a new array of provided data type if dtype is different from the current dtype of the array.

```
MaskedArray.__array_wrap__(obj, context=None)
```

Special hook for ufuncs. Wraps the numpy array and sets the mask according to context.

Container customization: (see Indexing)

```
MaskedArray.__len__() <=> len(x)
MaskedArray.__getitem__(index) x.__getitem__(y) <=> x[y]
MaskedArray.__setitem__(index, value) x.__setitem__(i, y) <=> x[i]=y
MaskedArray.__delitem__() x.__delitem__(y) <=> del x[y]
MaskedArray.__getslice__(i, j) x.__getslice__(i, j) <=> x[i:j]
```

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<th>Method</th>
<th>Description</th>
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<tr>
<td>MaskedArray.<strong>setslice</strong></td>
<td>x.<strong>setslice</strong>(i, j, value) &lt;==&gt; x[i:j]=value</td>
</tr>
<tr>
<td>MaskedArray.<strong>contains</strong></td>
<td>x.<strong>contains</strong>(y) &lt;==&gt; y in x</td>
</tr>
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</table>

MaskedArray.__len__(i) <==> len(x)

MaskedArray.__getitem__(indx)

x.__getitem__(y) <==> x[y]

Return the item described by i, as a masked array.

MaskedArray.__setitem__(indx, value)

x.__setitem__(i, y) <==> x[i]=y

Set item described by index. If value is masked, masks those locations.

MaskedArray.__delitem__

x.__delitem__(y) <==> del x[y]

MaskedArray.__getslice__

x.__getslice__(i, j) <==> x[i:j]

Return the slice described by (i, j). The use of negative indices is not supported.

MaskedArray.__setslice__

x.__setslice__(i, j, value) <==> x[i:j]=value

Set the slice (i,j) of a to value. If value is masked, mask those locations.

MaskedArray.__contains__

x.__contains__(y) <==> y in x

Specific methods

Handling the mask

The following methods can be used to access information about the mask or to manipulate the mask.

<table>
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<tr>
<td>MaskedArray.<strong>setmask</strong></td>
<td>Set the mask.</td>
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<tr>
<td>MaskedArray.harden_mask()</td>
<td>Force the mask to hard.</td>
</tr>
<tr>
<td>MaskedArray.soften_mask()</td>
<td>Force the mask to soft.</td>
</tr>
<tr>
<td>MaskedArray.unshare_mask()</td>
<td>Copy the mask and set the sharedmask flag to False.</td>
</tr>
<tr>
<td>MaskedArray.shrink_mask()</td>
<td>Reduce a mask to nomask when possible.</td>
</tr>
</tbody>
</table>

MaskedArray.__setmask__(mask, copy=False)

Set the mask.

MaskedArray.harden_mask()

Force the mask to hard.

Whether the mask of a masked array is hard or soft is determined by its hardmask property. harden_mask sets hardmask to True.

See also:

hardmask

MaskedArray.soften_mask()

Force the mask to soft.
Whether the mask of a masked array is hard or soft is determined by its `hardmask` property. `soften_mask` sets `hardmask` to False.

**See also:**
- `hardmask`

MaskedArray.`unshare_mask()`  
Copy the mask and set the sharedmask flag to False.

Whether the mask is shared between masked arrays can be seen from the `sharedmask` property. `unshare_mask` ensures the mask is not shared. A copy of the mask is only made if it was shared.

**See also:**
- `sharedmask`

MaskedArray.`shrink_mask()`  
Reduce a mask to nomask when possible.

**Parameters**
None

**Returns**
None

**Examples**

```python
>>> x = np.ma.array([[1, 2], [3, 4]], mask=[0]*4)
>>> x.mask
array([[False, False],
       [False, False]], dtype=bool)
>>> x.shrink_mask()
>>> x.mask
False
```

**Handling the fill_value**

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<th>MaskedArray.get_fill_value()</th>
<th>Return the filling value of the masked array.</th>
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</thead>
<tbody>
<tr>
<td>MaskedArray.set_fill_value([value])</td>
<td>Set the filling value of the masked array.</td>
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</table>

MaskedArray.`get_fill_value()`  
Return the filling value of the masked array.

**Returns**

`fill_value`: scalar

The filling value.

**Examples**

```python
>>> for dt in [np.int32, np.int64, np.float64, np.complex128]:
...    np.ma.array([0, 1], dtype=dt).get_fill_value()
... 999999
999999
1e+20
(1e+20+0j)
```
>>> x = np.ma.array([0, 1.], fill_value=-np.inf)
>>> x.get_fill_value()
-inf

MaskedArray.set_fill_value(value=None)
Set the filling value of the masked array.

Parameters:
value : scalar, optional
    The new filling value. Default is None, in which case a default based on the data type is used.

See also:

ma.set_fill_value
    Equivalent function.

Examples
>>> x = np.ma.array([0, 1.], fill_value=-np.inf)
>>> x.fill_value
-inf
>>> x.set_fill_value(np.pi)
>>> x.fill_value
3.1415926535897931

Reset to default:
>>> x.set_fill_value()
>>> x.fill_value
1e+20

Counting the missing elements

MaskedArray.count(axis=None)  Count the non-masked elements of the array along the given axis.

MaskedArray.count(axis=None)
Count the non-masked elements of the array along the given axis.

Parameters:
axis : int, optional
    Axis along which to count the non-masked elements. If axis is None, all non-masked elements are counted.

Returns:
result : int or ndarray
    If axis is None, an integer count is returned. When axis is not None, an array with shape determined by the lengths of the remaining axes, is returned.

See also:

count_masked
    Count masked elements in array or along a given axis.
Examples

>>> import numpy.ma as ma
>>> a = ma.arange(6).reshape((2, 3))
>>> a[1, :] = ma.masked
>>> a
masked_array(data =
[[0 1 2]
[-- -- --]],
mask =
[[False False False]
[ True  True  True]],
fill_value = 999999)
>>> a.count()
3

When the axis keyword is specified an array of appropriate size is returned.

>>> a.count(axis=0)
array([1, 1, 1])
>>> a.count(axis=1)
array([3, 0])

1.7.7 Masked array operations

Constants

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<thead>
<tr>
<th>ma.MaskType</th>
<th>Numpy’s Boolean type.</th>
</tr>
</thead>
</table>

numpy.ma.MaskType
alias of bool_

Creation

From existing data

| ma.masked_array | An array class with possibly masked values. |
| ma.array(data[, dtype, copy, order, mask, ...]) | An array class with possibly masked values. |
| ma.copy | copy |
| ma.frombuffer(buffer[, dtype, count, offset]) | Interpret a buffer as a 1-dimensional array. |
| ma.fromfunction(function, shape, **kwargs) | Construct an array by executing a function over each coordinate. |
| ma.MaskedArray.copy([order]) | Return a copy of the array. |

numpy.ma.masked_array
alias of MaskedArray

numpy.ma.array(data, dtype=None, copy=False, order=False, mask=False, fill_value=None, keep_mask=True, hard_mask=False, shrink=True, subok=True, ndmin=0)

An array class with possibly masked values.

Masked values of True exclude the corresponding element from any computation.

Construction:
x = MaskedArray(data, mask=nomask, dtype=None,  
    copy=False, subok=True, ndmin=0, fill_value=None,  
    keep_mask=True, hard_mask=None, shrink=True)

Parameters

data : array_like
    Input data.

mask : sequence, optional
    Mask. Must be convertible to an array of booleans with the same shape as data. True
    indicates a masked (i.e. invalid) data.

dtype : dtype, optional
    Data type of the output. If dtype is None, the type of the data argument (data.dtype)
    is used. If dtype is not None and different from data.dtype, a copy is performed.

copy : bool, optional
    Whether to copy the input data (True), or to use a reference instead. Default is False.

subok : bool, optional
    Whether to return a subclass of MaskedArray if possible (True) or a plain
    MaskedArray. Default is True.

ndmin : int, optional
    Minimum number of dimensions. Default is 0.

fill_value : scalar, optional
    Value used to fill in the masked values when necessary. If None, a default based on the
    data-type is used.

keep_mask : bool, optional
    Whether to combine mask with the mask of the input data, if any (True), or to use only
    mask for the output (False). Default is True.

hard_mask : bool, optional
    Whether to use a hard mask or not. With a hard mask, masked values cannot be un-
    masked. Default is False.

shrink : bool, optional
    Whether to force compression of an empty mask. Default is True.

numpy.ma.copy = <numpy.ma.core._frommethod instance at 0x4243f50c>
copy a.copy(order='C')

Return a copy of the array.

Parameters

    Controls the memory layout of the copy. ‘C’ means C-order, ‘F’ means F-order, ‘A’
    means ‘F’ if a is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of a as
    closely as possible. (Note that this function and :func:numpy.copy are very similar, but
    have different default values for their order= arguments.)
Examples

```python
>>> x = np.array([[1, 2, 3], [4, 5, 6]], order='F')
>>> y = x.copy()
>>> x.fill(0)
>>> x
array([[0, 0, 0],
       [0, 0, 0]])
>>> y
array([[1, 2, 3],
       [4, 5, 6]])
>>> y.flags['C_CONTIGUOUS']
True
```

```python
numpy.ma.frombuffer(buffer, dtype=float, count=-1, offset=0) = <numpy.ma.core._convert2ma instance at 0x4243fb4c>
Interpret a buffer as a 1-dimensional array.

Parameters
buffer : buffer_like
   An object that exposes the buffer interface.

dtype : data-type, optional
   Data-type of the returned array; default: float.

count : int, optional
   Number of items to read. -1 means all data in the buffer.

offset : int, optional
   Start reading the buffer from this offset; default: 0.

Notes
If the buffer has data that is not in machine byte-order, this should be specified as part of the data-type, e.g.:

```python
>>> dt = np.dtype(int)
>>> dt = dt.newbyteorder('>')
>>> np.frombuffer(buf, dtype=dt)
```

The data of the resulting array will not be byteswapped, but will be interpreted correctly.

Examples

```python
>>> s = 'hello world'
>>> np.frombuffer(s, dtype='S1', count=5, offset=6)
```

```python
numpy.ma.fromfunction(function, shape, **kwargs) = <numpy.ma.core._convert2ma instance at 0x4243fb6c>
Construct an array by executing a function over each coordinate.

The resulting array therefore has a value \( f(x, y, z) \) at coordinate \((x, y, z)\).
Parameters

- **function**: callable
  The function is called with \( N \) parameters, where \( N \) is the rank of `shape`. Each parameter represents the coordinates of the array varying along a specific axis. For example, if `shape` were \((2, 2)\), then the parameters in turn be \((0, 0), (0, 1), (1, 0), (1, 1)\).

- **shape**: \((N,)\) tuple of ints
  Shape of the output array, which also determines the shape of the coordinate arrays passed to `function`.

- **dtype**: data-type, optional
  Data-type of the coordinate arrays passed to `function`. By default, `dtype` is float.

Returns

- **fromfunction**: any
  The result of the call to `function` is passed back directly. Therefore the shape of `fromfunction` is completely determined by `function`. If `function` returns a scalar value, the shape of `fromfunction` would match the `shape` parameter.

See also:

- `indices`, `meshgrid`

Notes

Keywords other than `dtype` are passed to `function`.

Examples

```python
>>> np.fromfunction(lambda i, j: i == j, (3, 3), dtype=int)
array([[ True, False, False],
       [False,  True, False],
       [False, False,  True]], dtype=bool)
```

```python
>>> np.fromfunction(lambda i, j: i + j, (3, 3), dtype=int)
array([[0, 1, 2],
       [1, 2, 3],
       [2, 3, 4]])
```

MaskedArray.**copy**(order='C')

Return a copy of the array.

Parameters

- **order**: {'C', 'F', 'A', 'K'}, optional
  Controls the memory layout of the copy. 'C' means C-order, 'F' means F-order, 'A' means 'F' if \( a \) is Fortran contiguous, 'C' otherwise. 'K' means match the layout of \( a \) as closely as possible. (Note that this function and :func: numpy.copy are very similar, but have different default values for their order= arguments.)

See also:

- `numpy.copy`, `numpy.copyto`

Examples

```python
>>> x = np.array([[1,2,3],[4,5,6]], order='F')
```
```python
>>> y = x.copy()
>>> x.fill(0)
>>> x
array([[0, 0, 0],
       [0, 0, 0]])
>>> y
array([[1, 2, 3],
       [4, 5, 6]])
>>> y.flags['C_CONTIGUOUS']
True
```

## Ones and zeros

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<td>Return a new array of given shape and type, filled with zeros.</td>
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</table>

```python
numpy.ma.empty((shape, dtype=float, order='C')) = <numpy.ma.core._convert2ma instance at 0x4243faec>
```

Return a new array of given shape and type, without initializing entries.

**Parameters**

- `shape`: int or tuple of int
  - Shape of the empty array
- `dtype`: data-type, optional
  - Desired output data-type.
- `order`: {‘C’, ‘F’}, optional
  - Whether to store multi-dimensional data in C (row-major) or Fortran (column-major) order in memory.

**Returns**

- `out`: ndarray
  - Array of uninitialized (arbitrary) data with the given shape, dtype, and order.

**See also:**

- `empty_like`, `zeros`, `ones`

**Notes**

`empty`, unlike `zeros`, does not set the array values to zero, and may therefore be marginally faster. On the other hand, it requires the user to manually set all the values in the array, and should be used with caution.

**Examples**
numpy.ma.empty_like(a, dtype=None, order='K', subok=True) = <numpy.ma.core._convert2ma instance at 0x4243fb2c>

Return a new array with the same shape and type as a given array.

Parameters

- **a**: array_like
  The shape and data-type of `a` define these same attributes of the returned array.

- **dtype**: data-type, optional
  New in version 1.6.0.
  Overrides the data type of the result.

- **order**: {'C', 'F', 'A', or 'K'}, optional
  New in version 1.6.0.
  Overrides the memory layout of the result. ‘C’ means C-order, ‘F’ means F-order, ‘A’ means ‘F’ if `a` is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of `a` as closely as possible.

- **subok**: bool, optional.
  If True, then the newly created array will use the sub-class type of `a`, otherwise it will be a base-class array. Defaults to True.

Returns

- **out**: ndarray
  Array of uninitialized (arbitrary) data with the same shape and type as `a`.

See also:

- `ones_like`
  Return an array of ones with shape and type of input.

- `zeros_like`
  Return an array of zeros with shape and type of input.

- `empty`
  Return a new uninitialized array.

- `ones`
  Return a new array setting values to one.

- `zeros`
  Return a new array setting values to zero.

Notes

This function does not initialize the returned array; to do that use `zeros_like` or `ones_like` instead. It may be marginally faster than the functions that do set the array values.
Examples

```python
>>> a = ([1,2,3], [4,5,6])  # a is array-like
>>> np.empty_like(a)
array([-1073741821, -1073741821, 3],  #random
       [ 0, 0, -1073741821])
```

```python
>>> a = np.array([[1., 2., 3.],[4.,5.,6.]])
>>> np.empty_like(a)
array([ [-2.00000715e+000, 1.48219694e-323, -2.00000572e+000],  #random
        [ 4.38791518e-305, -2.00000715e+000, 4.17269252e-309]])
```

`numpy.ma.masked_all(shape, dtype=<type 'float'>)`

Empty masked array with all elements masked.

Return an empty masked array of the given shape and dtype, where all the data are masked.

**Parameters**

- `shape`: tuple
  
  Shape of the required MaskedArray.

- `dtype`: dtype, optional
  
  Data type of the output.

**Returns**

- `a`: MaskedArray
  
  A masked array with all data masked.

**See also:**

`masked_all_like`  
Empty masked array modelled on an existing array.

**Examples**

```python
>>> import numpy.ma as ma
>>> ma.masked_all((3, 3))
masked_array(data = [[-- -- --]  
                     [-- -- --]  
                     [-- -- --]],  
            mask = [[ True  True  True]  
                     [ True  True  True]  
                     [ True  True  True]],  
            fill_value=1e+20)
```

The `dtype` parameter defines the underlying data type.

```python
>>> a = ma.masked_all((3, 3))
>>> a.dtype
dtype('float64')
```

```python
>>> a = ma.masked_all((3, 3), dtype=np.int32)
>>> a.dtype
dtype('int32')
```

`numpy.ma.masked_all_like(arr)`  
Empty masked array with the properties of an existing array.

Return an empty masked array of the same shape and dtype as the array `arr`, where all the data are masked.
Parameters

arr : ndarray

An array describing the shape and dtype of the required MaskedArray.

Returns

a : MaskedArray

A masked array with all data masked.

Raises

AttributeError

If arr doesn’t have a shape attribute (i.e. not an ndarray)

See also:

masked_all

Empty masked array with all elements masked.

Examples

```python
>>> import numpy.ma as ma

arr = np.zeros((2, 3), dtype=np.float32)
>>> arr
array([[ 0.,  0.,  0.],
       [ 0.,  0.,  0.]], dtype=float32)

>>> ma.masked_all_like(arr)
masked_array(data =
[-- -- --]
[-- -- --],
mask =
[[ True  True  True]
 [ True  True  True]],
fill_value=1e+20)
```

The dtype of the masked array matches the dtype of arr.

```python
>>> arr.dtype
dtype('float32')

>>> ma.masked_all_like(arr).dtype
dtype('float32')
```

numpy.ma.ones(shape, dtype=None, order='C') = <numpy.ma.core._convert2ma instance at 0x4243fc0c>

Return a new array of given shape and type, filled with ones.

Parameters

shape : int or sequence of ints

Shape of the new array, e.g., (2, 3) or 2.

dtype : data-type, optional

The desired data-type for the array, e.g., numpy.int8. Default is numpy.float64.

order : {'C', 'F'}, optional

Whether to store multidimensional data in C- or Fortran-contiguous (row- or column-wise) order in memory.

Returns

out : ndarray
Array of ones with the given shape, dtype, and order.

See also:

zeros, ones_like

Examples

```python
>>> np.ones(5)
array([1., 1., 1., 1., 1.])

>>> np.ones((5,), dtype=np.int)
array([1, 1, 1, 1, 1])

>>> np.ones((2, 1))
array([[1.],
       [1.]]

>>> s = (2, 2)
>>> np.ones(s)
array([[1., 1.],
       [1., 1.]])
```

def numpy.ma.zeros(shape, dtype=float, order='C')

Return a new array of given shape and type, filled with zeros.

Parameters:

- **shape**: int or sequence of ints
  - Shape of the new array, e.g., (2, 3) or 2.

- **dtype**: data-type, optional
  - The desired data-type for the array, e.g., numpy.int8. Default is numpy.float64.

- **order**: {'C', 'F'}, optional
  - Whether to store multidimensional data in C- or Fortran-contiguous (row- or column-wise) order in memory.

Returns:

- **out**: ndarray
  - Array of zeros with the given shape, dtype, and order.

See also:

zeros_like
  - Return an array of zeros with shape and type of input.

ones_like
  - Return an array of ones with shape and type of input.

empty_like
  - Return an empty array with shape and type of input.

ones
  - Return a new array setting values to one.

empty
  - Return a new uninitialized array.
Examples

```python
>>> np.zeros(5)
array([ 0.,  0.,  0.,  0.,  0.])

>>> np.zeros((5,), dtype=numpy.int)
array([0, 0, 0, 0, 0])

>>> np.zeros((2, 1))
array([[ 0.],
       [ 0.]])

>>> s = (2,2)
>>> np.zeros(s)
array([[ 0.,  0.],
       [ 0.,  0.]])

>>> np.zeros((2,), dtype=[('x', 'i4'), ('y', 'i4')])
# custom dtype
array([(0, 0), (0, 0)],
dtype=[('x', '<i4'), ('y', '<i4')])
```

Inspecting the array

```python
def numpy.ma.all(self[, axis, out])
    Check if all of the elements of a are true.

def numpy.ma.any(self[, axis, out])
    Check if any of the elements of a are true.

def numpy.ma.count(self[, axis])
    Count the non-masked elements of the array along the given axis.

def numpy.ma.count_masked(arr[, axis])
    Count the number of masked elements along the given axis.

def numpy.ma.getmask(a)
    Return the mask of a masked array, or nomask.

def numpy.ma.getmaskarray(arr)
    Return the mask of a masked array, or full boolean array of False.

def numpy.ma.getdata(a[, subok])
    Return the data of a masked array as an ndarray.

def numpy.ma.nonzero(self)
    Return the indices of unmasked elements that are not zero.

def numpy.ma.shape(obj)
    Return the shape of an array.

def numpy.ma.size(obj[, axis])
    Return the number of elements along a given axis.

def numpy.ma.is_masked(x)
    Determine whether input has masked values.

def numpy.ma.is_mask(m)
    Return True if m is a valid, standard mask.

def numpy.ma.MaskedArray.data
    Return the current data, as a view of the original underlying data.

def numpy.ma.MaskedArray.mask
    Mask

def numpy.ma.MaskedArray.recordmask
    Return the mask of the records.

def numpy.ma.MaskedArray.all([axis, out])
    Check if all of the elements of a are true.

    Performs a logical_and over the given axis and returns the result. Masked values are considered as True during computation. For convenience, the output array is masked where ALL the values along the current axis are masked: if the output would have been a scalar and that all the values are masked, then the output is masked.

Parameters

1.7. Masked arrays
**axis**: {None, integer}

Axis to perform the operation over. If None, perform over flattened array.

**out**: {None, array}, optional

Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**See also:**

all

equivalent function

### Examples

```python
gnp.ma.array([1, 2, 3]).all()
True
gnp.ma.array([1, 2, 3], mask=True)
>>> (a.all() is np.ma.masked)
True
```

**numpy.ma.any** *(self, axis=None, out=None)*

Check if any of the elements of *a* are true.

Performs a logical_or over the given axis and returns the result. Masked values are considered as False during computation.

**Parameters**

- **axis**: {None, integer}
  
  Axis to perform the operation over. If None, perform over flattened array and return a scalar.

- **out**: {None, array}, optional
  
  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**See also:**

any

equivalent function

**numpy.ma.count** *(a, axis=None)*

Count the non-masked elements of the array along the given axis.

**Parameters**

- **axis**: int, optional
  
  Axis along which to count the non-masked elements. If *axis* is *None*, all non-masked elements are counted.

**Returns**

- **result**: int or ndarray
  
  If *axis* is *None*, an integer count is returned. When *axis* is not *None*, an array with shape determined by the lengths of the remaining axes, is returned.

**See also:**
count_masked
Count masked elements in array or along a given axis.

Examples
>>> import numpy.ma as ma
>>> a = ma.arange(6).reshape((2, 3))
>>> a[1, :] = ma.masked
>>> a
masked_array(data =
[[0 1 2]
[-- -- --]],
    mask =
[[False False False]
[ True  True  True]],
    fill_value = 999999)
>>> a.count()
3

When the axis keyword is specified an array of appropriate size is returned.

>>> a.count(axis=0)
array([1, 1, 1])
>>> a.count(axis=1)
array([3, 0])

numpy.ma.count_masked(arr, axis=None)
Count the number of masked elements along the given axis.

Parameters
arr: array_like
    An array with (possibly) masked elements.
axis: int, optional
    Axis along which to count. If None (default), a flattened version of the array is used.

Returns
count: int, ndarray
    The total number of masked elements (axis=None) or the number of masked elements
    along each slice of the given axis.

See also:

MaskedArray.count
Count non-masked elements.

Examples
>>> import numpy.ma as ma
>>> a = np.arange(9).reshape((3,3))
>>> a = ma.array(a)
>>> a[1, 0] = ma.masked
>>> a[1, 2] = ma.masked
>>> a[2, 1] = ma.masked
>>> a
masked_array(data =
[[0 1 2]
[-- 4 --]],
    mask =
[[False False False]
[ True False False]],
    fill_value = 999999)
[6 -- 8]),
    mask =
    [[False False False]
     [ True False  True]
     [False  True False]],
    fill_value=999999)
>>> ma.count_masked(a)
3

When the `axis` keyword is used an array is returned.

>>> ma.count_masked(a, axis=0)
array([1, 1, 1])
>>> ma.count_masked(a, axis=1)
array([0, 2, 1])

numpy.ma.getmask(a)
Return the mask of a masked array, or nomask.

Return the mask of `a` as an ndarray if `a` is a `MaskedArray` and the mask is not `nomask`, else return `nomask`. To guarantee a full array of booleans of the same shape as `a`, use `getmaskarray`.

Parameters
    a : array_like
        Input `MaskedArray` for which the mask is required.

See also:

getdata Return the data of a masked array as an ndarray.

getmaskarray Return the mask of a masked array, or full array of False.

Examples
>>> import numpy.ma as ma
>>> a = ma.masked_equal([[1,2],[3,4]], 2)
>>> a
masked_array(data =
[[1 --]
 [3 4]],
   mask =
[[False  True]
 [False False]],
   fill_value=999999)
>>> ma.getmask(a)
array([[False, True],
       [False, False]], dtype=bool)

Equivalently use the `MaskedArray` mask attribute.

>>> a.mask
array([[False, True],
       [False, False]], dtype=bool)

Result when mask == nomask
```python
>>> b = ma.masked_array([[1,2],[3,4]])
>>> b
masked_array(data =
   [[1 2]
    [3 4]],
   mask =
   False,
   fill_value=999999)
>>> ma.nomask
False
>>> ma.getmask(b) == ma.nomask
True
>>> b.mask == ma.nomask
True
```

`numpy.ma.getmaskarray(arr)`

Return the mask of a masked array, or full boolean array of False.

Return the mask of `arr` as an ndarray if `arr` is a `MaskedArray` and the mask is not `nomask`, else return a full boolean array of False of the same shape as `arr`.

**Parameters**

- `arr`: array_like
  Input `MaskedArray` for which the mask is required.

**See also:**

- `getmask`: Return the mask of a masked array, or nomask.
- `getdata`: Return the data of a masked array as an ndarray.

**Examples**

```python
>>> import numpy.ma as ma

>>> a = ma.masked_equal([[1,2],[3,4]], 2)
>>> a
masked_array(data =
   [[1 --]
    [3 4]],
   mask =
   [[False  True]
    [False False]],
   fill_value=999999)
>>> ma.getmaskarray(a)
array([[False,  True],
       [False, False]], dtype=bool)
```

Result when mask == nomask

```python
>>> b = ma.masked_array([[1,2],[3,4]])
>>> b
masked_array(data =
   [[1 2]
    [3 4]],
   mask =
   False,
   fill_value=999999)
```
>>> ma.getmaskarray(b)
array([[False, False],
       [False, False]], dtype=bool)

numpy.ma.getdata(a, subok=True)

Return the data of a masked array as an ndarray.

Return the data of `a` (if any) as an ndarray if `a` is a `MaskedArray`, else return `a` as a ndarray or subclass (depending on `subok`) if not.

**Parameters**

- `a` : array_like
  
  Input `MaskedArray`, alternatively a ndarray or a subclass thereof.

- `subok` : bool
  
  Whether to force the output to be a pure `ndarray` (False) or to return a subclass of `ndarray` if appropriate (True, default).

**See also:**

- `getmask`
  
  Return the mask of a masked array, or nomask.

- `getmaskarray`
  
  Return the mask of a masked array, or full array of False.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = ma.masked_equal([[1,2],[3,4]], 2)
>>> a
masked_array(data =
    [[1 --]
     [3 4]],
   mask =
    [[False  True]
     [False False]],
   fill_value=999999)
>>> ma.getdata(a)
array([[1, 2],
       [3, 4]])
```

Equivalently use the `MaskedArray data` attribute.

```python
>>> a.data
array([[1, 2],
       [3, 4]])
```

```python
numpy.ma.nonzero(self) = <numpy.ma.core._frommethod instance at 0x4243f60c>

Return the indices of unmasked elements that are not zero.

Returns a tuple of arrays, one for each dimension, containing the indices of the non-zero elements in that dimension. The corresponding non-zero values can be obtained with:

```python
a[a.nonzero()]
```

To group the indices by element, rather than dimension, use instead:
np.transpose(a.nonzero())

The result of this is always a 2d array, with a row for each non-zero element.

Parameters
None

Returns
tuple_of_arrays : tuple

Indices of elements that are non-zero.

See also:

numpy.nonzero
Function operating on ndarrays.

flatnonzero
Return indices that are non-zero in the flattened version of the input array.

ndarray.nonzero
Equivalent ndarray method.

count_nonzero
Counts the number of non-zero elements in the input array.

Examples

>>> import numpy.ma as ma
>>> x = ma.array(np.eye(3))
>>> x
masked_array(data =
[[ 1.  0.  0.]
[ 0.  1.  0.]
[ 0.  0.  1.]],
mask =
False,
fill_value=1e+20)
>>> x.nonzero()
(array([0, 1, 2]), array([0, 1, 2]))

Masked elements are ignored.

>>> x[1, 1] = ma.masked
>>> x
masked_array(data =
[[ 1.0  0.0  0.0]
[ 0.0  --  0.0]
[ 0.0  0.0  1.0]],
mask =
[[False False False]
[False   True False]
[False False False]],
fill_value=1e+20)
>>> x.nonzero()
(array([0, 2]), array([0, 2]))

Indices can also be grouped by element.
>>> np.transpose(x.nonzero())
array([[0, 0],
       [2, 2]])

A common use for nonzero is to find the indices of an array, where a condition is True. Given an array `a`, the condition `a > 3` is a boolean array and since False is interpreted as 0, `ma.nonzero(a > 3)` yields the indices of the `a` where the condition is true.

```python
>>> a = ma.array([[1,2,3],[4,5,6],[7,8,9]])
>>> a > 3
masked_array(data =
     [[False False False]
      [ True  True  True]
      [ True  True  True]],
    mask = False,
    fill_value=999999)
```

```python
>>> ma.nonzero(a > 3)
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

The nonzero method of the condition array can also be called.

```python
>>> (a > 3).nonzero()
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

`numpy.ma.shape(obj)`

Return the shape of an array.

**Parameters**

- `a` : array_like
  - Input array.

**Returns**

- `shape` : tuple of ints
  - The elements of the shape tuple give the lengths of the corresponding array dimensions.

**See also:**

`alen`

`ndarray.shape`

Equivalent array method.

**Examples**

```python
>>> np.shape(np.eye(3))
(3, 3)
>>> np.shape([[1, 2]])
(1, 2)
>>> np.shape([0])
(1,)
>>> np.shape(0)
()  
```

```python
>>> a = np.array([[1, 2], (3, 4)], dtype=[('x', 'i4'), ('y', 'i4')])
>>> np.shape(a)
(2,)
>>> a.shape
(2,)
```
**numpy.ma.size**(obj, axis=None)

Return the number of elements along a given axis.

**Parameters**

- a : array_like
  
  Input data.

- axis : int, optional
  
  Axis along which the elements are counted. By default, give the total number of elements.

**Returns**

- element_count : int
  
  Number of elements along the specified axis.

**See also:**

- shape
dimensions of array

- ndarray.shape
dimensions of array

- ndarray.size
  number of elements in array

**Examples**

```python
>>> a = np.array([[1, 2, 3], [4, 5, 6]])
>>> np.size(a)
6
>>> np.size(a, 1)
3
>>> np.size(a, 0)
2
```

**numpy.ma.is_masked**(x)

Determine whether input has masked values.

Accepts any object as input, but always returns False unless the input is a MaskedArray containing masked values.

**Parameters**

- x : array_like
  
  Array to check for masked values.

**Returns**

- result : bool
  
  True if x is a MaskedArray with masked values, False otherwise.

**Examples**

```python
>>> import numpy.ma as ma

>>> x = ma.masked_equal([0, 1, 0, 2, 3], 0)
```

---

**1.7. Masked arrays**
>>> ma.is_masked(x)
True
>>> x = ma.masked_equal([0, 1, 0, 2, 3], 42)
>>> x
masked_array(data = [0 1 0 2 3],
             mask = False,
             fill_value=999999)
>>> ma.is_masked(x)
False

Always returns False if x isn’t a MaskedArray.

>>> x = [False, True, False]
>>> ma.is_masked(x)
False
>>> x = ‘a string’
>>> ma.is_masked(x)
False

**numpy.ma.is_mask(m)**

Return True if m is a valid, standard mask.

This function does not check the contents of the input, only that the type is MaskType. In particular, this function returns False if the mask has a flexible dtype.

**Parameters**

m : array_like
   Array to test.

**Returns**

result : bool
   True if m.dtype.type is MaskType, False otherwise.

**See also:**

*isMaskedArray*

Test whether input is an instance of MaskedArray.

**Examples**

```python
>>> import numpy.ma as ma
>>> m = ma.masked_equal([0, 1, 0, 2, 3], 0)
>>> m
masked_array(data = [-- 1 -- 2 3],
             mask = [ True False True False False],
             fill_value=999999)
>>> ma.is_mask(m)
False
>>> ma.is_mask(m.mask)
True
```

Input must be an ndarray (or have similar attributes) for it to be considered a valid mask.

```python
>>> m = [False, True, False]
>>> ma.is_mask(m)
False
>>> m = np.array([False, True, False])
>>> m
array([False, True, False], dtype=bool)
```
Arrays with complex dtypes don’t return True.

```
>>> dtype = np.dtype({
    'names': ['monty', 'pithon'],
    'formats': [np.bool, np.bool]
})
```

```
>>> m = np.array([(True, False), (False, True), (True, False)],
               dtype=dtype)
```

```
>>> ma.is_mask(m)
False
```

MaskedArray.data
Return the current data, as a view of the original underlying data.

MaskedArray.mask
Mask

MaskedArray.recordmask
Return the mask of the records. A record is masked when all the fields are masked.

MaskedArray.all
Check if all of the elements of a are true.

Performs a logical_and over the given axis and returns the result. Masked values are considered as True during computation. For convenience, the output array is masked where ALL the values along the current axis are masked: if the output would have been a scalar and that all the values are masked, then the output is masked.

Parameters
- axis: {None, integer}
  Axis to perform the operation over. If None, perform over flattened array.
- out: {None, array}, optional
  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

See also:

all
equivalent function

Examples

```
>>> np.ma.array([1,2,3]).all()
True
```

```
>>> a = np.ma.array([1,2,3,], mask=True)
```

```
>>> (a.all() is np.ma.masked)
True
```

MaskedArray.any
Check if any of the elements of a are true.

Performs a logical_or over the given axis and returns the result. Masked values are considered as False during computation.

Examples

```
>>> np.ma.array([1,2,3]).all()
True
```

```
>>> a = np.ma.array([1,2,3], mask=True)
```

```
>>> (a.all() is np.ma.masked)
True
```
Parameters

axis : {None, integer}

Axis to perform the operation over. If None, perform over flattened array and return a scalar.

out : {None, array}, optional

Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

See also:

any
equivalent function

MaskedArray.count(axis=None)
Count the non-masked elements of the array along the given axis.

Parameters

axis : int, optional

Axis along which to count the non-masked elements. If axis is None, all non-masked elements are counted.

Returns

result : int or ndarray

If axis is None, an integer count is returned. When axis is not None, an array with shape determined by the lengths of the remaining axes, is returned.

See also:

count_masked
Count masked elements in array or along a given axis.

Examples

>>> import numpy.ma as ma
>>> a = ma.arange(6).reshape((2, 3))
>>> a[1, :] = ma.masked
>>> a
masked_array(data =
[[0 1 2]
[-- -- --]],
mask =
[[False False False]
[ True  True  True]],
fill_value = 999999)
>>> a.count()
3

When the axis keyword is specified an array of appropriate size is returned.

>>> a.count(axis=0)
array([1, 1, 1])

>>> a.count(axis=1)
array([3, 0])

MaskedArray.nonzero()
Return the indices of unmasked elements that are not zero.
Returns a tuple of arrays, one for each dimension, containing the indices of the non-zero elements in that dimension. The corresponding non-zero values can be obtained with:

```python
a[a.nonzero()]
```

To group the indices by element, rather than dimension, use instead:

```python
np.transpose(a.nonzero())
```

The result of this is always a 2d array, with a row for each non-zero element.

**Parameters**
None

**Returns**
tuple_of_arrays : tuple
Indices of elements that are non-zero.

**See also:**

- `numpy.nonzero` Function operating on ndarrays.
- `flatnonzero` Return indices that are non-zero in the flattened version of the input array.
- `ndarray.nonzero` Equivalent ndarray method.
- `count_nonzero` Counts the number of non-zero elements in the input array.

**Examples**

```python
>>> import numpy.ma as ma
>>> x = ma.array(np.eye(3))
>>> x
masked_array(data =
[[ 1.  0.  0.]
 [ 0.  1.  0.]
 [ 0.  0.  1.]],
mask = False,
fill_value=1e+20)
>>> x.nonzero()
(array([0, 1, 2]), array([0, 1, 2]))
```

Masked elements are ignored.

```python
>>> x[1, 1] = ma.masked
>>> x
masked_array(data =
[[1.0 0.0 0.0]
 [0.0 -- 0.0]
 [0.0 0.0 1.0]],
mask = [[False False False]
[False  True False]
[False False False]],
fill_value=1e+20)
```
Indices can also be grouped by element.

```python
>>> np.transpose(x.nonzero())
array([[0, 0],
       [2, 2]])
```

A common use for `nonzero` is to find the indices of an array, where a condition is True. Given an array `a`, the condition `a > 3` is a boolean array and since False is interpreted as 0, `ma.nonzero(a > 3)` yields the indices of the `a` where the condition is true.

```python
>>> a = ma.array([[1,2,3],[4,5,6],[7,8,9]])
>>> a > 3
masked_array(data =
 [ [False False False]
   [ True  True  True]
   [ True  True  True]],
mask =
False,
fill_value=999999)
```  

```python
>>> ma.nonzero(a > 3)
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

The `nonzero` method of the condition array can also be called.

```python
>>> (a > 3).nonzero()
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

### numpy.ma.shape(obj)

Return the shape of an array.

**Parameters**

- `a`: array_like
  
  Input array.

**Returns**

- `shape`: tuple of ints
  
  The elements of the shape tuple give the lengths of the corresponding array dimensions.

**See also:**

- `alen`

**ndarray.shape**

Equivalent array method.

**Examples**

```python
>>> np.shape(np.eye(3))
(3, 3)
>>> np.shape([[1, 2]])
(1, 2)
>>> np.shape([0])
(1,)
>>> np.shape(0)
()`
```python
>>> a = np.array([(1, 2), (3, 4)], dtype=[('x', 'i4'), ('y', 'i4')])
>>> np.shape(a)
(2,)
>>> a.shape
(2,)
```

```python
def numpy.ma.size(obj, axis=None)

Return the number of elements along a given axis.

Parameters
---

- **obj**: array_like
  - Input data.

- **axis**: int, optional
  - Axis along which the elements are counted. By default, give the total number of elements.

Returns
---

- **element_count**: int
  - Number of elements along the specified axis.

See also:
- `shape`
  - dimensions of array
- `ndarray.shape`
  - dimensions of array
- `ndarray.size`
  - number of elements in array
```

**Examples**
```python
>>> a = np.array([[1, 2, 3], [4, 5, 6]])
>>> np.size(a)
6
>>> np.size(a, 1)
3
>>> np.size(a, 0)
2
```

### Manipulating a MaskedArray

#### Changing the shape

- `ma.ravel(self)`: Returns a 1D version of self, as a view.
- `ma.reshape(a, new_shape[, order])`: Returns an array containing the same data with a new shape.
- `ma.resize(x, new_shape)`: Return a new masked array with the specified size and shape.
- `ma.MaskedArray.flatten([order])`: Return a copy of the array collapsed into one dimension.
- `ma.MaskedArray.ravel()`: Returns a 1D version of self, as a view.
- `ma.MaskedArray.reshape(*s, **kwargs)`: Give a new shape to the array without changing its data.
- `ma.MaskedArray.resize(newshape[, refcheck, ...])`:
numpy.ma.ravel(self) = <numpy.ma.core._frommethod instance at 0x4243f72c>

Returns a 1D version of self, as a view.

**Returns**

MaskedArray

Output view is of shape (self.size,) (or (np.ma.product(self.shape),)).

**Examples**

```python
>>> x = np.ma.array([[1,2,3], [4,5,6], [7,8,9]], mask=[0] + [1,0]*4)
>>> print x
[[1 -- 3]
 [-- 5 --]
 [7 -- 9]]
>>> print x.ravel()
[1 -- 3 -- 5 -- 7 -- 9]
```

numpy.ma.reshape(a, new_shape, order='C')

Returns an array containing the same data with a new shape.

Refer to MaskedArray.reshape for full documentation.

See also:

MaskedArray.reshape
equivalent function

numpy.ma.resize(x, new_shape)

Return a new masked array with the specified size and shape.

This is the masked equivalent of the numpy.resize function. The new array is filled with repeated copies of x (in the order that the data are stored in memory). If x is masked, the new array will be masked, and the new mask will be a repetition of the old one.

See also:

numpy.resize
Equivalent function in the top level NumPy module.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = ma.array([[1, 2], [3, 4]])
>>> a[0, 1] = ma.masked
>>> a
masked_array(data =
[[1 --]
 [3 4]],
    mask =
[[False True]
 [False False]],
    fill_value = 999999)
>>> np.resize(a, (3, 3))
array([[1, 2, 3],
 [4, 1, 2],
 [3, 4, 1]])
>>> ma.resize(a, (3, 3))
masked_array(data =
[[1 -- 3]
 [4 -- 1] --]
 [3 -- 4 -- 1]],
    mask =
[[False True]
 [False False] --]
 [False False False]],
    fill_value = 999999)
```
```
[[1 -- 3]
[4 1 --]
[3 4 1]],
    mask =
[[False  True False]
[False False  True]
[False False False]],
    fill_value = 999999)
```

A MaskedArray is always returned, regardless of the input type.

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> ma.resize(a, (3, 3))
masked_array(data =
[[1 2 3]
[4 1 2]
[3 4 1]],
    mask =
False,
    fill_value = 999999)
```

`MaskedArray.flatten(order='C')`

Return a copy of the array collapsed into one dimension.

**Parameters**

- **order**: {'C', 'F', 'A'}, optional
  
  Whether to flatten in C (row-major), Fortran (column-major) order, or preserve the C/Fortran ordering from `a`. The default is 'C'.

**Returns**

- **y**: ndarray
  
  A copy of the input array, flattened to one dimension.

**See also:**

- `ravel`
  
  Return a flattened array.

- `flat`
  
  A 1-D flat iterator over the array.

**Examples**

```python
>>> a = np.array([[1,2], [3,4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])
```

`MaskedArray.ravel()`

Returns a 1D version of self, as a view.

**Returns**

- **MaskedArray**
  
  Output view is of shape `(self.size,)` (or `(np.ma.product(self.shape),)`).
MaskedArray.**reshape**(*s, **kwargs*)

Give a new shape to the array without changing its data.

Returns a masked array containing the same data, but with a new shape. The result is a view on the original array; if this is not possible, a ValueError is raised.

**Parameters**

- **shape**: int or tuple of ints
  
The new shape should be compatible with the original shape. If an integer is supplied, then the result will be a 1-D array of that length.

- **order**: {'C', 'F'}, optional
  
  Determines whether the array data should be viewed as in C (row-major) or FORTRAN (column-major) order.

**Returns**

- **reshaped_array**: array
  
  A new view on the array.

**See also:**

- **reshape**
  
  Equivalent function in the masked array module.

- **numpy.ndarray.reshape**
  
  Equivalent method on ndarray object.

- **numpy.reshape**
  
  Equivalent function in the NumPy module.

**Notes**

The reshaping operation cannot guarantee that a copy will not be made, to modify the shape in place, use `a.shape = s`

**Examples**

```python
>>> x = np.ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]], mask=[0] + [1, 0]*4)
>>> print x
[[1 -- 3]
 [-- 5 --]
 [7 -- 9]]
>>> print x.ravel()
[1 -- 3 -- 5 -- 7 -- 9]
```

```python
MaskedArray
```

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MaskedArray.resize(newshape, refcheck=True, order=False)

**Warning:** This method does nothing, except raise a ValueError exception. A masked array does not own its data and therefore cannot safely be resized in place. Use the `numpy.ma.resize` function instead.

This method is difficult to implement safely and may be deprecated in future releases of NumPy.

**Modifying axes**

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<td><code>ma.swapaxes(a, axes)</code></td>
<td>Permute the dimensions of an array.</td>
</tr>
<tr>
<td><code>ma.transpose(a, axes=None)</code></td>
<td>Returns a view of the array with axes transposed.</td>
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<tr>
<td><code>ma.MaskedArray.swapaxes(axis1, axis2)</code></td>
<td>Return a view of the array with <code>axis1</code> and <code>axis2</code> interchanged.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.transpose(*axes)</code></td>
<td>Returns a view of the array with axes transposed.</td>
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```
numpy.ma.swapaxes = <numpy.ma.core._frommethod instance at 0x4243f88c>
```

swapaxes a.swapaxes(axis1, axis2)

Return a view of the array with `axis1` and `axis2` interchanged.

Refer to `numpy.swapaxes` for full documentation.

See also:

```
numpy.swapaxes
```

Equivalent function

```
numpy.ma.transpose(a, axes=None)
```

Permute the dimensions of an array.

This function is exactly equivalent to `numpy.transpose`.

See also:

```
numpy.transpose
```

Equivalent function in top-level NumPy module.

**Examples**

```python
>>> import numpy.ma as ma
>>> x = ma.arange(4).reshape((2,2))
>>> x[1, 1] = ma.masked
>>> x
masked_array(data =
[[ 0 1]
[ 2 --]],
mask =
[[False False]
[False  True]],
fill_value = 999999)
```

```python
>>> ma.transpose(x)
masked_array(data =
[[ 0 2]
[ 1 --]],
mask =
[[False False]
[False  True]],
fill_value = 999999)
```
MaskedArray\texttt{.swapaxes}(axis1, axis2)

Return a view of the array with \textit{axis1} and \textit{axis2} interchanged.

Refer to \texttt{numpy.swapaxes} for full documentation.

See also:

\texttt{numpy.swapaxes}

\texttt{equivalent function}

MaskedArray\texttt{.transpose(*axes)}

Returns a view of the array with axes transposed.

For a 1-D array, this has no effect. (To change between column and row vectors, first cast the 1-D array into a matrix object.) For a 2-D array, this is the usual matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided and \texttt{a.shape = (i[0], i[1], \ldots, i[n-2], i[n-1])}, then \texttt{a.transpose().shape = (i[n-1], i[n-2], \ldots, i[1], i[0])}.

Parameters

\texttt{axes}: None, tuple of ints, or \texttt{n} ints

• None or no argument: reverses the order of the axes.
• tuple of ints: \textit{i} in the \textit{j}-th place in the tuple means \textit{a}'s \textit{i}-th axis becomes \textit{a.transpose()}’s \textit{j}-th axis.
• \texttt{n} ints: same as an \texttt{n}-tuple of the same ints (this form is intended simply as a “convenience” alternative to the tuple form)

Returns

\texttt{out}: ndarray

View of \textit{a}, with axes suitably permuted.

See also:

\texttt{ndarray.T}

Array property returning the array transposed.

Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])
```

Changing the number of dimensions

\texttt{ma.atleast_1d(*arys)}

Convert inputs to arrays with at least one dimension.

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<td><code>ma.atleast_2d(*arys)</code></td>
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<td><code>ma.expand_dims(x, axis)</code></td>
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<td><code>ma.column_stack(tup)</code></td>
<td>Stack 1-D arrays as columns into a 2-D array.</td>
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<td><code>ma.concatenate(arrays[, axis])</code></td>
<td>Concatenate a sequence of arrays along the given axis.</td>
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<td><code>ma.dstack(tup)</code></td>
<td>Stack arrays in sequence depth wise (along third axis).</td>
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<td>Stack arrays in sequence horizontally (column wise).</td>
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<td><code>ma.hsplit(ary, indices_or_sections)</code></td>
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<td><code>ma.Translate_slice_objects_to_concatenation_along_first_axis</code></td>
<td>Translate slice objects to concatenation along the first axis.</td>
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<td><code>ma.row_stack(tup)</code></td>
<td>Stack arrays in sequence vertically (row wise).</td>
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<td><code>ma.vstack(tup)</code></td>
<td>Stack arrays in sequence vertically (row wise).</td>
</tr>
</tbody>
</table>

```
numpy.ma.atleast_1d(*arys) = <numpy.ma.extras._fromnxfunction instance at 0x424452ac>
```

Convert inputs to arrays with at least one dimension. Scalar inputs are converted to 1-dimensional arrays, whilst higher-dimensional inputs are preserved.

**Parameters**

- `arys1, arys2, ... : array_like`
  
  One or more input arrays.

**Returns**

- `ret : ndarray`
  
  An array, or sequence of arrays, each with `a.ndim >= 1`. Copies are made only if necessary.

**Notes**

The function is applied to both the `_data` and the `_mask`, if any.

**Examples**

```python
>>> np.atleast_1d(1.0)
array([1.])

>>> x = np.arange(9.0).reshape(3,3)
>>> np.atleast_1d(x)
array([[ 0.,  1.,  2.],
      [ 3.,  4.,  5.],
      [ 6.,  7.,  8.]])

>>> np.atleast_1d(x) is x
True

>>> np.atleast_1d(1, [3, 4])
[array([1]), array([3, 4])]  
```

```
numpy.ma.atleast_2d(*arys) = <numpy.ma.extras._fromnxfunction instance at 0x4244536c>
```

View inputs as arrays with at least two dimensions.
Parameters

arys1, arys2, ... : array_like

One or more array-like sequences. Non-array inputs are converted to arrays. Arrays that already have two or more dimensions are preserved.

Returns

res, res2, ... : ndarray

An array, or tuple of arrays, each with a.ndim >= 2. Copies are avoided where possible, and views with two or more dimensions are returned.

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```python
>>> np.atleast_2d(3.0)
array([[3.]])

>>> x = np.arange(3.0)
>>> np.atleast_2d(x)
array([[0., 1., 2.]])

>>> np.atleast_2d(x).base is x
True

>>> np.atleast_2d(1, [1, 2], [[1, 2]])
[array([[1]]), array(([[1, 2]]), array(([[1, 2]]))]
```

```
numpy.ma.atleast_3d(*arys) = <numpy.ma.extras._fromnxfunction instance at 0x424453ac>
```

View inputs as arrays with at least three dimensions.

Parameters

arys1, arys2, ... : array_like

One or more array-like sequences. Non-array inputs are converted to arrays. Arrays that already have three or more dimensions are preserved.

Returns

res1, res2, ... : ndarray

An array, or tuple of arrays, each with a.ndim >= 3. Copies are avoided where possible, and views with three or more dimensions are returned. For example, a 1-D array of shape (N,) becomes a view of shape (1, N, 1), and a 2-D array of shape (M, N) becomes a view of shape (M, N, 1).

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```python
>>> np.atleast_3d(3.0)
array([[3.]])

>>> x = np.arange(3.0)
>>> np.atleast_3d(x).shape
(1, 3, 1)
```
>>> x = np.arange(12.0).reshape(4,3)
>>> np.atleast_3d(x).shape
(4, 3, 1)
>>> np.atleast_3d(x).base is x
True

>>> for arr in np.atleast_3d([1, 2], [[1, 2]], [[[1, 2]]]):
...   print(arr, arr.shape)
...
[[[1]
 [2]]] (1, 2, 1)
[[[1]
 [2]]] (1, 2, 1)
[[[1 2]]] (1, 1, 2)

numpy.ma.expand_dims(x, axis)
Expand the shape of an array.
Expands the shape of the array by including a new axis before the one specified by the axis parameter. This function behaves the same as numpy.expand_dims but preserves masked elements.

See also:

numpy.expand_dims
Equivalent function in top-level NumPy module.

Examples

>>> import numpy.ma as ma
>>> x = ma.array([1, 2, 4])
>>> x[1] = ma.masked
>>> x
masked_array(data = [1 -- 4],
             mask = [False True False],
             fill_value = 999999)
>>> np.expand_dims(x, axis=0)
array([[1, 2, 4]])
>>> ma.expand_dims(x, axis=0)
masked_array(data =
             mask =
             fill_value = 999999)

The same result can be achieved using slicing syntax with np.newaxis.

>>> x[np.newaxis, :]
masked_array(data =
             mask =
             fill_value = 999999)

numpy.ma.squeeze(a, axis=None)
Remove single-dimensional entries from the shape of an array.

Parameters

a : array_like
Input data.
**axis** : None or int or tuple of ints, optional

New in version 1.7.0.

Selects a subset of the single-dimensional entries in the shape. If an axis is selected with shape entry greater than one, an error is raised.

**Returns**

*squeezed* : ndarray

The input array, but with all or a subset of the dimensions of length 1 removed. This is always *a* itself or a view into *a*.

**Examples**

```python
g = np.array([[0], [1], [2]])
g.shape
(1, 3, 1)
g.squeeze().shape
(3,)
g.squeeze(axis=2).shape
(1, 3)
```

**MaskedArray**. **squeeze** *(axis=None)*

Remove single-dimensional entries from the shape of *a*.

Refer to **numpy.squeeze** for full documentation.

**See also:**

**numpy.squeeze**

equivalent function

**numpy.ma.column_stack** *(tup)* = <numpy.ma.extras._fromnxfunction instance at 0x4244548c>

Stack 1-D arrays as columns into a 2-D array.

Take a sequence of 1-D arrays and stack them as columns to make a single 2-D array. 2-D arrays are stacked as-is, just like with **hstack**. 1-D arrays are turned into 2-D columns first.

**Parameters**

*tup* : sequence of 1-D or 2-D arrays.

Arrays to stack. All of them must have the same first dimension.

**Returns**

*stacked* : 2-D array

The array formed by stacking the given arrays.

**Notes**

The function is applied to both the _data and the _mask, if any.

**Examples**

```python
g = np.array([1, 2, 3])
h = np.array([2, 3, 4])
array([[1, 2]],

```

```python
g = np.array([1, 2, 3])
h = np.array([2, 3, 4])
array([[1, 2]],
```
numpy.ma.concatenate(arrays, axis=0)

Concatenate a sequence of arrays along the given axis.

**Parameters**

- **arrays**: sequence of array_like
  The arrays must have the same shape, except in the dimension corresponding to `axis` (the first, by default).

- **axis**: int, optional
  The axis along which the arrays will be joined. Default is 0.

**Returns**

- **result**: MaskedArray
  The concatenated array with any masked entries preserved.

**See also:**

numpy.concatenate

Equivalent function in the top-level NumPy module.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = ma.arange(3)
>>> a[1] = ma.masked
>>> b = ma.arange(2, 5)
>>> a
masked_array(data = [0 -- 2],
             mask = [False True False],
             fill_value = 999999)
>>> b
masked_array(data = [2 3 4],
             mask = False,
             fill_value = 999999)
>>> ma.concatenate([a, b])
masked_array(data = [0 -- 2 2 3 4],
             mask = [False True False False False False],
             fill_value = 999999)
```

numpy.ma.dstack(tup) = <numpy.ma.extras_fromnxfuction instance at 0x424454ac>

Stack arrays in sequence depth wise (along third axis).

Takes a sequence of arrays and stack them along the third axis to make a single array. Rebuilds arrays divided by `dsplit`. This is a simple way to stack 2D arrays (images) into a single 3D array for processing.

**Parameters**

- **tup**: sequence of arrays
  Arrays to stack. All of them must have the same shape along all but the third axis.

**Returns**

- **stacked**: ndarray

1.7. Masked arrays
The array formed by stacking the given arrays.

See also:

**vstack**

Stack along first axis.

**hstack**

Stack along second axis.

**concatenate**

Join arrays.

**dstack**

Split array along third axis.

**Notes**

The function is applied to both the _data and the _mask, if any.

**Examples**

```python
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.dstack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])

>>> a = np.array([[1],[2],[3]])
>>> b = np.array([[2],[3],[4]])
>>> np.dstack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])
```

```
numpy.ma.hstack(tup) = <numpy.ma.extras._fromnxfunction instance at 0x4244544c>
```

Stack arrays in sequence horizontally (column wise).

Take a sequence of arrays and stack them horizontally to make a single array. Rebuild arrays divided by **hsplit**.

**Parameters**

- **tup**: sequence of ndarrays

  All arrays must have the same shape along all but the second axis.

**Returns**

- **stacked**: ndarray

  The array formed by stacking the given arrays.

See also:

**vstack**

Stack arrays in sequence vertically (row wise).

**dstack**

Stack arrays in sequence depth wise (along third axis).
**concatenate**

Join a sequence of arrays together.

**hstack**

Split array along second axis.

**Notes**

The function is applied to both the _data and the _mask, if any.

**Examples**

```python
generate_examples()```

```python
generate_examples()```

```
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.hstack((a,b))
array([1, 2, 3, 2, 3, 4])

>>> a = np.array([[1],[2],[3]])
>>> b = np.array([[2],[3],[4]])
>>> np.hstack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])
```

```
numpy.ma.hsplit(ary, indices_or_sections) = <numpy.ma.extras._fromnxfunction instance at 0x4244550c>

Split an array into multiple sub-arrays horizontally (column-wise).

Please refer to the `split` documentation. `hsplit` is equivalent to `split` with `axis=1`, the array is always split along the second axis regardless of the array dimension.

See also:

**split**

Split an array into multiple sub-arrays of equal size.

**Notes**

The function is applied to both the _data and the _mask, if any.

**Examples**

```python
generate_examples()```

```
>>> x = np.arange(16.0).reshape(4, 4)
array([[ 0.,  1.,  2.,  3.],
       [ 4.,  5.,  6.,  7.],
       [ 8.,  9., 10., 11.],
       [12., 13., 14., 15.]])

>>> np.hsplit(x, 2)
[array([[ 0.,  1.],
        [ 4.,  5.],
        [ 8.,  9.],
        [12., 13.]]),
 array([[ 2.,  3.],
        [ 6.,  7.],
        [10., 11.],
        [14., 15.]])]

>>> np.hsplit(x, np.array([3, 6]))
[array([[ 0.,  1.,  2.],
        [ 4.,  5.,  6.],
        [ 8.,  9., 10.],
        [12., 13., 14.],
        [16., 17., 18.],
        [20., 21., 22.],
        [24., 25., 26.],
        [28., 29., 30.]], dtype=object)]
```

1.7. Masked arrays
With a higher dimensional array the split is still along the second axis.

```python
>>> x = np.arange(8.0).reshape(2, 2, 2)
>>> x
array([[[ 0.,  1.],
        [ 2.,  3.]],
       [[ 4.,  5.],
        [ 6.,  7.]]])
```

```python
>>> np.hsplit(x, 2)
[array([[[ 0.,  1.]],
        [[ 4.,  5.]]]),
   array([[[ 2.,  3.]],
        [[ 6.,  7.]]])]
```

```
numpy.ma.mr_ = <numpy.ma.extras.mr_class object at 0x4244568c>
Translate slice objects to concatenation along the first axis.

This is the masked array version of `lib.index_tricks.RClass`.

See also:
`lib.index_tricks.RClass`

Examples

```python
>>> np.ma.mr_[np.ma.array([1,2,3]), 0, 0, np.ma.array([4,5,6])]
array([1, 2, 3, 0, 0, 4, 5, 6])
```

```
numpy.ma.row_stack (tup) = <numpy.ma.extras._fromnxfunction instance at 0x424453ec>
```

Stack arrays in sequence vertically (row wise).

Take a sequence of arrays and stack them vertically to make a single array. Rebuild arrays divided by `vsplit`.

Parameters

tup : sequence of ndarrays
   Tuple containing arrays to be stacked. The arrays must have the same shape along all but the first axis.

Returns

stacked : ndarray
   The array formed by stacking the given arrays.

See also:
`hstack`

Stack arrays in sequence horizontally (column wise).
**dstack**  
Stack arrays in sequence depth wise (along third dimension).

**concatenate**  
Join a sequence of arrays together.

**vsplit**  
Split array into a list of multiple sub-arrays vertically.

**Notes**  
The function is applied to both the _data and the _mask, if any.

**Examples**
```
>>> a = np.array([1, 2, 3])
>>> b = np.array([2, 3, 4])
>>> np.vstack((a,b))
array([[1, 2, 3],
       [2, 3, 4]])
```
```
>>> a = np.array([[1], [2], [3]])
>>> b = np.array([[2], [3], [4]])
>>> np.vstack((a,b))
array([[1],
       [2],
       [3],
       [2],
       [3],
       [4]])
```

```
numpy.ma.vstack (tup) = <numpy.ma.extras._fromnxfunction instance at 0x424453ec>
```

Stack arrays in sequence vertically (row wise).
Take a sequence of arrays and stack them vertically to make a single array. Rebuild arrays divided by vsplit.

**Parameters**
- **tup** : sequence of ndarrays
  Tuple containing arrays to be stacked. The arrays must have the same shape along all but the first axis.

**Returns**
- **stacked** : ndarray
  The array formed by stacking the given arrays.

**See also:**

**hstack**  
Stack arrays in sequence horizontally (column wise).

**dstack**  
Stack arrays in sequence depth wise (along third dimension).

**concatenate**  
Join a sequence of arrays together.
vspli

Split array into a list of multiple sub-arrays vertically.

Notes

The function is applied to both the data and the mask, if any.

Examples

```python
g = np.array([1, 2, 3])
>>> b = np.array([2, 3, 4])
>>> np.vstack((g, b))
array([[1, 2, 3],
       [2, 3, 4]])

>>> a = np.array([[1], [2], [3]])
>>> b = np.array([[2], [3], [4]])
>>> np.vstack((a, b))
array([[1],
       [2],
       [3],
       [2],
       [3],
       [4]])
```

Joining arrays

- **ma.column_stack(tup)**: Stack 1-D arrays as columns into a 2-D array.
- **ma.concatenate(arrays[, axis])**: Concatenate a sequence of arrays along the given axis.
- **ma.append(a, b[, axis])**: Append values to the end of an array.
- **ma.dstack(tup)**: Stack arrays in sequence depth wise (along third axis).
- **ma.hstack(tup)**: Stack arrays in sequence horizontally (column wise).
- **ma.vstack(tup)**: Stack arrays in sequence vertically (row wise).

numpy.ma.column_stack(tup) = <numpy.ma.extras._fromnxfunction instance at 0x4244548c>

Stack 1-D arrays as columns into a 2-D array.

Take a sequence of 1-D arrays and stack them as columns to make a single 2-D array. 2-D arrays are stacked as-is, just like with hstack. 1-D arrays are turned into 2-D columns first.

Parameters

tup : sequence of 1-D or 2-D arrays.

Arrays to stack. All of them must have the same first dimension.

Returns

stacked : 2-D array

The array formed by stacking the given arrays.

Notes

The function is applied to both the data and the mask, if any.
Examples

```python
>>> a = np.array((1, 2, 3))
>>> b = np.array((2, 3, 4))
>>> np.column_stack((a, b))
array([[1, 2],
       [2, 3],
       [3, 4]])
```

```
numpy.ma.concatenate(arrays, axis=0)

Concatenate a sequence of arrays along the given axis.

Parameters
arrays : sequence of array_like
  The arrays must have the same shape, except in the dimension corresponding to axis (the first, by default).
axis : int, optional
  The axis along which the arrays will be joined. Default is 0.

Returns
result : MaskedArray
  The concatenated array with any masked entries preserved.

See also:

numpy.concatenate
  Equivalent function in the top-level NumPy module.
```

Examples

```python
>>> import numpy.ma as ma
>>> a = ma.arange(3)
>>> a[1] = ma.masked
>>> b = ma.arange(2, 5)
>>> a
masked_array(data = [0 -- 2],
             mask = [False True False],
             fill_value = 999999)
>>> b
masked_array(data = [2 3 4],
             mask = False,
             fill_value = 999999)
>>> ma.concatenate([a, b])
masked_array(data = [0 -- 2 3 4],
             mask = [False True False False False False],
             fill_value = 999999)
```

```
numpy.ma.append(a, b, axis=None)

Append values to the end of an array.

New in version 1.9.0.

Parameters
arr : array_like
  Values are appended to a copy of this array.
values : array_like
```

1.7. Masked arrays
These values are appended to a copy of \( arr \). It must be of the correct shape (the same shape as \( arr \), excluding \( axis \)). If \( axis \) is not specified, \( values \) can be any shape and will be flattened before use.

\[
\text{axis : int, optional}
\]

The axis along which \( values \) are appended. If \( axis \) is not given, both \( arr \) and \( values \) are flattened before use.

**Returns**

\[
\text{append : MaskedArray}
\]

A copy of \( arr \) with \( values \) appended to \( axis \). Note that \( append \) does not occur in-place: a new array is allocated and filled. If \( axis \) is None, the result is a flattened array.

**Examples**

\[
>>> \text{import numpy.ma as ma}
>>> a = ma.masked_values([1, 2, 3], 2)
>>> b = ma.masked_values([4, 5, 6], [7, 8, 9], 7)
>>> print(ma.append(a, b))
[1 -- 3 4 5 6 -- 8 9]
\]

**numpy.ma.dstack**

Stack arrays in sequence depth wise (along third axis).

Takes a sequence of arrays and stack them along the third axis to make a single array. Rebuilds arrays divided by \( dsplit \). This is a simple way to stack 2D arrays (images) into a single 3D array for processing.

**Parameters**

\[
\text{tup : sequence of arrays}
\]

Arrays to stack. All of them must have the same shape along all but the third axis.

**Returns**

\[
\text{stacked : ndarray}
\]

The array formed by stacking the given arrays.

**See also:**

- **vstack**
  - Stack along first axis.

- **hstack**
  - Stack along second axis.

- **concatenate**
  - Join arrays.

- **dsplit**
  - Split array along third axis.
Notes

The function is applied to both the _data and the _mask, if any.

Examples

```python
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.dstack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])

>>> a = np.array([[1],[2],[3]])
>>> b = np.array([[2],[3],[4]])
>>> np.dstack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])
```

```
numpy.ma.hstack(tup) = <numpy.ma.extras._fromnxfunction instance at 0x4244544c>
```

Stack arrays in sequence horizontally (column wise).

Take a sequence of arrays and stack them horizontally to make a single array. Rebuild arrays divided by `hsplit`.

Parameters

- `tup`: sequence of ndarrays
  
  All arrays must have the same shape along all but the second axis.

Returns

- `stacked`: ndarray
  
  The array formed by stacking the given arrays.

See also:

- `vstack` Stack arrays in sequence vertically (row wise).
- `dstack` Stack arrays in sequence depth wise (along third axis).
- `concatenate` Join a sequence of arrays together.
- `hsplit` Split array along second axis.

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```python
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.hstack((a,b))
```
```python
array([1, 2, 3, 2, 3, 4])
>>> a = np.array([[1], [2], [3]])
>>> b = np.array([[2], [3], [4]])
>>> np.hstack((a, b))
array([[1, 2],  
       [2, 3],  
       [3, 4]])
```

```
numpy.ma.vstack(tup) = <numpy.ma.extras._fromnxfunction instance at 0x424453ec>
```

Stack arrays in sequence vertically (row wise).

Take a sequence of arrays and stack them vertically to make a single array. Rebuild arrays divided by `vsplit`.

**Parameters**

- `tup` : sequence of ndarrays
  
  Tuple containing arrays to be stacked. The arrays must have the same shape along all but the first axis.

**Returns**

- `stacked` : ndarray
  
  The array formed by stacking the given arrays.

**See also:**

- `hstack`
  Stack arrays in sequence horizontally (column wise).

- `dstack`
  Stack arrays in sequence depth wise (along third dimension).

- `concatenate`
  Join a sequence of arrays together.

- `vsplit`
  Split array into a list of multiple sub-arrays vertically.

**Notes**

The function is applied to both the `_data` and the `_mask`, if any.

**Examples**

```python
>>> a = np.array([1, 2, 3])
>>> b = np.array([2, 3, 4])
>>> np.vstack((a, b))
array([[1, 2, 3],  
       [2, 3, 4]])
```

```python
>>> a = np.array([[1], [2], [3]])
>>> b = np.array([[2], [3], [4]])
>>> np.vstack((a, b))
array([[1],  
       [2],  
       [3],  
       [2],
```
Operations on masks

Creating a mask

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```
numpy.ma.make_mask (m, copy=False, shrink=True, dtype=<type 'numpy.bool_'>)
```

Create a boolean mask from an array.

Return m as a boolean mask, creating a copy if necessary or requested. The function can accept any sequence that is convertible to integers, or nomask. Does not require that contents must be 0s and 1s, values of 0 are interpreted as False, everything else as True.

**Parameters**

- m : array_like
  Potential mask.
- copy : bool, optional
  Whether to return a copy of m (True) or m itself (False).
- shrink : bool, optional
  Whether to shrink m to nomask if all its values are False.
- dtype : dtype, optional
  Data-type of the output mask. By default, the output mask has a dtype of MaskType (bool). If the dtype is flexible, each field has a boolean dtype.

**Returns**

- result : ndarray
  A boolean mask derived from m.

**Examples**

```
>>> import numpy.ma as ma
>>> m = [True, False, True, True]
>>> ma.make_mask(m)
array([ True, False, True, True], dtype=bool)
>>> m = [1, 0, 1, 1]
>>> ma.make_mask(m)
array([ True, False, True, True], dtype=bool)
>>> m = [1, 0, 2, -3]
>>> ma.make_mask(m)
array([ True, False, True, True], dtype=bool)
```

Effect of the shrink parameter.
>>> m = np.zeros(4)
>>> m
array([0., 0., 0., 0.])
>>> ma.make_mask(m)
False
>>> ma.make_mask(m, shrink=False)
array([False, False, False, False], dtype=bool)

Using a flexible **dtype**.

```python
>>> m = [1, 0, 1, 1]
>>> n = [0, 1, 0, 0]
>>> arr = []
>>> for man, mouse in zip(m, n):
...     arr.append((man, mouse))
...     arr
[(1, 0), (0, 1), (1, 0), (1, 0)]
```

```python
dtype = np.dtype({'names': ['man', 'mouse'],
                 'formats': [np.int, np.int]})
```

```python
arr = np.array(arr, dtype=dtype)
```

```python
arr
array([(1, 0), (0, 1), (1, 0), (1, 0)],
      dtype=[('man', '<i4'), ('mouse', '<i4')])
```

```python
ma.make_mask(arr, dtype=dtype)
```

```python
array([(True, False), (False, True), (True, False), (True, False)],
      dtype=[('man', '|b1'), ('mouse', '|b1')])
```

numpy.ma.make_mask_none(newshape, dtype=None)

Return a boolean mask of the given shape, filled with False.

This function returns a boolean ndarray with all entries False, that can be used in common mask manipulations. If a complex dtype is specified, the type of each field is converted to a boolean type.

**Parameters**

- **newshape** : tuple
  A tuple indicating the shape of the mask.

- **dtype** : {None, dtype}, optional
  If None, use a MaskType instance. Otherwise, use a new datatype with the same fields as dtype, converted to boolean types.

**Returns**

- **result** : ndarray
  An ndarray of appropriate shape and dtype, filled with False.

**See also:**

- **make_mask**
  Create a boolean mask from an array.

- **make_mask_descr**
  Construct a dtype description list from a given dtype.

**Examples**

```python
>>> import numpy.ma as ma
>>> ma.make_mask_none((3,))
array([False, False, False], dtype=bool)
```
Defining a more complex dtype.

>>> dtype = np.dtype({'names': ['foo', 'bar'],
                    'formats': [np.float32, np.int]})
>>> dtype
dtype([('foo', '<f4'), ('bar', '<i4')])
>>> ma.make_mask_none((3,), dtype=dtype)
array([(False, False), (False, False), (False, False)],
      dtype=[('foo', '|b1'), ('bar', '|b1')])

numpy.ma.mask_or (m1, m2, copy=False, shrink=True)
Combine two masks with the logical_or operator.

The result may be a view on m1 or m2 if the other is nomask (i.e. False).

Parameters
  m1, m2 : array_like
    Input masks.
  copy : bool, optional
    If copy is False and one of the inputs is nomask, return a view of the other input mask.
    Defaults to False.
  shrink : bool, optional
    Whether to shrink the output to nomask if all its values are False. Defaults to True.

Returns
  mask : output mask
    The result masks values that are masked in either m1 or m2.

Raises
  ValueError
    If m1 and m2 have different flexible dtypes.

Examples

>>> m1 = np.ma.make_mask([0, 1, 1, 0])
>>> m2 = np.ma.make_mask([1, 0, 0, 0])
>>> np.ma.mask_or(m1, m2)
array([ True,  True,  True, False], dtype=bool)

numpy.ma.make_mask_descr (ndtype)
Construct a dtype description list from a given dtype.

Returns a new dtype object, with the type of all fields in ndtype to a boolean type. Field names are not altered.

Parameters
  ndtype : dtype
    The dtype to convert.

Returns
  result : dtype
    A dtype that looks like ndtype, the type of all fields is boolean.
Examples

```python
>>> import numpy.ma as ma
>>> dtype = np.dtype({'names': ['foo', 'bar'],
                   'formats': [np.float32, np.int]})
>>> dtype
dtype([('foo', '<f4'), ('bar', '<i4')])
>>> ma.make_mask_descr(dtype)
dtype([('foo', '|b1'), ('bar', '|b1')])
>>> ma.make_mask_descr(np.float32)
<type 'numpy.bool_'>
```

Accessing a mask

To access the mask of a masked array, you can use:

- **`ma.getmask(a)`**
  - Return the mask of a masked array, or nomask.

- **`ma.getmaskarray(arr)`**
  - Return the mask of a masked array, or full boolean array of False.

- **`ma.masked_array.mask`**
  - Mask

```
numpy.ma.getmask(a)
```

Return the mask of a masked array, or nomask.

Return the mask of `a` as an ndarray if `a` is a `MaskedArray` and the mask is not `nomask`, else return `nomask`.

To guarantee a full array of booleans of the same shape as `a`, use `getmaskarray`.

Parameters

- **`a`**: array_like
  - Input `MaskedArray` for which the mask is required.

See also:

- **`getdata`**
  - Return the data of a masked array as an ndarray.

- **`getmaskarray`**
  - Return the mask of a masked array, or full array of False.

Examples

```python
>>> import numpy.ma as ma
>>> a = ma.masked_equal([[1,2],[3,4]], 2)
>>> a
masked_array(data =
[[1 --]
[3 4]],
mask =
[[False  True]
[False False]],
fill_value=999999)
```

Equivalently use the `MaskedArray mask` attribute.

```python
>>> a.mask
array([[False,  True],
       [False, False]], dtype=bool)
```
Result when mask == \texttt{nomask}

```python
g = ma.masked_array([[1, 2], [3, 4]])
g
masked_array(data =

[[ 1 2]

[3 4]],

mask =

False,

fill_value=999999)
g
ma.nomask
False
g
ma.getmask(b) == ma.nomask
True
g
b.mask == ma.nomask
True
```

\texttt{numpy.ma.getmaskarray}(arr)

Return the mask of a masked array, or full boolean array of False.

Return the mask of \textit{arr} as an ndarray if \textit{arr} is a \texttt{MaskedArray} and the mask is not \texttt{nomask}, else return a full boolean array of False of the same shape as \textit{arr}.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{arr} : array_like
    Input \texttt{MaskedArray} for which the mask is required.
\end{itemize}

\textbf{See also:}

getmask

Return the mask of a masked array, or nomask.

getdata

Return the data of a masked array as an ndarray.

\textbf{Examples}

```python
>>> import numpy.ma as ma

>>> a = ma.masked_equal([[1, 2], [3, 4]], 2)

>>> a
masked_array(data =

[[ 1 --]

[3 4]],

mask =

[[False True]

[False False]],

fill_value=999999)

>>> ma.getmaskarray(a)
array([False, True],

[False, False], dtype=bool)
```

Result when mask == \texttt{nomask}

```python
>>> b = ma.masked_array([[1, 2], [3, 4]])

>>> b
masked_array(data =

[[ 1 2]

[3 4]],

mask =
```

1.7. Masked arrays
False,
    fill_value=999999)
>>> >ma.getmaskarray(b)
array([[False, False],
    [False, False]], dtype=bool)

masked_array.mask
Mask

Finding masked data

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**numpy.ma.flatnotmasked_contiguous(a)**

Find contiguous unmasked data in a masked array along the given axis.

**Parameters**

- `a`: array
  
  The input array.

**Returns**

- `slice_list`: list
  
  A sorted sequence of slices (start index, end index).

**See also:**

`flatnotmasked_edges`, `notmasked_contiguous`, `notmasked_edges`, clump_masked, clump_unmasked

**Notes**

Only accepts 2-D arrays at most.

**Examples**

```python
>>> a = np.ma.arange(10)
>>> np.ma.extras.flatnotmasked_contiguous(a)
slice(0, 10, None)

>>> mask = (a < 3) | (a > 8) | (a == 5)
>>> a[mask] = np.ma.masked
>>> np.array(a[~a.mask])
array([3, 4, 6, 7, 8])

>>> np.ma.extras.flatnotmasked_contiguous(a)
[slice(3, 5, None), slice(6, 9, None)]
>>> a[:] = np.ma.masked
>>> print np.ma.extras.flatnotmasked_edges(a)
None
```

**numpy.ma.flatnotmasked_edges(a)**

Find the indices of the first and last unmasked values.

Expect a 1-D `MaskedArray`, returns None if all values are masked.
Parameters

arr : array_like
Input 1-D MaskedArray

Returns

edges : ndarray or None
The indices of first and last non-masked value in the array. Returns None if all values
are masked.

See also:

flatnotmasked_contiguous, notmasked_contiguous, notmasked_edges, clump_masked,
clump_unmasked

Notes

Only accepts 1-D arrays.

Examples

```python
>>> a = np.ma.arange(10)
>>> flatnotmasked_edges(a)
[0, -1]

>>> mask = (a < 3) | (a > 8) | (a == 5)
>>> a[mask] = np.ma.masked
>>> np.array(a[~a.mask])
array([3, 4, 6, 7, 8])

>>> flatnotmasked_edges(a)
array([3, 8])
```

numpy.ma.notmasked_contiguous (a, axis=None)
Find contiguous unmasked data in a masked array along the given axis.

Parameters

a : array_like
The input array.

axis : int, optional
Axis along which to perform the operation. If None (default), applies to a flattened
version of the array.

Returns

endpoints : list
A list of slices (start and end indexes) of unmasked indexes in the array.

See also:
flatnotmasked_edges, flatnotmasked_contiguous, notmasked_edges, clump_masked,
clump_unmasked

Notes

Only accepts 2-D arrays at most.
Examples

```python
>>> a = np.arange(9).reshape((3, 3))
>>> mask = np.zeros_like(a)
>>> mask[1:, 1:] = 1

>>> ma = np.ma.array(a, mask=mask)
>>> np.array(ma[~ma.mask])
array([0, 1, 2, 3, 6])

>>> np.ma.extras.notmasked_contiguous(ma)
[slice(0, 4, None), slice(6, 7, None)]
```

**numpy.ma.notmasked_edges (a, axis=None)**

Find the indices of the first and last unmasked values along an axis.

If all values are masked, return None. Otherwise, return a list of two tuples, corresponding to the indices of the first and last unmasked values respectively.

**Parameters**

- `a`: array_like
  The input array.
- `axis`: int, optional
  Axis along which to perform the operation. If None (default), applies to a flattened version of the array.

**Returns**

- `edges`: ndarray or list
  An array of start and end indexes if there are any masked data in the array. If there are no masked data in the array, `edges` is a list of the first and last index.

**See also:**

- `flatnotmasked_contiguous`, `flatnotmasked_edges`, `notmasked_contiguous`, `clump_masked`, `clump_unmasked`

## Modifying a mask

- `ma.mask_cols(a[, axis])`: Mask columns of a 2D array that contain masked values.
- `ma.mask_or(m1, m2[, copy, shrink])`: Combine two masks with the logical_or operator.
- `ma.mask_rowcols(a[, axis])`: Mask rows and/or columns of a 2D array that contain masked values.
- `ma.mask_rows(a[, axis])`: Mask rows of a 2D array that contain masked values.
- `ma.harden_mask(self)`: Force the mask to hard.
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**numpy.ma.mask_cols(a, axis=None)**

Mask columns of a 2D array that contain masked values.

This function is a shortcut to `mask_rowcols` with `axis` equal to 1.

**See also:**

- `mask_rowcols`
  Mask rows and/or columns of a 2D array.

- `masked_where`
  Mask where a condition is met.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = np.zeros((3, 3), dtype=np.int)
>>> a[1, 1] = 1
>>> a
array([[0, 0, 0],
       [0, 1, 0],
       [0, 0, 0]])
>>> a = ma.masked_equal(a, 1)
>>> a
masked_array(data =
 [[0 0 0],
  [0 -- 0],
  [0 0 0]],
mask =
[[False False False],
 [False True False],
 [False False False]],
fill_value=999999)
>>> ma.mask_cols(a)
masked_array(data =
 [[-- -- 0],
  [-- -- 0],
  [-- -- 0]],
mask =
[[False True False],
 [False True False],
 [False True False]],
fill_value=999999)
```

**numpy.ma.mask_or(m1, m2, copy=False, shrink=True)**

Combine two masks with the `logical_or` operator.

The result may be a view on `m1` or `m2` if the other is `nomask` (i.e. False).

**Parameters**

- `m1, m2` : array_like
Input masks.

**copy**: bool, optional

If copy is False and one of the inputs is `nomask`, return a view of the other input mask. Defaults to False.

**shrink**: bool, optional

Whether to shrink the output to `nomask` if all its values are False. Defaults to True.

**Returns**

**mask**: output mask

The result masks values that are masked in either $m1$ or $m2$.

**Raises**

**ValueError**

If $m1$ and $m2$ have different flexible dtypes.

**Examples**

```python
>>> m1 = np.ma.make_mask([0, 1, 1, 0])
>>> m2 = np.ma.make_mask([1, 0, 0, 0])
>>> np.ma.mask_or(m1, m2)
array([ True,  True,  True,  False], dtype=bool)
```

`numpy.ma.mask_rowcols(a, axis=None)`

Mask rows and/or columns of a 2D array that contain masked values.

Mask whole rows and/or columns of a 2D array that contain masked values. The masking behavior is selected using the `axis` parameter.

- If `axis` is None, rows and columns are masked.
- If `axis` is 0, only rows are masked.
- If `axis` is 1 or -1, only columns are masked.

**Parameters**

- `a`: array_like, MaskedArray
  
The array to mask. If not a MaskedArray instance (or if no array elements are masked). The result is a MaskedArray with `mask` set to `nomask` (False). Must be a 2D array.

- `axis`: int, optional
  
Axis along which to perform the operation. If None, applies to a flattened version of the array.

**Returns**

- `a`: MaskedArray
  
A modified version of the input array, masked depending on the value of the `axis` parameter.

**Raises**

**NotImplementedError**

If input array $a$ is not 2D.

**See also:**
mask_rows
Mask rows of a 2D array that contain masked values.

mask_cols
Mask cols of a 2D array that contain masked values.

masked_where
Mask where a condition is met.

Notes
The input array's mask is modified by this function.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.zeros((3, 3), dtype=np.int)
>>> a[1, 1] = 1
>>> a
array([[0, 0, 0],
       [0, 1, 0],
       [0, 0, 0]])
>>> a = ma.masked_equal(a, 1)
>>> a
masked_array(data =
              [[0 0 0],
               [0 -- 0],
               [0 0 0]],
             mask =
              [[False False False],
               [False  True False],
               [False False False]],
            fill_value=999999)
>>> ma.mask_rowcols(a)
masked_array(data =
              [[0 -- 0],
               [--- -- --],
               [0 -- 0]],
             mask =
              [[False  True False],
               [ True  True True],
               [False  True False]],
            fill_value=999999)
```

numpy.ma.mask_rows(a, axis=None)
Mask rows of a 2D array that contain masked values.

This function is a shortcut to mask_rowcols with axis equal to 0.

See also:

mask_rowcols
Mask rows and/or columns of a 2D array.

masked_where
Mask where a condition is met.
Examples

```python
>>> import numpy.ma as ma
>>> a = np.zeros((3, 3), dtype=np.int)
>>> a[1, 1] = 1
>>> a
array([[0, 0, 0],
        [0, 1, 0],
        [0, 0, 0]])
>>> a = ma.masked_equal(a, 1)
>>> a
masked_array(data =
[[0 0 0]
[0 -- 0]
[0 0 0]],
mask =
[[False False False]
[False True False]
[False False False]],
fill_value=999999)
>>> ma.mask_rows(a)
masked_array(data =
[[0 0 0]
[-- -- --]
[0 0 0]],
mask =
[[False False False]
[ True True True]
[False False False]],
fill_value=999999)
```

`numpy.ma.harden_mask(self) = <numpy.ma.core._frommethod instance at 0x4243f4ac>`

Force the mask to hard.

Whether the mask of a masked array is hard or soft is determined by its `hardmask` property. `harden_mask` sets `hardmask` to True.

See also:

`hardmask`

`numpy.ma.soften_mask(self) = <numpy.ma.core._frommethod instance at 0x4243f76c>`

Force the mask to soft.

Whether the mask of a masked array is hard or soft is determined by its `hardmask` property. `soften_mask` sets `hardmask` to False.

See also:

`hardmask`

`MaskedArray.harden_mask()`

Force the mask to hard.

Whether the mask of a masked array is hard or soft is determined by its `hardmask` property. `harden_mask` sets `hardmask` to True.

See also:

`hardmask`

`MaskedArray.soften_mask()`

Force the mask to soft.
Whether the mask of a masked array is hard or soft is determined by its `hardmask` property. `soften_mask` sets `hardmask` to False.

**See also:**

`hardmask`

`MaskedArray.shrink_mask()`  
Reduce a mask to nomask when possible.

**Parameters**

None

**Returns**

None

**Examples**

```python
>>> x = np.ma.array([[1, 2], [3, 4]], mask=[0]*4)
>>> x.mask
array([[False, False],
       [False, False]], dtype=bool)
>>> x.shrink_mask()
>>> x.mask
False
```

`MaskedArray.unshare_mask()`  
Copy the mask and set the sharedmask flag to False.

Whether the mask is shared between masked arrays can be seen from the `sharedmask` property. `unshare_mask` ensures the mask is not shared. A copy of the mask is only made if it was shared.

**See also:**

`sharedmask`

---

**Conversion operations**

>` to a masked array

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<td><code>ma.masked_object(x[, value[, copy, shrink]])</code></td>
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<td>Mask an array where a condition is met.</td>
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**numpy.ma.asarray** *(a, dtype=None, order=None)*

Convert the input to a masked array of the given data-type.

No copy is performed if the input is already an *ndarray*. If *a* is a subclass of *MaskedArray*, a base class *MaskedArray* is returned.

**Parameters**

*a* : array_like

Input data, in any form that can be converted to a masked array. This includes lists, lists of tuples, tuples, tuples of tuples, tuples of lists, ndarrays and masked arrays.

dtype : dtype, optional

By default, the data-type is inferred from the input data.

*order* : {'C', 'F'}, optional

Whether to use row-major ('C') or column-major ('FORTRAN') memory representation. Default is 'C'.

**Returns**

*out* : MaskedArray

Masked array interpretation of *a*.

**See also:**

*asanyarray*

Similar to *asarray*, but conserves subclasses.

**Examples**

```python
>>> x = np.arange(10.).reshape(2, 5)
>>> x
array([[ 0.,  1.,  2.,  3.,  4.],
       [ 5.,  6.,  7.,  8.,  9.]])
>>> np.ma.asarray(x)
masked_array(data = [[ 0.  1.  2.  3.  4.]
                     [ 5.  6.  7.  8.  9.]],
             mask = False,
             fill_value = 1e+20)
>>> type(np.ma.asarray(x))
<class 'numpy.ma.core.MaskedArray'>
```

**numpy.ma.asanyarray** *(a, dtype=None)*

Convert the input to a masked array, conserving subclasses.

If *a* is a subclass of *MaskedArray*, its class is conserved. No copy is performed if the input is already an *ndarray*.

**Parameters**

*a* : array_like

Input data, in any form that can be converted to an array.

dtype : dtype, optional

By default, the data-type is inferred from the input data.

*order* : {'C', 'F'}, optional
Whether to use row-major (‘C’) or column-major (‘FORTRAN’) memory representation. Default is ‘C’.

Returns

out : MaskedArray

MaskedArray interpretation of a.

See also:

asarray

Similar to asanyarray, but does not conserve subclass.

Examples

```python
>>> x = np.arange(10.).reshape(2, 5)
>>> x
array([[ 0.,  1.,  2.,  3.,  4.],
       [ 5.,  6.,  7.,  8.,  9.]])
>>> np.ma.asanyarray(x)
masked_array(data = [[ 0.  1.  2.  3.  4.]
   [ 5.  6.  7.  8.  9.]],
   mask = False,
   fill_value = 1e+20)
>>> type(np.ma.asanyarray(x))
<class 'numpy.ma.core.MaskedArray'>
```

**numpy.ma.fix_invalid(a, mask=False, copy=True, fill_value=None)**

Return input with invalid data masked and replaced by a fill value.

Invalid data means values of `nan`, `inf`, etc.

Parameters

- **a**: array_like
  
  Input array, a (subclass of) ndarray.

- **copy**: bool, optional
  
  Whether to use a copy of `a` (True) or to fix `a` in place (False). Default is True.

- **fill_value**: scalar, optional
  
  Value used for fixing invalid data. Default is None, in which case the `a.fill_value` is used.

Returns

- **b**: MaskedArray
  
  The input array with invalid entries fixed.

Notes

A copy is performed by default.

Examples

```python
>>> x = np.ma.array([1., -1, np.nan, np.inf], mask=[1] + [0]*3)
>>> x
masked_array(data = [ -- -1.0 nan inf],
   mask = [ True False False False],
```

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```python
>>> np.ma.fix_invalid(x)
masked_array(data = [-- -1.0 -- --],
             mask = [ True False True True],
             fill_value = 1e+20)
```

```python
>>> fixed = np.ma.fix_invalid(x)
>>> fixed.data
array([ 1.00000000e+00, -1.00000000e+00, 1.00000000e+20,
       1.00000000e+20])
```

```python
x.data
array([ 1., -1., NaN, Inf])
```

numpy.ma.masked_equal(x, value, copy=True)
Mask an array where equal to a given value.

This function is a shortcut to masked_where, with condition = (x == value). For floating point arrays, consider using masked_values(x, value).

See also:

masked_where
Mask where a condition is met.

masked_values
Mask using floating point equality.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_equal(a, 2)
masked_array(data = [0 1 -- 3],
             mask = [False False True False],
             fill_value=999999)
```

numpy.ma.masked_greater(x, value, copy=True)
Mask an array where greater than a given value.

This function is a shortcut to masked_where, with condition = (x > value).

See also:

masked_where
Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_greater(a, 2)
masked_array(data = [0 1 2 --],
             mask = [ False False False True],
             fill_value=999999)
```
numpy.ma\texttt{.\texttt{masked_greater_equal}}(\textit{x}, \textit{value}, \textit{copy=False})

Mask an array where greater than or equal to a given value.

This function is a shortcut to \texttt{masked_where}, with \textit{condition} = \texttt{(x \geq\ value)}.

See also:

\texttt{masked_where}

Mask where a condition is met.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_greater_equal(a, 2)
masked_array(data = [0 1 -- --],
           mask = [False False True True],
          fill_value=999999)
```

numpy.ma\texttt{.\texttt{masked_inside}}(\textit{x}, \textit{v1}, \textit{v2}, \textit{copy=True})

Mask an array inside a given interval.

Shortcut to \texttt{masked_where}, where \textit{condition} is True for \textit{x} inside the interval \([v1,v2]\) \((v1 \leq x \leq v2)\). The boundaries \textit{v1} and \textit{v2} can be given in either order.

See also:

\texttt{masked_where}

Mask where a condition is met.

**Notes**

The array \textit{x} is prefilled with its filling value.

**Examples**

```python
>>> import numpy.ma as ma
>>> x = [0.31, 1.2, 0.01, 0.2, -0.4, -1.1]
>>> ma.masked_inside(x, -0.3, 0.3)
masked_array(data = [0.31 1.2 -- -- -0.4 -1.1],
            mask = [False False True True False False],
           fill_value=1e+20)
```

The order of \textit{v1} and \textit{v2} doesn’t matter.

```python
>>> ma.masked_inside(x, 0.3, -0.3)
masked_array(data = [0.31 1.2 -- -- -0.4 -1.1],
            mask = [False False True True False False],
           fill_value=1e+20)
```

numpy.ma\texttt{.\texttt{masked_invalid}}(\textit{a}, \textit{copy=True})

Mask an array where invalid values occur (NaNs or infs).

This function is a shortcut to \texttt{masked_where}, with \textit{condition} = \texttt{~(np.isfinite(a))}. Any pre-existing mask is conserved. Only applies to arrays with a dtype where NaNs or infs make sense (i.e. floating point types), but accepts any array-like object.

See also:
masked_where

Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(5, dtype=np.float)
>>> a[2] = np.NaN
>>> a[3] = np.PINF
>>> a
array([ 0., 1., NaN, Inf, 4.])
```
```python
>>> ma.masked_invalid(a)
masked_array(data = [0.0 1.0 -- -- 4.0],
              mask = [False False True True False],
              fill_value=1e+20)
```

numpy.ma.masked_less(x, value, copy=True)

Mask an array where less than a given value.

This function is a shortcut to masked_where, with condition = (x < value).

See also:

masked_where

Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
```
```python
>>> ma.masked_less(a, 2)
masked_array(data = [-- -- 2 3],
              mask = [ True True False False],
              fill_value=999999)
```

numpy.ma.masked_less_equal(x, value, copy=True)

Mask an array where less than or equal to a given value.

This function is a shortcut to masked_where, with condition = (x <= value).

See also:

masked_where

Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
```
```python
>>> ma.masked_less_equal(a, 2)
masked_array(data = [-- -- -- 3],
              mask = [ True True True False],
              fill_value=999999)
```

numpy.ma.masked_not_equal(x, value, copy=True)

Mask an array where not equal to a given value.
This function is a shortcut to masked_where, with condition = (x != value).

See also:

**masked_where**

Mask where a condition is met.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_not_equal(a, 2)
mixed_array(data = [ -- -- 2 --],
        mask = [ True True False True],
        fill_value=999999)
```

**numpy.ma.masked_object** (x, value, copy=True, shrink=True)

Mask the array x where the data are exactly equal to value.

This function is similar to masked_values, but only suitable for object arrays: for floating point, use masked_values instead.

**Parameters**

- x : array_like
  Array to mask
- value : object
  Comparison value
- copy : {True, False}, optional
  Whether to return a copy of x.
- shrink : {True, False}, optional
  Whether to collapse a mask full of False to nomask

**Returns**

- result : MaskedArray
  The result of masking x where equal to value.

See also:

**masked_where**

Mask where a condition is met.

**masked_equal**

Mask where equal to a given value (integers).

**masked_values**

Mask using floating point equality.

**Examples**

```python
>>> import numpy.ma as ma
>>> food = np.array([‘green_eggs’, ‘ham’], dtype=object)
>>> # don’t eat spoiled food
>>> eat = ma.masked_object(food, ‘green_eggs’)
```
```python
>>> print eat
|-- ham
>>> # plain ol' ham is boring
>>> fresh_food = np.array(['cheese', 'ham', 'pineapple'], dtype=object)
>>> eat = ma.masked_object(fresh_food, 'green_eggs')
>>> print eat
[cheese ham pineapple]
```

Note that *mask* is set to *nomask* if possible.

```python
>>> eat
masked_array(data = [cheese ham pineapple],
mask = False,
fill_value=?)
```

**numpy.ma.masked_outside**(x, v1, v2, copy=True)

Mask an array outside a given interval.

Shortcut to *masked_where*, where *condition* is True for *x* outside the interval \([v1, v2]\) \((x < v1)(x > v2)\). The boundaries \(v1\) and \(v2\) can be given in either order.

See also:

*masked_where*

Mask where a condition is met.

Notes

The array \(x\) is prefilled with its filling value.

Examples

```python
>>> import numpy.ma as ma
>>> x = [0.31, 1.2, 0.01, 0.2, -0.4, -1.1]
>>> ma.masked_outside(x, -0.3, 0.3)
masked_array(data = [-- -- 0.01 0.2 -- --],
mask = [ True True False False True True],
fill_value=1e+20)
```

The order of \(v1\) and \(v2\) doesn’t matter.

```python
>>> ma.masked_outside(x, 0.3, -0.3)
masked_array(data = [-- -- 0.01 0.2 -- --],
mask = [ True True False False True True],
fill_value=1e+20)
```

**numpy.ma.masked_values**(x, value, rtol=1e-05, atol=1e-08, copy=True, shrink=True)

Mask using floating point equality.

Return a MaskedArray, masked where the data in array \(x\) are approximately equal to \(value\), i.e. where the following condition is True

\[(\text{abs}(x - \text{value}) \leq \text{atol+rtol*abs(value)})\]

The fill_value is set to \(value\) and the mask is set to *nomask* if possible. For integers, consider using *masked_equal*.

Parameters

- \(x\) : array_like
  - Array to mask.
value : float
    Masking value.

rtol : float, optional
    Tolerance parameter.

atol : float, optional
    Tolerance parameter (1e-8).

copy : bool, optional
    Whether to return a copy of x.

shrink : bool, optional
    Whether to collapse a mask full of False to nomask.

Returns
result : MaskedArray
    The result of masking x where approximately equal to value.

See also:

masked_where
    Mask where a condition is met.

masked_equal
    Mask where equal to a given value (integers).

Examples
>>> import numpy.ma as ma
>>> x = np.array([1, 1.1, 2, 1.1, 3])
>>> ma.masked_values(x, 1.1)
masked_array(data = [1.0 -- 2.0 -- 3.0],
             mask = [False True False True False],
            fill_value=1.1)

Note that mask is set to nomask if possible.

>>> ma.masked_values(x, 1.5)
masked_array(data = [ 1. 1.1 2. 1.1 3. ],
             mask = False,
            fill_value=1.5)

For integers, the fill value will be different in general to the result of masked_equal.

>>> x = np.arange(5)
>>> x
array([0, 1, 2, 3, 4])
>>> ma.masked_values(x, 2)
masked_array(data = [0 1 -- 3 4],
             mask = [False False True False False],
            fill_value=2)
>>> ma.masked_equal(x, 2)
masked_array(data = [0 1 -- 3 4],
             mask = [False False True False False],
            fill_value=999999)
numpy.ma.masked_where(condition, a, copy=True)

Mask an array where a condition is met.

Return a as an array masked where condition is True. Any masked values of a or condition are also masked in the output.

Parameters

condition : array_like
    Masking condition. When condition tests floating point values for equality, consider using masked_values instead.

a : array_like
    Array to mask.

copy : bool
    If True (default) make a copy of a in the result. If False modify a in place and return a view.

Returns

result : MaskedArray
    The result of masking a where condition is True.

See also:

masked_values
    Mask using floating point equality.

masked_equal
    Mask where equal to a given value.

masked_not_equal
    Mask where not equal to a given value.

masked_less_equal
    Mask where less than or equal to a given value.

masked_greater_equal
    Mask where greater than or equal to a given value.

masked_less
    Mask where less than a given value.

masked_greater
    Mask where greater than a given value.

masked_inside
    Mask inside a given interval.

masked_outside
    Mask outside a given interval.

masked_invalid
    Mask invalid values (NaNs or infs).

Examples

>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_where(a <= 2, a)
masked_array(data = [-- -- -- 3],
            mask = [ True  True  True False],
            fill_value=999999)

Mask array b conditional on a.

>>> b = ['a', 'b', 'c', 'd']
>>> ma.masked_where(a == 2, b)
masked_array(data = ['a' 'b' -- 'd'],
            mask = [False False True False],
            fill_value=N/A)

Effect of the copy argument.

>>> c = ma.masked_where(a <= 2, a)
>>> c
masked_array(data = [-- -- -- 3],
            mask = [ True  True  True False],
            fill_value=999999)
>>> c[0] = 99
>>> c
masked_array(data = [99 -- -- 3],
            mask = [False True  True False],
            fill_value=999999)

>>> a
array([0, 1, 2, 3])
>>> c = ma.masked_where(a <= 2, a, copy=False)
>>> c
masked_array(data = [99 -- -- 3],
            mask = [False True  True False],
            fill_value=999999)

>>> a
array([99, 1, 2, 3])

When condition or a contain masked values.

>>> a = np.arange(4)
>>> a = ma.masked_where(a == 2, a)
>>> a
masked_array(data = [0 1 -- 3],
            mask = [False False True False],
            fill_value=999999)

> to a ndarray

ma.compress_cols(a) Suppress whole columns of a 2-D array that contain masked values.
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<th>Function</th>
<th>Description</th>
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<td><code>ma.compress_rowcols(x[, axis])</code></td>
<td>Suppress the rows and/or columns of a 2-D array that contain masked values.</td>
</tr>
<tr>
<td><code>ma.compress_rows(a)</code></td>
<td>Suppress whole rows of a 2-D array that contain masked values.</td>
</tr>
<tr>
<td><code>ma.compressed(x)</code></td>
<td>Return all the non-masked data as a 1-D array.</td>
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<tr>
<td><code>ma.filled(a[, fill_value])</code></td>
<td>Return input as an array with masked data replaced by a fill value.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.compressed()</code></td>
<td>Return all the non-masked data as a 1-D array.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.filled([fill_value])</code></td>
<td>Return a copy of self, with masked values filled with a given value.</td>
</tr>
</tbody>
</table>

**numpy.ma.compress_cols(a)**

Suppress whole columns of a 2-D array that contain masked values.

This is equivalent to `np.ma.extras.compress_rowcols(a, 1)`. See `extras.compress_rowcols` for details.

**See also:**
`extras.compress_rowcols`

**numpy.ma.compress_rowcols(x, axis=None)**

Suppress the rows and/or columns of a 2-D array that contain masked values.

The suppression behavior is selected with the `axis` parameter.

- If `axis` is None, both rows and columns are suppressed.
- If `axis` is 0, only rows are suppressed.
- If `axis` is 1 or -1, only columns are suppressed.

**Parameters**

- `axis` : int, optional

  Axis along which to perform the operation. Default is None.

**Returns**

- `compressed_array` : ndarray

  The compressed array.

**Examples**

```python
>>> x = np.ma.array(np.arange(9).reshape(3, 3), mask=[[1, 0, 0], ...
... [1, 0, 0],
... [0, 0, 0]])
```

```python
>>> x
masked_array(data =
[[-- 1 2]
[-- 4 5]
[6 7 8]],
mask =
[[ True False False]
[ True False False]
[False False False]],
fill_value = 999999)
```

```python
>>> np.ma.extras.compress_rowcols(x)
array([[7, 8]])
```

```python
>>> np.ma.extras.compress_rowcols(x, 0)
array([[6, 7, 8]])
```

```python
>>> np.ma.extras.compress_rowcols(x, 1)
```
```python
array([[1, 2],
       [4, 5],
       [7, 8]])
```

```python
numpy.ma.compress_rows(a)
```
Suppress whole rows of a 2-D array that contain masked values.

This is equivalent to `np.ma.extras.compress_rowcols(a, 0)`, see
`extras.compress_rowcols` for details.

See also:

`extras.compress_rowcols`

```python
numpy.ma.compressed(x)
```
Return all the non-masked data as a 1-D array.

This function is equivalent to calling the “compressed” method of a `MaskedArray`, see
`MaskedArray.compressed` for details.

See also:

`MaskedArray.compressed`

Equivalent method.

```python
numpy.ma.filled(a, fill_value=None)
```
Return input as an array with masked data replaced by a fill value.

If `a` is not a `MaskedArray`, `a` itself is returned. If `a` is a `MaskedArray` and `fill_value` is None, `fill_value` is
set to `a.fill_value`.

Parameters

- `a` : MaskedArray or array_like
  An input object.

- `fill_value` : scalar, optional
  Filling value. Default is None.

Returns

- `a` : ndarray
  The filled array.

See also:

`compressed`

Examples

```python
>>> x = np.ma.array(np.arange(9).reshape(3, 3), mask=[[1, 0, 0],
...          [1, 0, 0],
...          [0, 0, 0]])
>>> x.filled()
array([[999999, 1, 2],
       [999999, 4, 5],
       [ 6, 7, 8]])
```

```python
MaskedArray.compressed()
```
Return all the non-masked data as a 1-D array.
Returns

data : ndarray

A new `ndarray` holding the non-masked data is returned.

Notes

The result is not a MaskedArray!

Examples

```python
>>> x = np.ma.array(np.arange(5), mask=[0]*2 + [1]*3)
>>> x.compressed()
array([0, 1])
>>> type(x.compressed())
<type 'numpy.ndarray'>
```

MaskedArray `.filled(fill_value=None)`

Return a copy of self, with masked values filled with a given value.

Parameters

fill_value : scalar, optional

The value to use for invalid entries (None by default). If None, the `fill_value` attribute of the array is used instead.

Returns

filled_array : ndarray

A copy of `self` with invalid entries replaced by `fill_value` (be it the function argument or the attribute of `self`.

Notes

The result is not a MaskedArray!

Examples

```python
>>> x = np.ma.array([1,2,3,4,5], mask=[0,0,1,0,1], fill_value=-999)
>>> x.filled()
array([1, 2, -999, 4, -999])
>>> type(x.filled())
<type 'numpy.ndarray'>
```

Subclassing is preserved. This means that if the data part of the masked array is a matrix, `.filled()` returns a matrix:

```python
>>> x = np.ma.array(np.matrix([[1, 2], [3, 4]]), mask=[[0, 1], [1, 0]])
>>> x.filled()
matrix([[ 1, 999999],
        [999999,   4]])
```

> to another object

```
ma.MaskedArray.tofile(fid[, sep, format])  # Save a masked array to a file in binary format.
ma.MaskedArray.tolist([fill_value])       # Return the data portion of the masked array as a hierarchical Python list.
ma.MaskedArray.torecords()               # Transforms a masked array into a flexible-type array.
ma.MaskedArray.tobytes([fill_value, order])  # Return the array data as a string containing the raw bytes in the array.
```
MaskedArray.tofile \((\text{fid}, \text{sep}=',', \text{format}='\%s')\)
Save a masked array to a file in binary format.

**Warning:** This function is not implemented yet.

**Raises**

`NotImplementedError` When `tofile` is called.

MaskedArray.tolist \((\text{fill_value}=\text{None})\)
Return the data portion of the masked array as a hierarchical Python list.

Data items are converted to the nearest compatible Python type. Masked values are converted to `fill_value`. If `fill_value` is None, the corresponding entries in the output list will be `None`.

**Parameters**

- `fill_value` : scalar, optional
  The value to use for invalid entries. Default is None.

**Returns**

- `result` : list
  The Python list representation of the masked array.

**Examples**

```python
>>> x = np.ma.array([[1,2,3], [4,5,6], [7,8,9]], mask=[0] + [1,0]*4)
>>> x.tolist()
[[1, None, 3], [None, 5, None], [7, None, 9]]
>>> x.tolist(-999)
[[1, -999, 3], [-999, 5, -999], [7, -999, 9]]
```

MaskedArray.torecords()
Transforms a masked array into a flexible-type array.

The flexible type array that is returned will have two fields:

- the `_data` field stores the `_data` part of the array.
- the `_mask` field stores the `_mask` part of the array.

**Parameters**

- None

**Returns**

- `record` : ndarray
  A new flexible-type ndarray with two fields: the first element containing a value, the second element containing the corresponding mask boolean. The returned record shape matches self.shape.

**Notes**

A side-effect of transforming a masked array into a flexible ndarray is that meta information (fill_value, ...) will be lost.

**Examples**
>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)

>>> print x

[[1 -- 3]
[ -- 5 --]
[7 -- 9]]

>>> print x.toflex()

[[[1, False) (2, True) (3, False)]
[[4, True) (5, False) (6, True)]
[[7, False) (8, True) (9, False)]

MaskedArray.tobytes (fill_value=None, order='C')

Return the array data as a string containing the raw bytes in the array.

The array is filled with a fill value before the string conversion.

New in version 1.9.0.

Parameters

fill_value : scalar, optional

Value used to fill in the masked values. Default is None, in which case
MaskedArray.fill_value is used.

order : {'C','F','A'}, optional

Order of the data item in the copy. Default is ‘C’.

• ‘C’ – C order (row major).
• ‘F’ – Fortran order (column major).
• ‘A’ – Any, current order of array.
• None – Same as ‘A’.

See also:
ndarray.tobytes,tolist,tofile

Notes

As for ndarray.tobytes, information about the shape, dtype, etc., but also about fill_value, will be lost.

Examples

>>> x = np.ma.array(np.array([[1, 2], [3, 4]]), mask=[[0, 1], [1, 0]])

>>> x.tobytes()

'\x01\x00\x00\x00?B\x0f\x00?B\x0f\x00\x04\x00\x00\x00'

Pickling and unpickling

ma.dump(a, F) Pickle a masked array to a file.

ma.dumps(a) Return a string corresponding to the pickling of a masked array.

ma.load(F) Wrapper around cPickle.load which accepts either a file-like object or a filename.

ma.loads(strg) Load a pickle from the current string.

numpy.ma.dump (a, F)

Pickle a masked array to a file.

This is a wrapper around cPickle.dump.

Parameters
a : MaskedArray
    The array to be pickled.
F : str or file-like object
    The file to pickle a to. If a string, the full path to the file.

\texttt{numpy.ma.dumps(a)}

Return a string corresponding to the pickling of a masked array.

This is a wrapper around \texttt{cPickle.dumps}.

\textbf{Parameters}

a : MaskedArray
    The array for which the string representation of the pickle is returned.

\texttt{numpy.ma.load(F)}

Wrapper around \texttt{cPickle.load} which accepts either a file-like object or a filename.

\textbf{Parameters}

F : str or file
    The file or file name to load.

\textbf{See also:}

dump
    Pickle an array

\textbf{Notes}

This is different from \texttt{numpy.load}, which does not use cPickle but loads the NumPy binary \texttt{npy} format.

\texttt{numpy.ma.loads(strg)}

Load a pickle from the current string.

The result of \texttt{cPickle.loads(strg)} is returned.

\textbf{Parameters}

strg : str
    The string to load.

\textbf{See also:}

dumps
    Return a string corresponding to the pickling of a masked array.

\textbf{Filling a masked array}

<table>
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<td>Return the common filling value of two masked arrays, if any.</td>
</tr>
<tr>
<td>\texttt{ma.default_fill_value(obj)}</td>
<td>Return the default fill value for the argument object.</td>
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<tr>
<td>\texttt{ma.maximum_fill_value(obj)}</td>
<td>Return the minimum value that can be represented by the dtype of an object.</td>
</tr>
<tr>
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<td>Return the minimum value that can be represented by the dtype of an object.</td>
</tr>
<tr>
<td>\texttt{ma.set_fill_value(a, fill_value)}</td>
<td>Set the filling value of a, if a is a masked array.</td>
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<td>Return the filling value of the masked array.</td>
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<td>\texttt{ma.MaskedArray.set_fill_value(value)}</td>
<td>Set the filling value of the masked array.</td>
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<td>Filling value.</td>
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\textbf{1.7. Masked arrays}
numpy.ma.common_fill_value(a, b)

Return the common filling value of two masked arrays, if any.

If a.fill_value == b.fill_value, return the fill value, otherwise return None.

Parameters
    a, b : MaskedArray

    The masked arrays for which to compare fill values.

Returns
    fill_value : scalar or None

    The common fill value, or None.

Examples
>>> x = np.ma.array([0, 1.], fill_value=3)
>>> y = np.ma.array([0, 1.], fill_value=3)
>>> np.ma.common_fill_value(x, y)
3.0

numpy.ma.default_fill_value(obj)

Return the default fill value for the argument object.

The default filling value depends on the datatype of the input array or the type of the input scalar:

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<tr>
<th>datatype</th>
<th>default</th>
</tr>
</thead>
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<td>bool</td>
<td>True</td>
</tr>
<tr>
<td>int</td>
<td>999999</td>
</tr>
<tr>
<td>float</td>
<td>1e20</td>
</tr>
<tr>
<td>complex</td>
<td>1e20+0j</td>
</tr>
<tr>
<td>object</td>
<td>‘?’</td>
</tr>
<tr>
<td>string</td>
<td>‘N/A’</td>
</tr>
</tbody>
</table>

Parameters
    obj : ndarray, dtype or scalar

    The array data-type or scalar for which the default fill value is returned.

Returns
    fill_value : scalar

    The default fill value.

Examples
>>> np.ma.default_fill_value(1)
999999
>>> np.ma.default_fill_value(np.array([1.1, 2., np.pi]))
1e+20
>>> np.ma.default_fill_value(np.dtype(complex))
(1e+20+0j)

numpy.ma.maximum_fill_value(obj)

Return the minimum value that can be represented by the dtype of an object.

This function is useful for calculating a fill value suitable for taking the maximum of an array with a given dtype.

Parameters
    obj : {ndarray, dtype}
An object that can be queried for its numeric type.

**Returns**

val : scalar

The minimum representable value.

**Raises**

TypeError

If obj isn’t a suitable numeric type.

**See also:**

**minimum_fill_value**

The inverse function.

**set_fill_value**

Set the filling value of a masked array.

**MaskedArray.fill_value**

Return current fill value.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = np.int8()
>>> ma.maximum_fill_value(a)
-128
>>> a = np.int32()
>>> ma.maximum_fill_value(a)
-2147483648
```

An array of numeric data can also be passed.

```python
>>> a = np.array([1, 2, 3], dtype=np.int)
>>> ma.maximum_fill_value(a)
-128
>>> a = np.array([1, 2, 3], dtype=np.float32)
>>> ma.maximum_fill_value(a)
-inf
```

```
numpy.ma.maximum_fill_value(obj)
Return the minimum value that can be represented by the dtype of an object.
```

This function is useful for calculating a fill value suitable for taking the maximum of an array with a given dtype.

**Parameters**

- obj : {ndarray, dtype}
  An object that can be queried for its numeric type.

**Returns**

val : scalar

The minimum representable value.

**Raises**

TypeError

If obj isn’t a suitable numeric type.

**See also:**
minimum_fill_value
The inverse function.

set_fill_value
Set the filling value of a masked array.

MaskedArray.fill_value
Return current fill value.

Examples
>>> import numpy.ma as ma
>>> a = np.int8()
>>> ma.maximum_fill_value(a)
-128
>>> a = np.int32()
>>> ma.maximum_fill_value(a)
-2147483648

An array of numeric data can also be passed.
>>> a = np.array([1, 2, 3], dtype=np.int8)
>>> ma.maximum_fill_value(a)
-128
>>> a = np.array([1, 2, 3], dtype=np.float32)
>>> ma.maximum_fill_value(a)
-inf

numpy.ma.set_fill_value(a, fill_value)
Set the filling value of a, if a is a masked array.

This function changes the fill value of the masked array a in place. If a is not a masked array, the function returns silently, without doing anything.

Parameters
  a : array_like
    Input array.

  fill_value : dtype
    Filling value. A consistency test is performed to make sure the value is compatible with the dtype of a.

Returns
  None
    Nothing returned by this function.

See also:

maximum_fill_value
Return the default fill value for a dtype.

MaskedArray.fill_value
Return current fill value.

MaskedArray.set_fill_value
Equivalent method.
Examples

>>> import numpy.ma as ma
>>> a = np.arange(5)
>>> a
array([0, 1, 2, 3, 4])
>>> a = ma.masked_where(a < 3, a)
>>> a
masked_array(data = [-- -- -- 3 4],
    mask = [ True True True False False],
    fill_value=999999)

Nothing happens if \( a \) is not a masked array.

>>> a = range(5)
>>> a
[0, 1, 2, 3, 4]
>>> ma.set_fill_value(a, 100)
>>> a
[0, 1, 2, 3, 4]
>>> a = np.arange(5)
>>> a
array([0, 1, 2, 3, 4])
>>> ma.set_fill_value(a, 100)
>>> a
array([0, 1, 2, 3, 4])

MaskedArray.get_fill_value()

Return the filling value of the masked array.

Returns

fill_value : scalar

The filling value.

Examples

>>> for dt in [np.int32, np.int64, np.float64, np.complex128]:
...    np.ma.array([0, 1], dtype=dt).get_fill_value()
...
999999
999999
1e+20
(1e+20+0j)

>>> x = np.ma.array([0, 1.], fill_value=-np.inf)
>>> x.get_fill_value()
-inf

MaskedArray.set_fill_value(value=None)

Set the filling value of the masked array.

Parameters

value : scalar, optional
The new filling value. Default is None, in which case a default based on the data type is used.

See also:

**ma.set_fill_value**
Equivalent function.

**Examples**

```python
>>> x = np.ma.array([0, 1.], fill_value=-np.inf)
>>> x.fill_value
-inf
>>> x.set_fill_value(np.pi)
>>> x.fill_value
3.1415926535897931
```

Reset to default:

```python
>>> x.set_fill_value()
>>> x.fill_value
1e+20
```

**MaskedArray.fill_value**
Filling value.

---

**Masked arrays arithmetics**

**Arithmetics**

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<td>Compute the variance along the specified axis.</td>
</tr>
</tbody>
</table>
numpy.ma.anom(self, axis=None, dtype=None) = <numpy.ma.core._frommethod instance at 0x4243f3ac>

Compute the anomalies (deviations from the arithmetic mean) along the given axis.

Returns an array of anomalies, with the same shape as the input and where the arithmetic mean is computed along the given axis.

Parameters

axis : int, optional

Axis over which the anomalies are taken. The default is to use the mean of the flattened array as reference.

dtype : dtype, optional

Type to use in computing the variance. For arrays of integer type the default is float32; for arrays of float types it is the same as the array type.

See also:

mean

Compute the mean of the array.

Examples

>>> a = np.ma.array([1,2,3])
>>> a.anom()
masked_array(data = [-1. 0. 1.],
             mask = False,
             fill_value = 1e+20)

numpy.ma.anomalies(self, axis=None, dtype=None) = <numpy.ma.core._frommethod instance at 0x4243f3ac>

Compute the anomalies (deviations from the arithmetic mean) along the given axis.

Returns an array of anomalies, with the same shape as the input and where the arithmetic mean is computed along the given axis.

Parameters

axis : int, optional

Axis over which the anomalies are taken. The default is to use the mean of the flattened array as reference.

dtype : dtype, optional

Type to use in computing the variance. For arrays of integer type the default is float32; for arrays of float types it is the same as the array type.

See also:

mean

Compute the mean of the array.

Examples

>>> a = np.ma.array([1,2,3])
>>> a.anom()
masked_array(data = [-1. 0. 1.],
             mask = False,
             fill_value = 1e+20)
numpy.ma.average(a, axis=None, weights=None, returned=False)

Return the weighted average of array over the given axis.

Parameters
- **a**: array_like
  Data to be averaged. Masked entries are not taken into account in the computation.
- **axis**: int, optional
  Axis along which the average is computed. The default is to compute the average of the flattened array.
- **weights**: array_like, optional
  The importance that each element has in the computation of the average. The weights array can either be 1-D (in which case its length must be the size of a along the given axis) or of the same shape as a. If weights=None, then all data in a are assumed to have a weight equal to one. If weights is complex, the imaginary parts are ignored.
- **returned**: bool, optional
  Flag indicating whether a tuple (result, sum of weights) should be returned as output (True), or just the result (False). Default is False.

Returns
- **average**, [**sum_of_weights**] : (tuple of) scalar or MaskedArray
  The average along the specified axis. When returned is True, return a tuple with the average as the first element and the sum of the weights as the second element. The return type is np.float64 if a is of integer type, otherwise it is of the same type as a. If returned, sum_of_weights is of the same type as average.

Examples
```python
>>> a = np.ma.array([1., 2., 3., 4.], mask=[False, False, True, True])
>>> np.ma.average(a, weights=[3, 1, 0, 0])
1.25

>>> x = np.ma.arange(6.).reshape(3, 2)
>>> print x
[[ 0.  1.]
 [ 2.  3.]
 [ 4.  5.]]
>>> avg, sumweights = np.ma.average(x, axis=0, weights=[1, 2, 3],
... returned=True)
>>> print avg
[2.66666666667 3.66666666667]
```

numpy.ma.conjugate(x[, out]) = <numpy.ma.core.MaskedUnaryOperation instance at 0x42430acc>

Return the complex conjugate, element-wise.

The complex conjugate of a complex number is obtained by changing the sign of its imaginary part.

Parameters
- **x**: array_like
  Input value.

Returns
- **y**: ndarray
  The complex conjugate of x, with same dtype as y.
Examples

```python
>>> np.conjugate(1+2j)
(1-2j)

>>> x = np.eye(2) + 1j * np.eye(2)
>>> np.conjugate(x)
array([[ 1.-1.j,  0.-0.j],
       [ 0.-0.j,  1.-1.j]])
```

```
numpy.ma.corrcoef (x, y=None, rowvar=True, bias=False, allow_masked=True, ddof=None)
Return correlation coefficients of the input array.

Except for the handling of missing data this function does the same as numpy.corrcoef. For more details
and examples, see numpy.corrcoef.

Parameters

x : array_like
    A 1-D or 2-D array containing multiple variables and observations. Each row of x
    represents a variable, and each column a single observation of all those variables. Also
    see rowvar below.

y : array_like, optional
    An additional set of variables and observations. y has the same shape as x.

rowvar : bool, optional
    If rowvar is True (default), then each row represents a variable, with observations in the
    columns. Otherwise, the relationship is transposed: each column represents a variable,
    while the rows contain observations.

bias : bool, optional
    Default normalization (False) is by \( (N-1) \), where \( N \) is the number of observations
    given (unbiased estimate). If bias is 1, then normalization is by \( N \). This keyword can be
    overridden by the keyword ddof in numpy versions >= 1.5.

allow_masked : bool, optional
    If True, masked values are propagated pair-wise: if a value is masked in x, the corre-
    sponding value is masked in y. If False, raises an exception.

ddof : {None, int}, optional
    New in version 1.5.
    If not None normalization is by \( (N - \text{ddof}) \), where \( N \) is the number of observations;
    this overrides the value implied by bias. The default value is None.

See also:

numpy.corrcoef
    Equivalent function in top-level NumPy module.

cov
    Estimate the covariance matrix.
```

```
numpy.ma.cov (x, y=None, rowvar=True, bias=False, allow_masked=True, ddof=None)
Estimate the covariance matrix.
```
Except for the handling of missing data, this function does the same as `numpy.cov`. For more details and examples, see `numpy.cov`.

By default, masked values are recognized as such. If `x` and `y` have the same shape, a common mask is allocated: if `x[i, j]` is masked, then `y[i, j]` will also be masked. Setting `allow_masked` to False will raise an exception if values are missing in either of the input arrays.

**Parameters**

- **x**: array_like
  A 1-D or 2-D array containing multiple variables and observations. Each row of `x` represents a variable, and each column a single observation of all those variables. Also see `rowvar` below.

- **y**: array_like, optional
  An additional set of variables and observations. `y` has the same form as `x`.

- **rowvar**: bool, optional
  If `rowvar` is True (default), then each row represents a variable, with observations in the columns. Otherwise, the relationship is transposed: each column represents a variable, while the rows contain observations.

- **bias**: bool, optional
  Default normalization (False) is by \((N-1)\), where \(N\) is the number of observations given (unbiased estimate). If `bias` is True, then normalization is by \(N\). This keyword can be overridden by the keyword `ddof` in numpy versions >= 1.5.

- **allow_masked**: bool, optional
  If True, masked values are propagated pair-wise: if a value is masked in `x`, the corresponding value is masked in `y`. If False, raises a `ValueError` exception when some values are missing.

- **ddof**: {None, int}, optional
  New in version 1.5.
  If `ddof` is not None, normalization is by \((N - ddof)\), where \(N\) is the number of observations; this overrides the value implied by `bias`. The default value is `None`.

**Raises**

- **ValueError**
  Raised if some values are missing and `allow_masked` is False.

**See also:**

- `numpy.cov`
- `numpy.ma.cumsum`

```python
numpy.ma.cumsum(self, axis=None, dtype=None, out=None) = <numpy.ma.core._frommethod instance at 0x4243f4cc>
```

Return the cumulative sum of the elements along the given axis. The cumulative sum is calculated over the flattened array by default, otherwise over the specified axis.

Masked values are set to 0 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

**Parameters**

- **axis**: {None, -1, int}, optional
Axis along which the sum is computed. The default \(axis = \text{None}\) is to compute over the flattened array. \(axis\) may be negative, in which case it counts from the last to the first axis.

**dtype**: \{\text{None}, \text{dtype}\}, optional

Type of the returned array and of the accumulator in which the elements are summed. If \(dtype\) is not specified, it defaults to the dtype of \(a\), unless \(a\) has an integer dtype with a precision less than that of the default platform integer. In that case, the default platform integer is used.

**out**: ndarray, optional

 Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

**Returns**

**cumsum**: ndarray.

A new array holding the result is returned unless \(out\) is specified, in which case a reference to \(out\) is returned.

**Notes**

The mask is lost if \(out\) is not a valid \texttt{MaskedArray}.

Arithmetic is modular when using integer types, and no error is raised on overflow.

**Examples**

```python
g\rangle marr = np.ma.array(np.arange(10), mask=[0,0,0,1,1,1,0,0,0,0])
g\rangle print marr.cumsum()
g\rangle [0 1 3 -- -- -- 9 16 24 33]
```

**numpy.ma.cumprod**\(self, axis=\text{None}, dtype=\text{None}, out=\text{None}\) = <\text{numpy.ma.core._frommethod instance at 0x4243f46c}>

Return the cumulative product of the elements along the given axis. The cumulative product is taken over the flattened array by default, otherwise over the specified axis.

Masked values are set to 1 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

**Parameters**

**axis**: \{\text{None}, -1, int\}, optional

Axis along which the product is computed. The default \((axis = \text{None})\) is to compute over the flattened array.

**dtype**: \{\text{None}, \text{dtype}\}, optional

Determines the type of the returned array and of the accumulator where the elements are multiplied. If \(dtype\) has the value \text{None} and the type of \(a\) is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of \(a\).

**out**: ndarray, optional

Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

**Returns**

**cumprod**: ndarray
A new array holding the result is returned unless out is specified, in which case a reference to out is returned.

**Notes**

The mask is lost if `out` is not a valid MaskedArray!

Arithmetic is modular when using integer types, and no error is raised on overflow.

```python
numpy.ma.mean (self, axis=None, dtype=None, out=None) = <numpy.ma.core._frommethod instance at 0x4243f58c>
```

Returns the average of the array elements.

Masked entries are ignored. The average is taken over the flattened array by default, otherwise over the specified axis. Refer to `numpy.mean` for the full documentation.

**Parameters**

- `a`: array_like
  
  Array containing numbers whose mean is desired. If `a` is not an array, a conversion is attempted.

- `axis`: int, optional
  
  Axis along which the means are computed. The default is to compute the mean of the flattened array.

- `dtype`: dtype, optional
  
  Type to use in computing the mean. For integer inputs, the default is float64; for floating point, inputs it is the same as the input dtype.

- `out`: ndarray, optional
  
  Alternative output array in which to place the result. It must have the same shape as the expected output but the type will be cast if necessary.

**Returns**

- `mean`: ndarray, see dtype parameter above

  If `out=None`, returns a new array containing the mean values, otherwise a reference to the output array is returned.

**See also:**

- `numpy.ma.mean`
  
  Equivalent function.

- `numpy.mean`
  
  Equivalent function on non-masked arrays.

- `numpy.ma.average`
  
  Weighted average.

**Examples**

```python
>>> a = np.ma.array([1, 2, 3], mask=[False, False, True])
>>> a
masked_array(data = [1 2 --],
             mask = [False False True],
             fill_value = 999999)
>>> a.mean()
1.5
```
numpy.ma.median(a, axis=None, out=None, overwrite_input=False)

Compute the median along the specified axis.

Returns the median of the array elements.

Parameters

- **a**: array_like
  - Input array or object that can be converted to an array.
- **axis**: int, optional
  - Axis along which the medians are computed. The default (None) is to compute the median along a flattened version of the array.
- **out**: ndarray, optional
  - Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.
- **overwrite_input**: bool, optional
  - If True, then allow use of memory of input array (a) for calculations. The input array will be modified by the call to median. This will save memory when you do not need to preserve the contents of the input array. Treat the input as undefined, but it will probably be fully or partially sorted. Default is False. Note that, if overwrite_input is True, and the input is not already an ndarray, an error will be raised.

Returns

- **median**: ndarray
  - A new array holding the result is returned unless out is specified, in which case a reference to out is returned. Return data-type is float64 for integers and floats smaller than float64, or the input data-type, otherwise.

See also:

- mean

Notes

Given a vector V with N non masked values, the median of V is the middle value of a sorted copy of V (Vs) - i.e. Vs[(N-1)/2], when N is odd, or {Vs[N/2 - 1] + Vs[N/2]}/2 when N is even.

Examples

```python
>>> x = np.ma.array(np.arange(8), mask=[0]*4 + [1]*4)
```
```python
>>> np.maextras.median(x)
```
```python
1.5
```

```python
>>> x = np.ma.array(np.arange(10).reshape(2, 5), mask=[0]*6 + [1]*4)
```
```python
>>> np.maextras.median(x)
```
```python
2.5
```
```python
>>> np.maextras.median(x, axis=-1, overwrite_input=True)
```
```python
masked_array(data = [ 2. 5.],
             mask = False,
            fill_value = 1e+20)
```

numpy.ma.power(a, b, third=None)

Returns element-wise base array raised to power from second array.

This is the masked array version of numpy.power. For details see numpy.power.

See also:
numpy.power

Notes

The `out` argument to `numpy.power` is not supported, `third` has to be `None`.

numpy.ma.prod(self, axis=None, dtype=None, out=None) = <numpy.ma.core._frommethod instance at 0x4243f5ec>

Return the product of the array elements over the given axis. Masked elements are set to 1 internally for computation.

Parameters

- `axis`: {None, int}, optional
  - Axis over which the product is taken. If `None` is used, then the product is over all the array elements.

- `dtype`: {None, dtype}, optional
  - Determines the type of the returned array and of the accumulator where the elements are multiplied. If `dtype` has the value `None` and the type of `a` is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the `dtype` is the same as that of `a`.

- `out`: {None, array}, optional
  - Alternative output array in which to place the result. It must have the same shape as the expected output but the type will be cast if necessary.

Returns

- `product_along_axis`: {array, scalar}, see `dtype` parameter above.
  - Returns an array whose shape is the same as `a` with the specified axis removed. Returns a 0d array when `a` is 1d or `axis=None`. Returns a reference to the specified output array if specified.

See also:

- `prod`
  - equivalent function

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

```python
>>> np.prod([1., 2.])
2.0
>>> np.prod([1., 2.], dtype=np.int32)
2
>>> np.prod([[1., 2.], [3., 4.]])
24.0
>>> np.prod([[1., 2.], [3., 4.]], axis=1)
array([ 2., 12.])
```

numpy.ma.std(self, axis=None, dtype=None, out=None, ddof=0) = <numpy.ma.core._frommethod instance at 0x4243f7ac>

Compute the standard deviation along the specified axis.

Returns the standard deviation, a measure of the spread of a distribution, of the array elements. The standard deviation is computed for the flattened array by default, otherwise over the specified axis.
Parameters

- **a**: array_like
  Calculate the standard deviation of these values.

- **axis**: int, optional
  Axis along which the standard deviation is computed. The default is to compute the standard deviation of the flattened array.

- **dtype**: dtype, optional
  Type to use in computing the standard deviation. For arrays of integer type the default is float64, for arrays of float types it is the same as the array type.

- **out**: ndarray, optional
  Alternative output array in which to place the result. It must have the same shape as the expected output but the type (of the calculated values) will be cast if necessary.

- **ddof**: int, optional
  Means Delta Degrees of Freedom. The divisor used in calculations is \( N - \text{ddof} \), where \( N \) represents the number of elements. By default \( \text{ddof} = 0 \).

- **keepdims**: bool, optional
  If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original \( \text{arr} \).

Returns

- **standard_deviation**: ndarray, see dtype parameter above.
  If \( \text{out} \) is None, return a new array containing the standard deviation, otherwise return a reference to the output array.

See also:

- **var**, **mean**, **nanmean**, **nanstd**, **nanvar**
- **numpy.doc.ufuncs**
  Section “Output arguments”

Notes

The standard deviation is the square root of the average of the squared deviations from the mean, i.e., \( \text{std} = \sqrt{\text{mean}(\text{abs}(x - \text{mean}(x))^2)} \).

The average squared deviation is normally calculated as \( x\text{.sum()} / N \), where \( N = \text{len}(x) \). If, however, \( \text{ddof} \) is specified, the divisor \( N - \text{ddof} \) is used instead. In standard statistical practice, \( \text{ddof}=1 \) provides an unbiased estimator of the variance of the infinite population. \( \text{ddof}=0 \) provides a maximum likelihood estimate of the variance for normally distributed variables. The standard deviation computed in this function is the square root of the estimated variance, so even with \( \text{ddof}=1 \), it will not be an unbiased estimate of the standard deviation per se.

Note that, for complex numbers, \( \text{std} \) takes the absolute value before squaring, so that the result is always real and nonnegative.

For floating-point input, the \( \text{std} \) is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the \( \text{dtype} \) keyword can alleviate this issue.
Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> np.std(a)
1.1180339887498949
>>> np.std(a, axis=0)
array([ 1., 1.])
>>> np.std(a, axis=1)
array([ 0.5, 0.5])
```

In single precision, std() can be inaccurate:

```python
>>> a = np.zeros((2,512*512), dtype=np.float32)
>>> a[0,:]=1.0
>>> a[1,:]=0.1
>>> np.std(a)
0.45172946707416706
```

Computing the standard deviation in float64 is more accurate:

```python
>>> np.std(a, dtype=np.float64)
0.44999999925552653
```

```
numpy.ma.sum(self, axis=None, dtype=None, out=None) = <numpy.ma.core._frommethod instance at 0x4243f86c>
```

Return the sum of the array elements over the given axis. Masked elements are set to 0 internally.

**Parameters**

- **axis**: {None, -1, int}, optional
  - Axis along which the sum is computed. The default (axis = None) is to compute over the flattened array.

- **dtype**: {None, dtype}, optional
  - Determines the type of the returned array and of the accumulator where the elements are summed. If dtype has the value None and the type of a is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of a.

- **out**: {None, ndarray}, optional
  - Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

**Returns**

- **sum_along_axis**: MaskedArray or scalar
  - An array with the same shape as self, with the specified axis removed. If self is a 0-d array, or if axis is None, a scalar is returned. If an output array is specified, a reference to out is returned.

**Examples**

```python
>>> x = np.ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]], mask=[0, 0, 0], dtype=object)
>>> print x
[[1 -- 3]
 [-- 5 --]
 [7 -- 9]]
>>> print x.sum()  # x is an object array
25
>>> print x.sum(axis=1)
```

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[4 5 16]
>>> print x.sum(axis=0)
[8 5 12]
>>> print type(x.sum(axis=0, dtype=np.int64)[0])
<type 'numpy.int64'>

numpy.ma.var(self, axis=None, dtype=None, out=None, ddof=0) = <numpy.ma.core._frommethod instance at 0x4243f92c>
Compute the variance along the specified axis.

Returns the variance of the array elements, a measure of the spread of a distribution. The variance is computed for the flattened array by default, otherwise over the specified axis.

**Parameters**

- **a**: array_like
  Array containing numbers whose variance is desired. If a is not an array, a conversion is attempted.

- **axis**: int, optional
  Axis along which the variance is computed. The default is to compute the variance of the flattened array.

- **dtype**: data-type, optional
  Type to use in computing the variance. For arrays of integer type the default is float32; for arrays of float types it is the same as the array type.

- **out**: ndarray, optional
  Alternate output array in which to place the result. It must have the same shape as the expected output, but the type is cast if necessary.

- **ddof**: int, optional
  “Delta Degrees of Freedom”: the divisor used in the calculation is N - ddof, where N represents the number of elements. By default ddof is zero.

- **keepdims**: bool, optional
  If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original arr.

**Returns**

- **variance**: ndarray, see dtype parameter above
  If out=None, returns a new array containing the variance; otherwise, a reference to the output array is returned.

**See also:**

std, mean, nanmean, nanstd, nanvar

numpy.doc.ufuncs

Section “Output arguments”

**Notes**

The variance is the average of the squared deviations from the mean, i.e., \( \text{var} = \text{mean}(\text{abs}(x - x.\text{mean()}**) 2) \).

The mean is normally calculated as \( x.\text{sum()} / N \), where \( N = \text{len}(x) \). If, however, \( ddof \) is specified, the divisor \( N - ddof \) is used instead. In standard statistical practice, \( ddof=1 \) provides an unbiased estimator
of the variance of a hypothetical infinite population. \( \text{ddof}=0 \) provides a maximum likelihood estimate of the variance for normally distributed variables.

Note that for complex numbers, the absolute value is taken before squaring, so that the result is always real and nonnegative.

For floating-point input, the variance is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for \texttt{float32} (see example below). Specifying a higher-accuracy accumulator using the \texttt{dtype} keyword can alleviate this issue.

**Examples**

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> np.var(a)
1.25
>>> np.var(a, axis=0)
array([ 1., 1.])
>>> np.var(a, axis=1)
array([ 0.25, 0.25])
```

In single precision, \texttt{var()} can be inaccurate:

```python
>>> a = np.zeros((2, 512*512), dtype=np.float32)
>>> a[0, :] = 1.0
>>> a[1, :] = 0.1
>>> np.var(a)
0.20405951142311096
```

Computing the variance in \texttt{float64} is more accurate:

```python
>>> np.var(a, dtype=np.float64)
0.20249999932997387
>>> ((1-0.55)**2 + (0.1-0.55)**2)/2
0.20250000000000001
```

**MaskedArray.\texttt{anom}(axis=None, dtype=None)**

Compute the anomalies (deviations from the arithmetic mean) along the given axis.

Returns an array of anomalies, with the same shape as the input and where the arithmetic mean is computed along the given axis.

**Parameters**

- **axis**: int, optional
  - Axis over which the anomalies are taken. The default is to use the mean of the flattened array as reference.

- **dtype**: dtype, optional
  - Type to use in computing the variance. For arrays of integer type the default is \texttt{float32}; for arrays of float types it is the same as the array type.

**See also:**

- **mean**
  - Compute the mean of the array.

**Examples**

```python
>>> a = np.ma.array([1, 2, 3])
>>> a.anom()
```
masked_array(data = [-1.  0.  1.],
               mask = False,
               fill_value = 1e+20)

MaskedArray.cumprod(axis=None, dtype=None, out=None)

Return the cumulative product of the elements along the given axis. The cumulative product is taken over the flattened array by default, otherwise over the specified axis.

Masked values are set to 1 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

Parameters
axis : {None, -1, int}, optional
   Axis along which the product is computed. The default (axis = None) is to compute over the flattened array.
dtype : {None, dtype}, optional
   Determines the type of the returned array and of the accumulator where the elements are multiplied. If dtype has the value None and the type of a is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of a.
out : ndarray, optional
   Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

Returns
cumprod : ndarray
   A new array holding the result is returned unless out is specified, in which case a reference to out is returned.

Notes
The mask is lost if out is not a valid MaskedArray!

Arithmetic is modular when using integer types, and no error is raised on overflow.

MaskedArray.cumsum(axis=None, dtype=None, out=None)

Return the cumulative sum of the elements along the given axis. The cumulative sum is calculated over the flattened array by default, otherwise over the specified axis.

Masked values are set to 0 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

Parameters
axis : {None, -1, int}, optional
   Axis along which the sum is computed. The default (axis = None) is to compute over the flattened array. axis may be negative, in which case it counts from the last to the first axis.
dtype : {None, dtype}, optional
   Type of the returned array and of the accumulator in which the elements are summed. If dtype is not specified, it defaults to the dtype of a, unless a has an integer dtype with a precision less than that of the default platform integer. In that case, the default platform integer is used.
out : ndarray, optional
Alternative output array in which to place the result. It must have the same shape and
buffer length as the expected output but the type will be cast if necessary.

Returns

cumsum : ndarray.

A new array holding the result is returned unless out is specified, in which case a
reference to out is returned.

Notes

The mask is lost if out is not a valid MaskedArray!

Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

>>> marr = np.ma.array(np.arange(10), mask=[0,0,0,1,1,1,0,0,0,0])
>>> print marr.cumsum()
[0 1 3 -- -- -- 9 16 24 33]

masked_array

Mean

MaskedArray.mean (axis=None, dtype=None, out=None)

Returns the average of the array elements.

Masked entries are ignored. The average is taken over the flattened array by default, otherwise over the specified
axis. Refer to numpy.mean for the full documentation.

Parameters

a : array_like

Array containing numbers whose mean is desired. If a is not an array, a conversion is
attempted.

axis : int, optional

Axis along which the means are computed. The default is to compute the mean of the
flattened array.

dtype : dtype, optional

Type to use in computing the mean. For integer inputs, the default is float64; for floating
point, inputs it is the same as the input dtype.

out : ndarray, optional

Alternative output array in which to place the result. It must have the same shape as the
expected output but the type will be cast if necessary.

Returns

mean : ndarray, see dtype parameter above

If out=None, returns a new array containing the mean values, otherwise a reference to
the output array is returned.

See also:

numpy.ma.mean

Equivalent function.

numpy.mean

Equivalent function on non-masked arrays.

numpy.ma.average

Weighted average.
Examples

```python
>>> a = np.ma.array([1, 2, 3], mask=[False, False, True])
>>> a
masked_array(data = [1 2 --],
             mask = [False False True],
            fill_value = 999999)
>>> a.mean()
1.5
```

MaskedArray.prod(\texttt{axis=None, dtype=None, out=None})

Return the product of the array elements over the given axis. Masked elements are set to 1 internally for computation.

**Parameters**

- **axis**: {None, int}, optional
  
  Axis over which the product is taken. If None is used, then the product is over all the array elements.

- **dtype**: {None, dtype}, optional
  
  Determines the type of the returned array and of the accumulator where the elements are multiplied. If \texttt{dtype} has the value \texttt{None} and the type of \texttt{a} is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of \texttt{a}.

- **out**: {None, array}, optional
  
  Alternative output array in which to place the result. It must have the same shape as the expected output but the type will be cast if necessary.

**Returns**

- **product_along_axis**: {array, scalar}, see dtype parameter above.
  
  Returns an array whose shape is the same as \texttt{a} with the specified axis removed. Returns a 0d array when \texttt{a} is 1d or axis=\texttt{None}. Returns a reference to the specified output array if specified.

See also:

- **prod**

  equivalent function

**Notes**

Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

```python
>>> np.prod([1., 2.])
2.0
>>> np.prod([1., 2.], dtype=np.int32)
2
>>> np.prod([[1., 2.], [3., 4.]])
24.0
>>> np.prod([[1., 2.], [3., 4.]], axis=1)
array([  2., 12.])
```

MaskedArray.std(\texttt{axis=None, dtype=None, out=None, ddof=0})

Compute the standard deviation along the specified axis.
Returns the standard deviation, a measure of the spread of a distribution, of the array elements. The standard deviation is computed for the flattened array by default, otherwise over the specified axis.

**Parameters**

- **a**: array_like
  Calculate the standard deviation of these values.

- **axis**: int, optional
  Axis along which the standard deviation is computed. The default is to compute the standard deviation of the flattened array.

- **dtype**: dtype, optional
  Type to use in computing the standard deviation. For arrays of integer type the default is float64, for arrays of float types it is the same as the array type.

- **out**: ndarray, optional
  Alternative output array in which to place the result. It must have the same shape as the expected output but the type (of the calculated values) will be cast if necessary.

- **ddof**: int, optional
  Means Delta Degrees of Freedom. The divisor used in calculations is \( N - \text{ddof} \), where \( N \) represents the number of elements. By default \( \text{ddof} = 0 \).

- **keepdims**: bool, optional
  If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original \( \text{arr} \).

**Returns**

- **standard_deviation**: ndarray, see dtype parameter above.
  If \( \text{out} \) is None, return a new array containing the standard deviation, otherwise return a reference to the output array.

**See also:**

- `var`, `mean`, `nanmean`, `nanstd`, `nanvar`

**Notes**

The standard deviation is the square root of the average of the squared deviations from the mean, i.e., \( \text{std} = \sqrt{\text{mean}((x - \text{mean}(x))^2)} \).

The average squared deviation is normally calculated as \( x.\text{sum()} / N \), where \( N = \text{len}(x) \). If, however, \( \text{ddof} \) is specified, the divisor \( N - \text{ddof} \) is used instead. In standard statistical practice, \( \text{ddof}=1 \) provides an unbiased estimator of the variance of the infinite population. \( \text{ddof}=0 \) provides a maximum likelihood estimate of the variance for normally distributed variables. The standard deviation computed in this function is the square root of the estimated variance, so even with \( \text{ddof}=1 \), it will not be an unbiased estimate of the standard deviation per se.

Note that, for complex numbers, \( \text{std} \) takes the absolute value before squaring, so that the result is always real and nonnegative.

For floating-point input, the \( \text{std} \) is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the \( \text{dtype} \) keyword can alleviate this issue.
Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> np.std(a)
1.1180339887498949
>>> np.std(a, axis=0)
array([ 1., 1.])
>>> np.std(a, axis=1)
array([ 0.5, 0.5])
```

In single precision, std() can be inaccurate:

```python
>>> a = np.zeros((2,512*512), dtype=np.float32)
>>> a[0,:]=1.0
>>> a[1,:]=0.1
>>> np.std(a)
0.45172946707416706
```

Computing the standard deviation in float64 is more accurate:

```python
>>> np.std(a, dtype=np.float64)
0.44999999925552653
```

MaskedArray.

```
sum
```

MaskedArray.sum(axis=None, dtype=None, out=None)

Return the sum of the array elements over the given axis. Masked elements are set to 0 internally.

Parameters

- **axis**: {None, -1, int}, optional
  Axis along which the sum is computed. The default (axis = None) is to compute over the flattened array.

- **dtype**: {None, dtype}, optional
  Determines the type of the returned array and of the accumulator where the elements are summed. If dtype has the value None and the type of a is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of a.

- **out**: {None, ndarray}, optional
  Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

Returns

**sum_along_axis**: MaskedArray or scalar

An array with the same shape as self, with the specified axis removed. If self is a 0-d array, or if axis is None, a scalar is returned. If an output array is specified, a reference to out is returned.

Examples

```python
>>> x = np.ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]], mask=[0] + [1,0]*4)
>>> print x
[[1 -- 3]
 [-- 5 --]
 [7 -- 9]]
>>> print x.sum()
25
>>> print x.sum(axis=1)
[4 5 16]
```
>>> print x.sum(axis=0)
[8 5 12]
>>> print type(x.sum(axis=0, dtype=np.int64)[0])
<type 'numpy.int64'>

MaskedArray.var (axis=None, dtype=None, out=None, ddof=0)
Compute the variance along the specified axis.

Returns the variance of the array elements, a measure of the spread of a distribution. The variance is computed
for the flattened array by default, otherwise over the specified axis.

Parameters
  a : array_like
      Array containing numbers whose variance is desired. If a is not an array, a conversion
      is attempted.
  axis : int, optional
      Axis along which the variance is computed. The default is to compute the variance of
      the flattened array.
  dtype : data-type, optional
      Type to use in computing the variance. For arrays of integer type the default is float32;
      for arrays of float types it is the same as the array type.
  out : ndarray, optional
      Alternate output array in which to place the result. It must have the same shape as the
      expected output, but the type is cast if necessary.
  ddof : int, optional
      “Delta Degrees of Freedom”: the divisor used in the calculation is N – ddof, where
      N represents the number of elements. By default ddof is zero.
  keepdims : bool, optional
      If this is set to True, the axes which are reduced are left in the result as dimensions with
      size one. With this option, the result will broadcast correctly against the original arr.

Returns
  variance : ndarray, see dtype parameter above
      If out=None, returns a new array containing the variance; otherwise, a reference to
      the output array is returned.

See also:
  std, mean, nanmean, nanstd, nanvar
  numpy.doc.ufuncs
      Section “Output arguments”

Notes
The variance is the average of the squared deviations from the mean, i.e., var = mean(abs(x –
x.mean())**2).

The mean is normally calculated as x.sum() / N, where N = len(x). If, however, ddof is specified, the
divisor N – ddof is used instead. In standard statistical practice, ddof=1 provides an unbiased estimator
of the variance of a hypothetic infinite population. ddof=0 provides a maximum likelihood estimate of the
variance for normally distributed variables.
Note that for complex numbers, the absolute value is taken before squaring, so that the result is always real and nonnegative.

For floating-point input, the variance is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the `dtype` keyword can alleviate this issue.

**Examples**

```python
g = np.array([[1,2],[3,4]])
np.var(g)  # Output: 1.25
np.var(g, axis=0)  # Output: array([ 1., 1.])
np.var(g, axis=1)  # Output: array([ 0.25, 0.25])
```

In single precision, `var()` can be inaccurate:

```python
g = np.zeros((2,512*512), dtype=np.float32)
g[0,:] = 1.0
ng[1,:] = 0.1
np.var(g)  # Output: 0.20405951142311096
```

Computing the variance in float64 is more accurate:

```python
g = np.zeros((2,512*512), dtype=np.float64)
g[0,:] = 1.0
ng[1,:] = 0.1
np.var(g)  # Output: 0.20249999932997387
```

**Minimum/maximum**

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<th>Description</th>
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<td><code>ma.argmax(a[, axis, fill_value])</code></td>
<td>Returns array of indices of the maximum values along the given axis. Masked values are treated as if they had the value <code>fill_value</code>.</td>
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<td><code>ma.argmin(a[, axis, fill_value])</code></td>
<td>Return array of indices to the minimum values along the given axis.</td>
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<tr>
<td><code>ma.max(obj[, axis, out, fill_value])</code></td>
<td>Return the maximum along a given axis.</td>
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<td><code>ma.min(obj[, axis, out, fill_value])</code></td>
<td>Return the minimum along a given axis.</td>
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<tr>
<td><code>ma.ptp(obj[, axis, out, fill_value])</code></td>
<td>Return (maximum - minimum) along the the given dimension (i.e. <code>np.ptp</code>).</td>
</tr>
<tr>
<td><code>ma.MaskedArray.argmax([axis, fill_value, out])</code></td>
<td>Returns array of indices of the maximum values along the given axis.</td>
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<td><code>ma.MaskedArray.argmin([axis, fill_value, out])</code></td>
<td>Return array of indices to the minimum values along the given axis.</td>
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<td><code>ma.MaskedArray.max([axis, out, fill_value])</code></td>
<td>Return the maximum along a given axis.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.min([axis, out, fill_value])</code></td>
<td>Return the minimum along a given axis.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.ptp([axis, out, fill_value])</code></td>
<td>Return (maximum - minimum) along the the given dimension (i.e. <code>np.ptp</code>).</td>
</tr>
</tbody>
</table>

**numpy.ma.argmax**

Returns array of indices of the maximum values along the given axis. Masked values are treated as if they had the value `fill_value`.

**Parameters**

- `axis` : {None, integer}
  - If None, the index is into the flattened array, otherwise along the specified axis
- `fill_value` : {var}, optional
  - Value used to fill in the masked values. If None, the output of maximum fill_value(self._data) is used instead.
out : {None, array}, optional

Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

Returns
index_array : {integer_array}

Examples
>>> a = np.arange(6).reshape(2,3)
>>> a.argmax()
5
>>> a.argmax(0)
array([1, 1, 1])
>>> a.argmax(1)
array([2, 2])

numpy.ma.argmin(a, axis=None, fill_value=None)

Return array of indices to the minimum values along the given axis.

Parameters
axis : {None, integer}

If None, the index is into the flattened array, otherwise along the specified axis
fill_value : {var}, optional

Value used to fill in the masked values. If None, the output of minimum_fill_value(self._data) is used instead.
out : {None, array}, optional

Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

Returns
{ndarray, scalar}

If multi-dimension input, returns a new ndarray of indices to the minimum values along the given axis. Otherwise, returns a scalar of index to the minimum values along the given axis.

Examples
>>> x = np.ma.array(arange(4), mask=[1,1,0,0])
>>> x.shape = (2,2)
>>> print x
[[-- --]
 [2 3]]
>>> print x.argmin(axis=0, fill_value=-1)
[0 0]
>>> print x.argmin(axis=0, fill_value=9)
[1 1]

numpy.ma.max(obj, axis=None, out=None, fill_value=None)

Return the maximum along a given axis.

Parameters
axis : {None, int}, optional

Axis along which to operate. By default, axis is None and the flattened input is used.
**out**: array_like, optional

Alternative output array in which to place the result. Must be of the same shape and
buffer length as the expected output.

**fill_value**: {var}, optional

Value used to fill in the masked values. If None, use the output of maximum_fill_value().

**Returns**

**amax**: array_like

New array holding the result. If `out` was specified, `out` is returned.

**See also:**

*maximum_fill_value*

Returns the maximum filling value for a given datatype.

**numpy.ma.min** *(obj=*, axis=*, out=*, fill_value=*)

Return the minimum along a given axis.

**Parameters**

**axis**: {None, int}, optional

Axis along which to operate. By default, `axis` is None and the flattened input is used.

**out**: array_like, optional

Alternative output array in which to place the result. Must be of the same shape and
buffer length as the expected output.

**fill_value**: {var}, optional

Value used to fill in the masked values. If None, use the output of minimum_fill_value().

**Returns**

**amin**: array_like

New array holding the result. If `out` was specified, `out` is returned.

**See also:**

*minimum_fill_value*

Returns the minimum filling value for a given datatype.

**numpy.ma.ptp** *(obj=*, axis=*, out=*, fill_value=*)

Return (maximum - minimum) along the the given dimension (i.e. peak-to-peak value).

**Parameters**

**axis**: {None, int}, optional

Axis along which to find the peaks. If None (default) the flattened array is used.

**out**: {None, array_like}, optional

Alternative output array in which to place the result. It must have the same shape and
buffer length as the expected output but the type will be cast if necessary.

**fill_value**: {var}, optional

Value used to fill in the masked values.
Returns

```
ptp : ndarray.
```

A new array holding the result, unless `out` was specified, in which case a reference to `out` is returned.

```
MaskedArray.argmax(axis=None, fill_value=None, out=None)
```

Returns array of indices of the maximum values along the given axis. Masked values are treated as if they had the value `fill_value`.

**Parameters**

- `axis` : {None, integer}
  
  If None, the index is into the flattened array, otherwise along the specified axis.

- `fill_value` : {var}, optional
  
  Value used to fill in the masked values. If None, the output of `maximum_fill_value(self._data)` is used instead.

- `out` : {None, array}, optional
  
  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**Returns**

```
index_array : {integer_array}
```

**Examples**

```python
>>> a = np.arange(6).reshape(2,3)
>>> a.argmax()
5
>>> a.argmax(0)
array([1, 1, 1])
>>> a.argmax(1)
array([2, 2])
```

```
MaskedArray.argmin(axis=None, fill_value=None, out=None)
```

Return array of indices to the minimum values along the given axis.

**Parameters**

- `axis` : {None, integer}
  
  If None, the index is into the flattened array, otherwise along the specified axis.

- `fill_value` : {var}, optional
  
  Value used to fill in the masked values. If None, the output of `minimum_fill_value(self._data)` is used instead.

- `out` : {None, array}, optional
  
  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**Returns**

```
{ndarray, scalar}
```

If multi-dimension input, returns a new `ndarray` of indices to the minimum values along the given axis. Otherwise, returns a scalar of index to the minimum values along the given axis.
Examples

```python
>>> x = np.ma.array(arange(4), mask=[1,1,0,0])
>>> x.shape = (2,2)
>>> print x
[[-- --]
 [2 3]]
>>> print x.argmin(axis=0, fill_value=-1)
[0 0]
>>> print x.argmin(axis=0, fill_value=9)
[1 1]
```

MaskedArray.**max** *(**axis=None**, **out=None**, **fill_value=None**)*

Return the maximum along a given axis.

**Parameters**

- **axis** : {None, int}, optional
  Axis along which to operate. By default, **axis** is None and the flattened input is used.

- **out** : array_like, optional
  Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output.

- **fill_value** : {var}, optional
  Value used to fill in the masked values. If None, use the output of maximum_fill_value().

**Returns**

- **amax** : array_like
  New array holding the result. If **out** was specified, **out** is returned.

See also:

**maximum_fill_value**
Returns the maximum filling value for a given datatype.

MaskedArray.**min** *(**axis=None**, **out=None**, **fill_value=None**)*

Return the minimum along a given axis.

**Parameters**

- **axis** : {None, int}, optional
  Axis along which to operate. By default, **axis** is None and the flattened input is used.

- **out** : array_like, optional
  Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output.

- **fill_value** : {var}, optional
  Value used to fill in the masked values. If None, use the output of minimum_fill_value().

**Returns**

- **amin** : array_like
  New array holding the result. If **out** was specified, **out** is returned.

See also:
minimum_fill_value
Returns the minimum filling value for a given datatype.

MaskedArray.ptp(axis=None, out=None, fill_value=None)
Return (maximum - minimum) along the the given dimension (i.e. peak-to-peak value).

Parameters
axis : {None, int}, optional
   Axis along which to find the peaks. If None (default) the flattened array is used.
out : {None, array_like}, optional
   Alternative output array in which to place the result. It must have the same shape and
   buffer length as the expected output but the type will be cast if necessary.
fill_value : {var}, optional
   Value used to fill in the masked values.

Returns
ptp : ndarray.
   A new array holding the result, unless out was specified, in which case a reference to
   out is returned.

Sorting

ma.argsort(a[, axis, kind, order, fill_value])
Return an ndarray of indices that sort the array along the specified axis.

ma.sort(a[, axis, kind, order, endwith, ...])
Sort the array, in-place :Parameters:
a : array_like to be sorted.

ma.MaskedArray.argsort([axis, kind, order, ...])
Return an ndarray of indices that sort the array along the specified axis.

ma.MaskedArray.sort([axis, kind, order, ...])
Sort the array, in-place :Parameters:
a : array_like to be sorted.

numpy.ma.argsort(a, axis=None, kind='quicksort', order=None, fill_value=None)
Return an ndarray of indices that sort the array along the specified axis. Masked values are filled beforehand to
fill_value.

Parameters
axis : int, optional
   Axis along which to sort. The default is -1 (last axis). If None, the flattened array is
   used.
fill_value : var, optional
   Value used to fill the array before sorting. The default is the fill_value attribute of the
   input array.
kind : {'quicksort', 'mergesort', 'heapsort'}, optional
   Sorting algorithm.
order : list, optional
   When a is an array with fields defined, this argument specifies which fields to compare
   first, second, etc. Not all fields need be specified.

Returns
index_array : ndarray, int
   Array of indices that sort a along the specified axis. In other words, a[index_array] yields a sorted a.
See also:

**sort**
Describes sorting algorithms used.

**lexsort**
Indirect stable sort with multiple keys.

**ndarray.sort**
Inplace sort.

**Notes**
See sort for notes on the different sorting algorithms.

**Examples**

```python
>>> a = np.ma.array([3,2,1], mask=[False, False, True])
```
```
>>> a
masked_array(data = [3 2 --],
              mask = [False False True],
              fill_value = 999999)
```
```
>>> a.argsort()
array([1, 0, 2])
```
```
numpy.ma.sort(a, axis=None, kind='quicksort', order=None, endwith=True, fill_value=None)
```
Sort the array, in-place

**Parameters**

- **a**: array_like
  Array to be sorted.

- **axis**: int, optional
  Axis along which to sort. If None, the array is flattened before sorting. The default is -1, which sorts along the last axis.

- **kind**: {'quicksort', 'mergesort', 'heapsort'}, optional
  Sorting algorithm. Default is ‘quicksort’.

- **order**: list, optional
  When a is a structured array, this argument specifies which fields to compare first, second, and so on. This list does not need to include all of the fields.

- **endwith**: {True, False}, optional
  Whether missing values (if any) should be forced in the upper indices (at the end of the array) (True) or lower indices (at the beginning). When the array contains unmasked values of the largest (or smallest if False) representable value of the datatype the ordering of these values and the masked values is undefined. To enforce the masked values are at the end (beginning) in this case one must sort the mask.

- **fill_value**: {var}, optional
  Value used internally for the masked values. If fill_value is not None, it supersedes endwith.

**Returns**

- **sorted_array**: ndarray
  Array of the same type and shape as a.
See also:

* `ndarray.sort`  
  Method to sort an array in-place.

* `argsort`  
  Indirect sort.

* `lexsort`  
  Indirect stable sort on multiple keys.

* `searchsorted`  
  Find elements in a sorted array.

Notes

See `sort` for notes on the different sorting algorithms.

Examples

```python
>>> a = ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # Default
>>> a.sort()
>>> print a
[1 3 5 -- --]

>>> a = ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # Put missing values in the front
>>> a.sort(endwith=False)
>>> print a
[-- -- 1 3 5]

>>> a = ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # fill_value takes over endwith
>>> a.sort(endwith=False, fill_value=3)
>>> print a
[1 -- -- 3 5]
```

MaskedArray `argsort` *(axis=None, kind='quicksort', order=None, fill_value=None)*

Return an ndarray of indices that sort the array along the specified axis. Masked values are filled beforehand to `fill_value`.

Parameters

- `axis` : int, optional
  Axis along which to sort. The default is -1 (last axis). If None, the flattened array is used.

- `fill_value` : var, optional
  Value used to fill the array before sorting. The default is the `fill_value` attribute of the input array.

- `kind` : {'quicksort', 'mergesort', 'heapsort'}, optional
  Sorting algorithm.

- `order` : list, optional
  When `a` is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.
Returns

index_array : ndarray, int

Array of indices that sort a along the specified axis. In other words, a[index_array] yields a sorted a.

See also:

sort
Describes sorting algorithms used.

lexsort
Indirect stable sort with multiple keys.

ndarray.sort
Inplace sort.

Notes

See sort for notes on the different sorting algorithms.

Examples

>>> a = np.ma.array([3, 2, 1], mask=[False, False, True])
>>> a
masked_array(data = [3 2 --],
             mask = [False False True],
             fill_value = 999999)
>>> a.argsort()
array([1, 0, 2])

MaskedArray.sort (axis=-1, kind='quicksort', order=None, endwith=True, fill_value=None)
Sort the array, in-place

Parameters

a : array_like

Array to be sorted.

axis : int, optional

Axis along which to sort. If None, the array is flattened before sorting. The default is -1, which sorts along the last axis.

kind : {'quicksort', 'mergesort', 'heapsort'}, optional

Sorting algorithm. Default is 'quicksort'.

order : list, optional

When a is a structured array, this argument specifies which fields to compare first, second, and so on. This list does not need to include all of the fields.

endwith : {True, False}, optional

Whether missing values (if any) should be forced in the upper indices (at the end of the array) (True) or lower indices (at the beginning). When the array contains unmasked values of the largest (or smallest if False) representable value of the datatype the ordering of these values and the masked values is undefined. To enforce the masked values are at the end (beginning) in this case one must sort the mask.

fill_value : {var}, optional
Value used internally for the masked values. If `fill_value` is not None, it supersedes `endwith`.

**Returns**

- `sorted_array` : ndarray

  Array of the same type and shape as `a`.

**See also:**

- `ndarray.sort`
  Method to sort an array in-place.
- `argsort`
  Indirect sort.
- `lexsort`
  Indirect stable sort on multiple keys.
- `searchsorted`
  Find elements in a sorted array.

**Notes**

See `sort` for notes on the different sorting algorithms.

**Examples**

```python
g = ma.array([1, 2, 5, 4, 3], mask=[0, 1, 0, 1, 0])
```

```
>>> # Default
>>> g.sort()
>>> print g
[1 3 5 -- --]
```

```
>>> g = ma.array([1, 2, 5, 4, 3], mask=[0, 1, 0, 1, 0])
>>> # Put missing values in the front
>>> g.sort(endwith=False)
>>> print g
[-- -- 1 3 5]
```

```
>>> g = ma.array([1, 2, 5, 4, 3], mask=[0, 1, 0, 1, 0])
>>> # fill_value takes over endwith
>>> g.sort(endwith=False, fill_value=3)
>>> print g
[1 -- -- 3 5]
```

**Algebra**

| `.diag(v[, k])` | Extract a diagonal or construct a diagonal array. |
| `.dot(a, b[, strict])` | Return the dot product of two arrays. |
| `.identity(n[, dtype])` | Return the identity array. |
| `.inner(a, b)` | Inner product of two arrays. |
| `.outerproduct(a, b)` | Inner product of two arrays. |
| `.outer(a, b)` | Compute the outer product of two vectors. |
| `.trace(self[, offset, axis1, axis2, ...])` | Compute the outer product of two vectors. |
| `.transpose(a[, axes])` | Return the sum along diagonals of the array. |
| `.MaskedArray.trace([offset, axis1, axis2, ...])` | Permute the dimensions of an array. |

| `.MaskedArray.trace([offset, axis1, axis2, ...])` | Return the sum along diagonals of the array. |

Continued on next page
Table 1.98 – continued from previous page

| ma.MaskedArray.transpose(*axes) | Returns a view of the array with axes transposed. |

`numpy.ma.diagonal(v, k=0)`

Extract a diagonal or construct a diagonal array.

This function is the equivalent of `numpy.diag` that takes masked values into account, see `numpy.diag` for details.

See also:

`numpy.diag`

Equivalent function for ndarrays.

`numpy.ma.dot(a, b, strict=False)`

Return the dot product of two arrays.

**Note:** Works only with 2-D arrays at the moment.

This function is the equivalent of `numpy.dot` that takes masked values into account, see `numpy.dot` for details.

**Parameters**

- `a, b`: ndarray
  Inputs arrays.

- `strict`: bool, optional
  Whether masked data are propagated (True) or set to 0 (False) for the computation. Default is False. Propagating the mask means that if a masked value appears in a row or column, the whole row or column is considered masked.

See also:

`numpy.dot`

Equivalent function for ndarrays.

**Examples**

```python
>>> a = ma.array([[1, 2, 3], [4, 5, 6]], mask=[[1, 0, 0], [0, 0, 0]])
>>> np.ma.dot(a, b)
mixed_array(data =
[[21 26]
 [45 64]],
mask =
[[False False]
 [True False]],
fill_value = 999999)
```

```python
>>> np.ma.dot(a, b, strict=True)
mixed_array(data =
[[-- --]
[-- 64]],
mask =
[[ True True]
[ True False]],
fill_value = 999999)
```
numpy.ma.identity (n, dtype=None) = <numpy.ma.core._convert2ma instance at 0x4243fbac>

Return the identity array.

The identity array is a square array with ones on the main diagonal.

Parameters
n : int
   Number of rows (and columns) in n x n output.
dtype : data-type, optional
   Data-type of the output. Defaults to float.

Returns
out : ndarray
   n x n array with its main diagonal set to one, and all other elements 0.

Examples
>>> np.identity(3)
array([[ 1.,  0.,  0.],
       [ 0.,  1.,  0.],
       [ 0.,  0.,  1.]])

numpy.ma.inner(a, b)

Inner product of two arrays.

Ordinary inner product of vectors for 1-D arrays (without complex conjugation), in higher dimensions a sum
product over the last axes.

Parameters
a, b : array_like
   If a and b are nonscalar, their last dimensions of must match.

Returns
out : ndarray
   out.shape = a.shape[:-1] + b.shape[:-1]

Raises
ValueError
   If the last dimension of a and b has different size.

See also:
tensordot
   Sum products over arbitrary axes.
dot
   Generalised matrix product, using second last dimension of b.
einsum
   Einstein summation convention.

Notes
Masked values are replaced by 0.
**Examples**

Ordinary inner product for vectors:

```python
>>> a = np.array([1, 2, 3])
>>> b = np.array([0, 1, 0])
>>> np.inner(a, b)
2
```

A multidimensional example:

```python
>>> a = np.arange(24).reshape((2,3,4))
>>> b = np.arange(4)
>>> np.inner(a, b)
array([[ 14,  38,  62],
       [ 86, 110, 134]])
```

An example where \(b\) is a scalar:

```python
>>> np.inner(np.eye(2), 7)
array([[ 7.,  0.],
       [ 0.,  7.]])
```

`numpy.ma.innerproduct(a, b)`

Inner product of two arrays.

Ordinary inner product of vectors for 1-D arrays (without complex conjugation), in higher dimensions a sum product over the last axes.

**Parameters**

- `a, b : array_like`
  
  If \(a\) and \(b\) are nonscalar, their last dimensions of must match.

**Returns**

- `out : ndarray`
  
  \(out.shape = a.shape[:-1] + b.shape[:-1]\)

**Raises**

- `ValueError`
  
  If the last dimension of \(a\) and \(b\) has different size.

**See also:**

- `tensordot`
  
  Sum products over arbitrary axes.

- `dot`
  
  Generalised matrix product, using second last dimension of \(b\).

- `einsum`
  
  Einstein summation convention.

**Notes**

Masked values are replaced by 0.

**Examples**

Ordinary inner product for vectors:
>>> a = np.array([1,2,3])
>>> b = np.array([0,1,0])
>>> np.inner(a, b)
2

A multidimensional example:

>>> a = np.arange(24).reshape((2,3,4))
>>> b = np.arange(4)
>>> np.inner(a, b)
array([[ 14, 38, 62],
       [ 86, 110, 134]])

An example where \(b\) is a scalar:

>>> np.inner(np.eye(2), 7)
array([[ 7., 0.],
       [ 0., 7.]])

\texttt{numpy.ma.outer}(a, b)

Compute the outer product of two vectors.

Given two vectors, \(a = [a_0, a_1, \ldots, a_M]\) and \(b = [b_0, b_1, \ldots, b_N]\), the outer product \([R50]\) is:

\[
\begin{bmatrix}
a_0 b_0 & a_0 b_1 & \cdots & a_0 b_N \\
a_1 b_0 & \cdots & & \\
\vdots & & & \\
a_M b_0 & & & a_M b_N
\end{bmatrix}
\]

Parameters

- \(a\) : \((M,)\) array_like
  - First input vector. Input is flattened if not already 1-dimensional.

- \(b\) : \((N,)\) array_like
  - Second input vector. Input is flattened if not already 1-dimensional.

- \(\text{out}\) : \((M, N)\) ndarray, optional
  - A location where the result is stored
  
  New in version 1.9.0.

Returns

- \(\text{out}\) : \((M, N)\) ndarray
  
  \(\text{out}[i, j] = a[i] * b[j]\)

See also:

- \texttt{inner}, \texttt{einsum}

Notes

Masked values are replaced by 0.

References

\cite{R50}
Examples

Make a (very coarse) grid for computing a Mandelbrot set:

```python
>>> rl = np.outer(np.ones((5,)), np.linspace(-2, 2, 5))
```

```python
array([[-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.])
```

```python
>>> im = np.outer(1j*np.linspace(2, -2, 5), np.ones((5,)))
```

```python
array([[ 0.+2.j,  0.+2.j,  0.+2.j,  0.+2.j,  0.+2.j],
       [ 0.+1.j,  0.+1.j,  0.+1.j,  0.+1.j,  0.+1.j],
       [ 0.+0.j,  0.+0.j,  0.+0.j,  0.+0.j,  0.+0.j],
       [ 0.-1.j,  0.-1.j,  0.-1.j,  0.-1.j,  0.-1.j],
       [ 0.-2.j,  0.-2.j,  0.-2.j,  0.-2.j,  0.-2.j]])
```

```python
>>> grid = rl + im
```

```python
array([[-2.+2.j, -1.+2.j,  0.+2.j,  1.+2.j,  2.+2.j],
       [-2.+1.j, -1.+1.j,  0.+1.j,  1.+1.j,  2.+1.j],
       [-2.+0.j, -1.+0.j,  0.+0.j,  1.+0.j,  2.+0.j],
       [-2.-1.j, -1.-1.j,  0.-1.j,  1.-1.j,  2.-1.j],
       [-2.-2.j, -1.-2.j,  0.-2.j,  1.-2.j,  2.-2.j]])
```

An example using a “vector” of letters:

```python
>>> x = np.array(['a', 'b', 'c'], dtype=object)
```

```python
array([['a', 'aa', 'aaa'],
       ['b', 'bb', 'bbb'],
       ['c', 'cc', 'ccc']], dtype=object)
```

numpy.ma.outerproduct(a, b)

Compute the outer product of two vectors.

Given two vectors, \(a = [a_0, a_1, \ldots, a_M]\) and \(b = [b_0, b_1, \ldots, b_N]\), the outer product \([R51]\) is:

\[
\begin{bmatrix}
[a_0*b_0 & a_0*b_1 & \ldots & a_0*b_N \\
a_1*b_0 & \ldots & \ldots & \ldots \\
\vdots & \vdots & \ddots & \vdots \\
a_M*b_0 & \ldots & \ldots & a_M*b_N
\end{bmatrix}
\]

Parameters

- **a** : (M,) array_like
  
  First input vector. Input is flattened if not already 1-dimensional.

- **b** : (N,) array_like
  
  Second input vector. Input is flattened if not already 1-dimensional.

- **out** : (M, N) ndarray, optional
  
  A location where the result is stored

  New in version 1.9.0.

Returns

- **out** : (M, N) ndarray
out[i, j] = a[i] * b[j]

See also:

inner, einsum

Notes

Masked values are replaced by 0.

References

[R51]

Examples

Make a (very coarse) grid for computing a Mandelbrot set:

```python
>>> r1 = np.outer(np.ones((5,)), np.linspace(-2, 2, 5))
>>> r1
array([[-2., -1., 0., 1., 2.],
       [-2., -1., 0., 1., 2.],
       [-2., -1., 0., 1., 2.],
       [-2., -1., 0., 1., 2.],
       [-2., -1., 0., 1., 2.]]
>>> im = np.outer(1j*np.linspace(2, -2, 5), np.ones((5,)))
>>> im
array([[-2.+2.j, -1.+2.j, 0.+2.j, 1.+2.j, 2.+2.j],
       [-2.+1.j, -1.+1.j, 0.+1.j, 1.+1.j, 2.+1.j],
       [-2.+0.j, -1.+0.j, 0.+0.j, 1.+0.j, 2.+0.j],
       [-2.-1.j, -1.-1.j, 0.-1.j, 1.-1.j, 2.-1.j],
       [-2.-2.j, -1.-2.j, 0.-2.j, 1.-2.j, 2.-2.j]])
>>> grid = r1 + im
>>> grid
array([[-2.+2.j, -1.+2.j, 0.+2.j, 1.+2.j, 2.+2.j],
       [-2.+1.j, -1.+1.j, 0.+1.j, 1.+1.j, 2.+1.j],
       [-2.+0.j, -1.+0.j, 0.+0.j, 1.+0.j, 2.+0.j],
       [-2.-1.j, -1.-1.j, 0.-1.j, 1.-1.j, 2.-1.j],
       [-2.-2.j, -1.-2.j, 0.-2.j, 1.-2.j, 2.-2.j]])
```

An example using a “vector” of letters:

```python
>>> x = np.array([‘a’, ‘b’, ‘c’], dtype=object)
>>> np.outer(x, [1, 2, 3])
array([[‘a’, ‘aa’, ‘aaa’],
       [‘b’, ‘bb’, ‘bbb’],
       [‘c’, ‘cc’, ‘ccc’]], dtype=object)
```

```
return numpy.ma.trace

narray(self, offset=0, axisl=0, axis2=1, dtype=None, out=None)
```

```
= <numpy.ma.core._frommethod instance at 0x4243f84c>
```

Return the sum along diagonals of the array.

Refer to `numpy.trace` for full documentation.

See also:

`numpy.trace`

equivalent function
numpy.ma.transpose(a, axes=None)
   Permute the dimensions of an array.

   This function is exactly equivalent to numpy.transpose.

   See also:

   * numpy.transpose
     Equivalent function in top-level NumPy module.

   Examples

   >>> import numpy.ma as ma
   >>> x = ma.arange(4).reshape((2,2))
   >>> x[1, 1] = ma.masked
   >>> x
   masked_array(data =
   [[0 1]
    [2 --]],
   mask =
   [[False False]
    [False  True]],
   fill_value = 999999)
   >>> ma.transpose(x)
   masked_array(data =
   [[0 2]
    [1 --]],
   mask =
   [[False False]
    [False  True]],
   fill_value = 999999)

MaskedArray.trace(offset=0, axis1=0, axis2=1, dtype=None, out=None)
   Return the sum along diagonals of the array.

   Refer to numpy.trace for full documentation.

   See also:

   * numpy.trace
     equivalent function

MaskedArray.transpose(*axes)
   Returns a view of the array with axes transposed.

   For a 1-D array, this has no effect. (To change between column and row vectors, first cast the 1-D array into a matrix object.) For a 2-D array, this is the usual matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided and a.shape = (i[0], i[1], ... i[n-2], i[n-1]), then a.transpose().shape = (i[n-1], i[n-2], ... i[1], i[0]).

   Parameters

   axes : None, tuple of ints, or n ints
      * None or no argument: reverses the order of the axes.
      * tuple of ints: i in the j-th place in the tuple means a’s i-th axis becomes a.transpose()’s j-th axis.
      * n ints: same as an n-tuple of the same ints (this form is intended simply as a “convenience” alternative to the tuple form)
Returns

\texttt{out} : \texttt{ndarray}

View of \( a \), with axes suitably permuted.

See also:

\texttt{ndarray.T}

Array property returning the array transposed.

Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
        [3, 4]])
>>> a.transpose()
array([[1, 3],
        [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
        [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
        [2, 4]])
```

Polynomial fit

\texttt{ma.vander(x[, n])} Generate a Vandermonde matrix.

\texttt{ma.polyfit(x, y, deg[, rcond, full, w, cov])} Least squares polynomial fit.

\texttt{numpy.ma.vander (x, n=None)}

Generate a Vandermonde matrix.

The columns of the output matrix are powers of the input vector. The order of the powers is determined by the \texttt{increasing} boolean argument. Specifically, when \texttt{increasing} is False, the \( i \)-th output column is the input vector raised element-wise to the power of \( N - i - 1 \). Such a matrix with a geometric progression in each row is named for Alexandre- Theophile Vandermonde.

Parameters

- \( x \) : array_like
  1-D input array.

- \( N \) : int, optional
  Number of columns in the output. If \( N \) is not specified, a square array is returned \((N = \text{len}(x))\).

- \texttt{increasing} : bool, optional
  Order of the powers of the columns. If True, the powers increase from left to right, if False (the default) they are reversed.

New in version 1.9.0.

Returns

- \texttt{out} : \texttt{ndarray}
Vandermonde matrix. If `increasing` is False, the first column is \(x^{(N-1)}\), the second \(x^{(N-2)}\) and so forth. If `increasing` is True, the columns are \(x^0, x^1, \ldots, x^{(N-1)}\).

See also:

`numpy.polynomial.polynomial.polyvander`

Notes

Masked values in the input array result in rows of zeros.

Examples

```python
g = np.array([1, 2, 3, 5])
g = np.vander(g, N)
g = np.column_stack([g**(N-1-i) for i in range(N)])
g = np.vander(g)
g = np.vander(g, increasing=True)
```

```python
np.linalg.det(np.vander(g))
```

```
48.000000000000043
```
y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

**deg**: int

Degree of the fitting polynomial

**rcond**: float, optional

Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

**full**: bool, optional

Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

**w**: array_like, shape (M,), optional

weights to apply to the y-coordinates of the sample points.

**cov**: bool, optional

Return the estimate and the covariance matrix of the estimate. If full is True, then cov is not returned.

**Returns**

**p**: ndarray, shape (M,) or (M, K)

Polynomial coefficients, highest power first. If y was 2-D, the coefficients for k-th data set are in p[:,k].

residuals, rank, singular_values, rcond :

Present only if full = True. Residuals of the least-squares fit, the effective rank of the scaled Vandermonde coefficient matrix, its singular values, and the specified value of rcond. For more details, see linalg.lstsq.

**V**: ndarray, shape (M,M) or (M,M,K)

Present only if full = False and cov=True. The covariance matrix of the polynomial coefficient estimates. The diagonal of this matrix are the variance estimates for each coefficient. If y is a 2-D array, then the covariance matrix for the ‘k’-th data set are in V[:,:,k]

**Warns**

**RankWarning**

The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if full = False.

The warnings can be turned off by

```python
>>> import warnings
>>> warnings.simplefilter('ignore', np.RankWarning)
```

**See also:**

**polyval**

Computes polynomial values.
linalg.lstsq
Computes a least-squares fit.

scipy.interpolate.UnivariateSpline
Computes spline fits.

Notes
Any masked values in x is propagated in y, and vice-versa.

References
[R52], [R53]

Examples
>>> x = np.array([0.0, 1.0, 2.0, 3.0, 4.0, 5.0])
>>> y = np.array([0.0, 0.8, 0.9, 0.1, -0.8, -1.0])
>>> z = np.polyfit(x, y, 3)
>>> z
array([ 0.08703704, -0.81349206, 1.69312169, -0.03968254])

It is convenient to use poly1d objects for dealing with polynomials:
>>> p = np.poly1d(z)
>>> p(0.5)
0.6143849206349179
>>> p(3.5)
-0.34732142857143039
>>> p(10)
22.579365079365115

High-order polynomials may oscillate wildly:
>>> p30 = np.poly1d(np.polyfit(x, y, 30))
/... RankWarning: Polyfit may be poorly conditioned...
>>> p30(4)
-0.80000000000000204
>>> p30(5)
-0.99999999999999445
>>> p30(4.5)
-0.10547061179440398

Illustration:
>>> import matplotlib.pyplot as plt
>>> xp = np.linspace(-2, 6, 100)
>>> _ = plt.plot(x, y, '.', xp, p(xp), '-', xp, p30(xp), '--')
>>> plt.ylim(-2, 2)
(-2, 2)
>>> plt.show()
### Clipping and rounding

<table>
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<tr>
<td><code>ma.around(a, a_min, a_max[, out])</code></td>
<td>Clip (limit) the values in an array.</td>
</tr>
<tr>
<td><code>ma.round(a[, decimals, out])</code></td>
<td>Return a copy of a, rounded to 'decimals' places.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.clip(a_min, a_max[, out])</code></td>
<td>Return an array whose values are limited to [a_min, a_max].</td>
</tr>
<tr>
<td><code>ma.MaskedArray.round([decimals, out])</code></td>
<td>Return a with each element rounded to the given number of decimals.</td>
</tr>
</tbody>
</table>

```
numpy.ma.around = <numpy.ma.core._MaskedUnaryOperation instance at 0x42430e0c>
```

Round an array to the given number of decimals.

Refer to `around` for full documentation.

See also:

- `around`
- equivalent function

```
numpy.ma.clip (a, a_min, a_max, out=None)
```

Clip (limit) the values in an array.

Given an interval, values outside the interval are clipped to the interval edges. For example, if an interval of [0, 1] is specified, values smaller than 0 become 0, and values larger than 1 become 1.

**Parameters**

- **a** : array_like
  - Array containing elements to clip.

- **a_min** : scalar or array_like
  - Minimum value.

- **a_max** : scalar or array_like
  - Maximum value. If `a_min` or `a_max` are array_like, then they will be broadcasted to the shape of a.

- **out** : ndarray, optional
The results will be placed in this array. It may be the input array for in-place clipping. 
\(out\) must be of the right shape to hold the output. Its type is preserved.

**Returns**
- **clipped_array**: ndarray
  - An array with the elements of \(a\), but where values < \(a_{\text{min}}\) are replaced with \(a_{\text{min}}\), and those > \(a_{\text{max}}\) with \(a_{\text{max}}\).

**See also:**
- `numpy.ufuncs`
- Section “Output arguments”

**Examples**
```python
>>> a = np.arange(10)
>>> np.clip(a, 1, 8)
array([1, 1, 2, 3, 4, 5, 6, 7, 8, 8])
```
```python
>>> np.clip(a, 3, 6, out=a)  # in-place clipping
array([3, 3, 3, 3, 4, 5, 6, 6, 6, 6])
```
```python
>>> a = np.arange(10)
>>> np.clip(a, [3,4,1,1,1,4,4,4,4,4], 8)
array([3, 4, 2, 3, 4, 5, 6, 7, 8, 8])
```

**numpy.ma.round\((a, decimals=0, out=None)\)**
- Return a copy of \(a\), rounded to ‘decimals’ places.

  When ‘decimals’ is negative, it specifies the number of positions to the left of the decimal point. The real and imaginary parts of complex numbers are rounded separately. Nothing is done if the array is not of float type and ‘decimals’ is greater than or equal to 0.

**Parameters**
- **decimals**: int
  - Number of decimals to round to. May be negative.
- **out**: array_like
  - Existing array to use for output. If not given, returns a default copy of \(a\).

**Notes**
- If out is given and does not have a mask attribute, the mask of \(a\) is lost!

**MaskedArray.clip\((a_{\text{min}}, a_{\text{max}}, out=None)\)**
- Return an array whose values are limited to \([a_{\text{min}}, a_{\text{max}}]\).

  Refer to `numpy.clip` for full documentation.

**See also:**
- `numpy.clip`
- equivalent function

**MaskedArray.round\((decimals=0, out=None)\)**
- Return \(a\) with each element rounded to the given number of decimals.
Refer to `numpy.around` for full documentation.

See also:

`numpy.around`

 equivalent function

**Miscellanea**

<table>
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<tr>
<th>Function</th>
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<td><code>ma.allequal(a, b[, fill_value])</code></td>
<td>Return True if all entries of a and b are equal, using fill_value as a truth value where either or both are masked.</td>
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<tr>
<td><code>ma.allclose(a, b[, masked_equal, rtol, atol])</code></td>
<td>Returns True if two arrays are element-wise equal within a tolerance.</td>
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<tr>
<td><code>ma.apply_along_axis(func1d, axis, arr[, ...])</code></td>
<td>Apply a function to 1-D slices along the given axis.</td>
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<td><code>ma.arange([start[, stop[, step[, dtype]]]])</code></td>
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<td><code>ma.choose(indices, choices[, out, mode])</code></td>
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<td><code>ma.where(condition[, x, y])</code></td>
<td>Return a masked array with elements from x or y, depending on condition.</td>
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**numpy.ma.allequal (a, b, fill_value=True)**

Return True if all entries of a and b are equal, using fill_value as a truth value where either or both are masked.

**Parameters**

- `a, b`: array_like
  - Input arrays to compare.
- `fill_value`: bool, optional
  - Whether masked values in a or b are considered equal (True) or not (False).

**Returns**

- `y`: bool
  - Returns True if the two arrays are equal within the given tolerance, False otherwise. If either array contains NaN, then False is returned.

See also:

`all, any, numpy.ma.allclose`

**Examples**

```python
>>> a = ma.array([1e10, 1e-7, 42.0], mask=[0, 0, 1])
>>> a
masked_array(data = [10000000000. 1e-07 --],
             mask = [False False True],
             fill_value=1e+20)

>>> b = array([1e10, 1e-7, -42.0])
>>> b
array([ 1.00000000e+10,  1.00000000e-07, -4.20000000e+01])
>>> ma.allequal(a, b, fill_value=False)
False
>>> ma.allequal(a, b)
True
```

**numpy.ma.allclose (a, b, masked_equal=True, rtol=1e-05, atol=1e-08)**

Returns True if two arrays are element-wise equal within a tolerance.
This function is equivalent to `allclose` except that masked values are treated as equal (default) or unequal, depending on the `masked_equal` argument.

**Parameters**
- `a, b` : array_like
  Input arrays to compare.
- `masked_equal` : bool, optional
  Whether masked values in `a` and `b` are considered equal (True) or not (False). They are considered equal by default.
- `rtol` : float, optional
  Relative tolerance. The relative difference is equal to `rtol * b`. Default is 1e-5.
- `atol` : float, optional
  Absolute tolerance. The absolute difference is equal to `atol`. Default is 1e-8.

**Returns**
- `y` : bool
  Returns True if the two arrays are equal within the given tolerance, False otherwise. If either array contains NaN, then False is returned.

**See also:**
- `all`
- `any`
- `numpy.allclose`
  the non-masked `allclose`.

**Notes**
If the following equation is element-wise True, then `allclose` returns True:

\[
\text{absolute}(\text{a} - \text{b}) \leq (\text{atol} + \text{rtol} \times \text{absolute}(\text{b}))
\]

Return True if all elements of `a` and `b` are equal subject to given tolerances.

**Examples**
```python
>>> a = ma.array([1e10, 1e-7, 42.0], mask=[0, 0, 1])
>>> a
masked_array(data = [10000000000.0 1e-07 --],
             mask = [False False True],
             fill_value = 1e+20)
>>> b = ma.array([1e10, 1e-8, -42.0], mask=[0, 0, 1])
>>> ma.allclose(a, b)
False
```
```python
>>> a = ma.array([1e10, 1e-8, 42.0], mask=[0, 0, 1])
>>> b = ma.array([1.00001e10, 1e-9, 42.0], mask=[0, 0, 1])
>>> ma.allclose(a, b)
True
```
```python
>>> ma.allclose(a, b, masked_equal=False)
False
```

Masked values are not compared directly.
```python
>>> a = ma.array([1e10, 1e-8, 42.0], mask=[0, 0, 1])
>>> b = ma.array([1.00001e10, 1e-9, 42.0], mask=[0, 0, 1])
>>> ma.allclose(a, b)
True
>>> ma.allclose(a, b, masked_equal=False)
False
```

```
numpy.ma.apply_along_axis(func1d, axis, arr, *args, **kwargs)

Apply a function to 1-D slices along the given axis.

Execute `func1d(a, *args)` where `func1d` operates on 1-D arrays and `a` is a 1-D slice of `arr` along `axis`.

Parameters

func1d : function
    This function should accept 1-D arrays. It is applied to 1-D slices of `arr` along the specified axis.

axis : integer
    Axis along which `arr` is sliced.

arr : ndarray
    Input array.

args : any
    Additional arguments to `func1d`.

kwargs : any
    Additional named arguments to `func1d`.

New in version 1.9.0.

Returns

apply_along_axis : ndarray
    The output array. The shape of `outarr` is identical to the shape of `arr`, except along the `axis` dimension, where the length of `outarr` is equal to the size of the return value of `func1d`. If `func1d` returns a scalar `outarr` will have one fewer dimensions than `arr`.

See also:

apply_over_axes
    Apply a function repeatedly over multiple axes.

Examples

```python
>>> def my_func(a):
...     '''Average first and last element of a 1-D array'''
...     return (a[0] + a[-1]) * 0.5
>>> b = np.array([[1,2,3], [4,5,6], [7,8,9]])
>>> np.apply_along_axis(my_func, 0, b)
array([ 4.,  5.,  6.])
>>> np.apply_along_axis(my_func, 1, b)
array([ 2.,  5.,  8.])
```

For a function that doesn’t return a scalar, the number of dimensions in `outarr` is the same as `arr`.
```
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>>> b = np.array([[8, 1, 7], [4, 3, 9], [5, 2, 6]])
>>> np.apply_along_axis(sorted, 1, b)
array([[1, 7, 8],
       [3, 4, 9],
       [2, 5, 6]])

numpy.ma.arange([start], stop[, step[, dtype=None]]) = <numpy.ma.core._convert2ma instance at 0x4243fa4c>

Return evenly spaced values within a given interval.

Values are generated within the half-open interval [start, stop) (in other words, the interval including start but excluding stop). For integer arguments the function is equivalent to the Python built-in range function, but returns an ndarray rather than a list.

When using a non-integer step, such as 0.1, the results will often not be consistent. It is better to use linspace for these cases.

Parameters

start : number, optional
    Start of interval. The interval includes this value. The default start value is 0.

stop : number
    End of interval. The interval does not include this value, except in some cases where step is not an integer and floating point round-off affects the length of out.

step : number, optional
    Spacing between values. For any output out, this is the distance between two adjacent values, out[i+1] - out[i]. The default step size is 1. If step is specified, start must also be given.

dtype : dtype
    The type of the output array. If dtype is not given, infer the data type from the other input arguments.

Returns

arange : ndarray
    Array of evenly spaced values.

For floating point arguments, the length of the result is ceil((stop - start)/step). Because of floating point overflow, this rule may result in the last element of out being greater than stop.

See also:

linspace
    Evenly spaced numbers with careful handling of endpoints.

ogrid
    Arrays of evenly spaced numbers in N-dimensions.

mgrid
    Grid-shaped arrays of evenly spaced numbers in N-dimensions.

Examples

>>> np.arange(3)
array([0, 1, 2])

>>> np.arange(3.0)
numpy.ma.choose (indices, choices, out=None, mode='raise')

Use an index array to construct a new array from a set of choices.

Given an array of integers and a set of n choice arrays, this method will create a new array that merges each of the choice arrays. Where a value in a is i, the new array will have the value that choices[i] contains in the same place.

Parameters

- **a**: ndarray of ints
  This array must contain integers in [0, n-1], where n is the number of choices.

- **choices**: sequence of arrays
  Choice arrays. The index array and all of the choices should be broadcastable to the same shape.

- **out**: array, optional
  If provided, the result will be inserted into this array. It should be of the appropriate shape and dtype.

- **mode**: {'raise', 'wrap', 'clip'}, optional
  Specifies how out-of-bounds indices will behave.
  - 'raise': raise an error
  - 'wrap': wrap around
  - 'clip': clip to the range

Returns

**merged_array**: array

See also:

choose 
equivalent function

Examples

```python
>>> choice = np.array([[1,1,1], [2,2,2], [3,3,3]])
>>> a = np.array([2, 1, 0])
>>> np.ma.choose(a, choice)
masked_array(data = [3 2 1],
mask = False,
fill_value=999999)
```

numpy.ma.ediff1d (arr, to_end=None, to_begin=None)

Compute the differences between consecutive elements of an array.

This function is the equivalent of numpy.ediff1d that takes masked values into account, see numpy.ediff1d for details.

See also:
**numpy.ediff1d**
Equivalent function for ndarrays.

**numpy.ma.indices (dimensions, dtype=<type 'int'>)**
Return an array representing the indices of a grid.

*Compute an array where the subarrays contain index values 0,1,... varying only along the corresponding axis.*

**Parameters**
- **dimensions**: sequence of ints
  The shape of the grid.
- **dtype**: dtype, optional
  Data type of the result.

**Returns**
- **grid**: ndarray
  The array of grid indices, grid.shape = (len(dimensions),) +
tuple(dimensions).

**See also:**
mgrid, meshgrid

**Notes**
The output shape is obtained by prepending the number of dimensions in front of the tuple of dimensions, i.e. if dimensions is a tuple (r0, ..., rN-1) of length N, the output shape is (N, r0, ..., rN-1).

The subarrays grid[k] contains the N-D array of indices along the k-th axis. Explicitly:
grid[k,i0,i1,...,iN-1] = ik

**Examples**
```python
>>> grid = np.indices((2, 3))
>>> grid.shape
(2, 2, 3)
>>> grid[0]  # row indices
array([[0, 0, 0],
       [1, 1, 1]])
>>> grid[1]  # column indices
array([[0, 1, 2],
       [0, 1, 2]])
```
The indices can be used as an index into an array.
```python
>>> x = np.arange(20).reshape(5, 4)
>>> row, col = np.indices((2, 3))
>>> x[row, col]
array([[0, 1, 2],
       [4, 5, 6]])
```
Note that it would be more straightforward in the above example to extract the required elements directly with x[::2, :3].

**numpy.ma.where (condition, x=None, y=None)**
Return a masked array with elements from x or y, depending on condition.
Returns a masked array, shaped like condition, where the elements are from \( x \) when \( condition \) is True, and from \( y \) otherwise. If neither \( x \) nor \( y \) are given, the function returns a tuple of indices where \( condition \) is True (the result of \( condition \).nonzero()).

**Parameters**

- **condition**: array_like, bool
  
  The condition to meet. For each True element, yield the corresponding element from \( x \), otherwise from \( y \).

- **\( x \), \( y \)**: array_like, optional
  
  Values from which to choose. \( x \) and \( y \) need to have the same shape as condition, or be broadcast-able to that shape.

**Returns**

- **out**: MaskedArray or tuple of ndarrays
  
  The resulting masked array if \( x \) and \( y \) were given, otherwise the result of \( condition \).nonzero().

**See also:**

- **numpy.where**
  
  Equivalent function in the top-level NumPy module.

**Examples**

```python
>>> x = np.ma.array(np.arange(9.).reshape(3, 3), mask=[[0, 1, 0],
... [1, 0, 1],
... [0, 1, 0]])
```

```python
>>> print x
[[ 0.0 -- 2.0]
 [-- 4.0 --]
[6.0 -- 8.0]]
```

```python
>>> np.ma.where(x > 5)  # return the indices where x > 5
(array([2, 2]), array([0, 2]))
```

```python
>>> print np.ma.where(x > 5, x, -3.1416)
[[-3.1416 -- -3.1416]
 [-- -3.1416 --]
[6.0 -- 8.0]]
```

### 1.8 The Array Interface

**Note:** This page describes the numpy-specific API for accessing the contents of a numpy array from other C extensions. PEP 3118 – The Revised Buffer Protocol introduces similar, standardized API to Python 2.6 and 3.0 for any extension module to use. Cython's buffer array support uses the PEP 3118 API; see the Cython numpy tutorial. Cython provides a way to write code that supports the buffer protocol with Python versions older than 2.6 because it has a backward-compatible implementation utilizing the array interface described here.

**version**

3

The array interface (sometimes called array protocol) was created in 2005 as a means for array-like Python objects to re-use each other’s data buffers intelligently whenever possible. The homogeneous N-dimensional array interface is a default mechanism for objects to share N-dimensional array memory and information. The interface consists of a
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Python-side and a C-side using two attributes. Objects wishing to be considered an N-dimensional array in application code should support at least one of these attributes. Objects wishing to support an N-dimensional array in application code should look for at least one of these attributes and use the information provided appropriately.

This interface describes homogeneous arrays in the sense that each item of the array has the same “type”. This type can be very simple or it can be a quite arbitrary and complicated C-like structure.

There are two ways to use the interface: A Python side and a C-side. Both are separate attributes.

### 1.8.1 Python side

This approach to the interface consists of the object having an `__array_interface__` attribute.

```
__array_interface__
```

A dictionary of items (3 required and 5 optional). The optional keys in the dictionary have implied defaults if they are not provided.

The keys are:

- **shape** (required)
  
  Tuple whose elements are the array size in each dimension. Each entry is an integer (a Python int or long). Note that these integers could be larger than the platform “int” or “long” could hold (a Python int is a C long). It is up to the code using this attribute to handle this appropriately; either by raising an error when overflow is possible, or by using `Py_LONG_LONG` as the C type for the shapes.

- **typestr** (required)
  
  A string providing the basic type of the homogenous array. The basic string format consists of 3 parts: a character describing the byteorder of the data (`<`: little-endian, `>`: big-endian, `|`: not-relevant), a character code giving the basic type of the array, and an integer providing the number of bytes the type uses.

  The basic type character codes are:

  - `t`: Bit field (following integer gives the number of bits in the bit field).
  - `b`: Boolean (integer type where all values are only True or False)
  - `i`: Integer
  - `u`: Unsigned integer
  - `f`: Floating point
  - `c`: Complex floating point
  - `O`: Object (i.e. the memory contains a pointer to `PyObject`)
  - `S`: String (fixed-length sequence of char)
  - `U`: Unicode (fixed-length sequence of `Py_UNICODE`)
  - `V`: Other (void * – each item is a fixed-size chunk of memory)

- **descr** (optional)
  
  A list of tuples providing a more detailed description of the memory layout for each item in the homogeneous array. Each tuple in the list has two or three elements. Normally, this attribute would be used when `typestr` is `V[0-9]+`, but this is not a requirement. The only requirement is that the number of bytes represented in the `typestr` key is the same as the total number of bytes represented here. The idea is to support descriptions of C-like structs (records) that make up array elements. The elements of each tuple in the list are

  1. A string providing a name associated with this portion of the record. This could also be a tuple of (`full name`, `basic_name`) where basic name would be a valid Python variable name representing the full name of the field.

  2. Either a basic-type description string as in `typestr` or another list (for nested records)
3. An optional shape tuple providing how many times this part of the record should be repeated. No repeats are assumed if this is not given. Very complicated structures can be described using this generic interface. Notice, however, that each element of the array is still of the same data-type. Some examples of using this interface are given below.

**Default**: [('', typestr)]

**data** (optional)

A 2-tuple whose first argument is an integer (a long integer if necessary) that points to the data-area storing the array contents. This pointer must point to the first element of data (in other words any offset is always ignored in this case). The second entry in the tuple is a read-only flag (true means the data area is read-only).

This attribute can also be an object exposing the buffer interface which will be used to share the data. If this key is not present (or returns None), then memory sharing will be done through the buffer interface of the object itself. In this case, the offset key can be used to indicate the start of the buffer. A reference to the object exposing the array interface must be stored by the new object if the memory area is to be secured.

**Default**: None

**strides** (optional)

Either None to indicate a C-style contiguous array or a Tuple of strides which provides the number of bytes needed to jump to the next array element in the corresponding dimension. Each entry must be an integer (a Python int or long). As with shape, the values may be larger than can be represented by a C “int” or “long”; the calling code should handle this appropriately, either by raising an error, or by using Py_LONG_LONG in C. The default is None which implies a C-style contiguous memory buffer. In this model, the last dimension of the array varies the fastest. For example, the default strides tuple for an object whose array entries are 8 bytes long and whose shape is (10,20,30) would be (4800, 240, 8)

**Default**: None (C-style contiguous)

**mask** (optional)

None or an object exposing the array interface. All elements of the mask array should be interpreted only as true or not true indicating which elements of this array are valid. The shape of this object should be “broadcastable” to the shape of the original array.

**Default**: None (All array values are valid)

**offset** (optional)

An integer offset into the array data region. This can only be used when data is None or returns a buffer object.

**Default**: 0.

**version** (required)

An integer showing the version of the interface (i.e. 3 for this version). Be careful not to use this to invalidate objects exposing future versions of the interface.

### 1.8.2 C-struct access

This approach to the array interface allows for faster access to an array using only one attribute lookup and a well-defined C-structure.
__array_struct__

A PyObject whose voidptr member contains a pointer to a filled PyArrayInterface structure. Memory for the structure is dynamically created and the PyObject is also created with an appropriate destructor so the retriever of this attribute simply has to apply Py_DECREF to the object returned by this attribute when it is finished. Also, either the data needs to be copied out, or a reference to the object exposing this attribute must be held to ensure the data is not freed. Objects exposing the __array_struct__ interface must also not reallocate their memory if other objects are referencing them.

The PyArrayInterface structure is defined in numpy/ndarrayobject.h as:

```c
typedef struct {
    int two;         /* contains the integer 2 -- simple sanity check */
    int nd;          /* number of dimensions */
    char typekind;   /* kind in array --- character code of typestr */
    int itemsize;    /* size of each element */
    int flags;       /* flags indicating how the data should be interpreted */
    Py_intptr_t *shape; /* A length-nd array of shape information */
    Py_intptr_t *strides; /* A length-nd array of stride information */
    void *data;      /* A pointer to the first element of the array */
    PyObject *descr; /* NULL or data-description (same as descr key
                      of __array_interface__) -- must set ARR_HAS_DESCR
                      flag or this will be ignored. */
} PyArrayInterface;
```

The flags member may consist of 5 bits showing how the data should be interpreted and one bit showing how the Interface should be interpreted. The data-bits are CONTIGUOUS (0x1), FORTRAN (0x2), ALIGNED (0x100), NOTSWAPPED (0x200), and WRITEABLE (0x400). A final flag ARR_HAS_DESCR (0x800) indicates whether or not this structure has the arrdescr field. The field should not be accessed unless this flag is present.

New since June 16, 2006:

In the past most implementations used the “desc” member of the PyObject itself (do not confuse this with the “descr” member of the PyArrayInterface structure above — they are two separate things) to hold the pointer to the object exposing the interface. This is now an explicit part of the interface. Be sure to own a reference to the object when the PyObject is created using PyObject_FromVoidPtrAndDesc.

1.8.3 Type description examples

For clarity it is useful to provide some examples of the type description and corresponding __array_interface__ ‘descr’ entries. Thanks to Scott Gilbert for these examples:

In every case, the ‘descr’ key is optional, but of course provides more information which may be important for various applications:

* Float data
  typestr == '>f4'
  descr == [('','>f4')]

* Complex double
  typestr == '>c8'
  descr == [('real','>f4'), ('imag','>f4')]

* RGB Pixel data
  typestr == '|V3'
  descr == [('r','|u1'), ('g','|u1'), ('b','|u1')]

1.8. The Array Interface
* Mixed endian (weird but could happen).
  
  ```
  typestr == '|V8' (or '>u8')
  descr == [('big','>i4'), ('little','<i4')]
  ```

* Nested structure
  ```
  struct {
    int ival;
    struct {
      unsigned short sval;
      unsigned char bval;
      unsigned char cval;
    } sub;
  }
  typestr == '|V8' (or '<u8' if you want)
  descr == [('ival','<i4'), ('sub', [('sval','<u2'), ('bval','|u1'), ('cval','|u1')])]
  ```

* Nested array
  ```
  struct {
    int ival;
    double data[16*4];
  }
  typestr == '|V516'
  descr == [('ival','>i4'), ('data','>f8',(16,4))]
  ```

* Padded structure
  ```
  struct {
    int ival;
    double dval;
  }
  typestr == '|V16'
  descr == [('ival','>i4'), ('dval','>f8')]
  ```

It should be clear that any record type could be described using this interface.

### 1.8.4 Differences with Array interface (Version 2)

The version 2 interface was very similar. The differences were largely aesthetic. In particular:

1. The PyArrayInterface structure had no descr member at the end (and therefore no flag ARR_HAS_DESCR).
2. The desc member of the PyCObject returned from __array_struct__ was not specified. Usually, it was the object exposing the array (so that a reference to it could be kept and destroyed when the C-object was destroyed). Now it must be a tuple whose first element is a string with “PyArrayInterface Version #” and whose second element is the object exposing the array.
3. The tuple returned from __array_interface__['data'] used to be a hex-string (now it is an integer or a long integer).
4. There was no __array_interface__ attribute instead all of the keys (except for version) in the __array_interface__ dictionary were their own attribute: Thus to obtain the Python-side information you had to access separately the attributes:
   ```
   • __array_data__
   • __array_shape__
   • __array_strides__
   • __array_typestr__
   ```
1.9 Datetimes and Timedeltas

New in version 1.7.0.

Starting in NumPy 1.7, there are core array data types which natively support datetime functionality. The data type is called “datetime64”, so named because “datetime” is already taken by the datetime library included in Python.

Note: The datetime API is experimental in 1.7.0, and may undergo changes in future versions of NumPy.

1.9.1 Basic Datetimes

The most basic way to create datetimes is from strings in ISO 8601 date or datetime format. The unit for internal storage is automatically selected from the form of the string, and can be either a date unit or a time unit. The date units are years (‘Y’), months (‘M’), weeks (‘W’), and days (‘D’), while the time units are hours (‘h’), minutes (‘m’), seconds (‘s’), milliseconds (‘ms’), and some additional SI-prefix seconds-based units.

Example
A simple ISO date:

```python
>>> np.datetime64('2005-02-25')
numpy.datetime64('2005-02-25')
```

Using months for the unit:

```python
>>> np.datetime64('2005-02')
numpy.datetime64('2005-02')
```

Specifying just the month, but forcing a ‘days’ unit:

```python
>>> np.datetime64('2005-02', 'D')
numpy.datetime64('2005-02-01')
```

Using UTC “Zulu” time:

```python
>>> np.datetime64('2005-02-25T03:30Z')
numpy.datetime64('2005-02-24T21:30-0600')
```

ISO 8601 specifies to use the local time zone if none is explicitly given:

```python
>>> np.datetime64('2005-02-25T03:30')
numpy.datetime64('2005-02-25T03:30-0600')
```

When creating an array of datetimes from a string, it is still possible to automatically select the unit from the inputs, by using the datetime type with generic units.

Example

```python
>>> np.array(['2007-07-13', '2006-01-13', '2010-08-13'], dtype='datetime64')
array(['2007-07-13', '2006-01-13', '2010-08-13'], dtype='datetime64[D]')
```
NumPy Reference, Release 1.9.2

```python
>>> np.array(['2001-01-01T12:00', '2002-02-03T13:56:03.172'], dtype='datetime64')
array(['2001-01-01T12:00:00.000-0600', '2002-02-03T13:56:03.172-0600'], dtype='datetime64[ms]')
```

The `datetime` type works with many common NumPy functions, for example `arange` can be used to generate ranges of dates.

**Example**

All the dates for one month:

```python
>>> np.arange('2005-02', '2005-03', dtype='datetime64[D]')
      dtype='datetime64[D]')
```

The `datetime` object represents a single moment in time. If two datetimes have different units, they may still be representing the same moment of time, and converting from a bigger unit like months to a smaller unit like days is considered a ‘safe’ cast because the moment of time is still being represented exactly.

**Example**

```python
>>> np.datetime64('2005') == np.datetime64('2005-01-01')
True

>>> np.datetime64('2010-03-14T15Z') == np.datetime64('2010-03-14T15:00:00.00Z')
True
```

An important exception to this rule is between datetimes with `date units` and datetimes with `time units`. This is because this kind of conversion generally requires a choice of timezone and particular time of day on the given date.

**Example**

```python
>>> np.datetime64('2003-12-25', 's')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Cannot parse "2003-12-25" as unit 's' using casting rule 'same_kind'

Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Cannot parse "2003-12-25" as unit 's' using casting rule 'same_kind'

>>> np.datetime64('2003-12-25') == np.datetime64('2003-12-25T00Z')
False
```

1.9.2 Datetime and Timedelta Arithmetic

NumPy allows the subtraction of two Datetime values, an operation which produces a number with a time unit. Because NumPy doesn’t have a physical quantities system in its core, the `timedelta64` data type was created to complement `datetime64`.

Datetimes and Timedeltas work together to provide ways for simple datetime calculations.
Example

```python
>>> np.datetime64('2009-01-01') - np.datetime64('2008-01-01')
numpy.timedelta64(366,'D')

>>> np.datetime64('2009') + np.timedelta64(20, 'D')
numpy.datetime64('2009-01-21')

>>> np.datetime64('2011-06-15T00:00') + np.timedelta64(12, 'h')
numpy.datetime64('2011-06-15T12:00-0500')

>>> np.timedelta64(1,'W') / np.timedelta64(1,'D')
7.0
```

There are two Timedelta units (‘Y’, years and ‘M’, months) which are treated specially, because how much time they represent changes depending on when they are used. While a timedelta day unit is equivalent to 24 hours, there is no way to convert a month unit into days, because different months have different numbers of days.

Example

```python
>>> a = np.timedelta64(1, 'Y')

>>> np.timedelta64(a, 'M')
numpy.timedelta64(12,'M')

>>> np.timedelta64(a, 'D')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Cannot cast NumPy timedelta64 scalar from metadata [Y] to [D] according to the rule 'same_kind'
```

1.9.3 Datetime Units

The Datetime and Timedelta data types support a large number of time units, as well as generic units which can be coerced into any of the other units based on input data.

Datetimes are always stored based on POSIX time (though having a TAI mode which allows for accounting of leap-seconds is proposed), with a epoch of 1970-01-01T00:00Z. This means the supported dates are always a symmetric interval around the epoch, called “time span” in the table below.

The length of the span is the range of a 64-bit integer times the length of the date or unit. For example, the time span for ‘W’ (week) is exactly 7 times longer than the time span for ‘D’ (day), and the time span for ‘D’ (day) is exactly 24 times longer than the time span for ‘h’ (hour).

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
<th>Time span (relative)</th>
<th>Time span (absolute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>year</td>
<td>+/- 9.2e18 years</td>
<td>[9.2e18 BC, 9.2e18 AD]</td>
</tr>
<tr>
<td>M</td>
<td>month</td>
<td>+/- 7.6e17 years</td>
<td>[7.6e17 BC, 7.6e17 AD]</td>
</tr>
<tr>
<td>W</td>
<td>week</td>
<td>+/- 1.7e17 years</td>
<td>[1.7e17 BC, 1.7e17 AD]</td>
</tr>
<tr>
<td>D</td>
<td>day</td>
<td>+/- 2.5e16 years</td>
<td>[2.5e16 BC, 2.5e16 AD]</td>
</tr>
</tbody>
</table>

1.9. Datetimes and Timedeltas
And here are the time units:

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
<th>Time span (relative)</th>
<th>Time span (absolute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td>hour</td>
<td>+/- 1.0e15 years</td>
<td>[1.0e15 BC, 1.0e15 AD]</td>
</tr>
<tr>
<td>m</td>
<td>minute</td>
<td>+/- 1.7e13 years</td>
<td>[1.7e13 BC, 1.7e13 AD]</td>
</tr>
<tr>
<td>s</td>
<td>second</td>
<td>+/- 2.9e12 years</td>
<td>[2.9e9 BC, 2.9e9 AD]</td>
</tr>
<tr>
<td>ms</td>
<td>millisecond</td>
<td>+/- 2.9e9 years</td>
<td>[2.9e6 BC, 2.9e6 AD]</td>
</tr>
<tr>
<td>us</td>
<td>microsecond</td>
<td>+/- 2.9e6 years</td>
<td>[290301 BC, 294241 AD]</td>
</tr>
<tr>
<td>ns</td>
<td>nanosecond</td>
<td>+/- 292 years</td>
<td>[1678 AD, 2262 AD]</td>
</tr>
<tr>
<td>ps</td>
<td>picosecond</td>
<td>+/- 106 days</td>
<td>[1969 AD, 1970 AD]</td>
</tr>
<tr>
<td>fs</td>
<td>femtosecond</td>
<td>+/- 2.6 hours</td>
<td>[1969 AD, 1970 AD]</td>
</tr>
<tr>
<td>as</td>
<td>attosecond</td>
<td>+/- 9.2 seconds</td>
<td>[1969 AD, 1970 AD]</td>
</tr>
</tbody>
</table>

### 1.9.4 Business Day Functionality

To allow the datetime to be used in contexts where only certain days of the week are valid, NumPy includes a set of “busday” (business day) functions.

The default for busday functions is that the only valid days are Monday through Friday (the usual business days). The implementation is based on a “weekmask” containing 7 Boolean flags to indicate valid days; custom weekmasks are possible that specify other sets of valid days.

The “busday” functions can additionally check a list of “holiday” dates, specific dates that are not valid days.

The function `busday_offset` allows you to apply offsets specified in business days to datetimes with a unit of ‘D’ (day).

**Example**

```python
>>> np.busday_offset('2011-06-23', 1)
numpy.datetime64('2011-06-24')
```

```python
>>> np.busday_offset('2011-06-23', 2)
numpy.datetime64('2011-06-27')
```

When an input date falls on the weekend or a holiday, `busday_offset` first applies a rule to roll the date to a valid business day, then applies the offset. The default rule is ‘raise’, which simply raises an exception. The rules most typically used are ‘forward’ and ‘backward’.

**Example**

```python
>>> np.busday_offset('2011-06-25', 2)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: Non-business day date in busday_offset
```

```python
>>> np.busday_offset('2011-06-25', 0, roll='forward')
numpy.datetime64('2011-06-27')
```

```python
>>> np.busday_offset('2011-06-25', 2, roll='forward')
numpy.datetime64('2011-06-29')
```

```python
>>> np.busday_offset('2011-06-25', 0, roll='backward')
numpy.datetime64('2011-06-24')
```
In some cases, an appropriate use of the roll and the offset is necessary to get a desired answer.

Example

The first business day on or after a date:

```python
>>> np.busday_offset('2011-03-20', 0, roll='forward')
numpy.datetime64('2011-03-21','D')
>>> np.busday_offset('2011-03-22', 0, roll='forward')
numpy.datetime64('2011-03-22','D')
```

The first business day strictly after a date:

```python
>>> np.busday_offset('2011-03-20', 1, roll='backward')
numpy.datetime64('2011-03-21','D')
>>> np.busday_offset('2011-03-22', 1, roll='backward')
numpy.datetime64('2011-03-23','D')
```

The function is also useful for computing some kinds of days like holidays. In Canada and the U.S., Mother's day is on the second Sunday in May, which can be computed with a custom weekmask.

Example

```python
>>> np.busday_offset('2012-05', 1, roll='forward', weekmask='Sun')
numpy.datetime64('2012-05-13','D')
```

When performance is important for manipulating many business dates with one particular choice of weekmask and holidays, there is an object `busdaycalendar` which stores the data necessary in an optimized form.

**np.is_busday():**

To test a datetime64 value to see if it is a valid day, use `is_busday`.

Example

```python
>>> np.is_busday(np.datetime64('2011-07-15'))  # a Friday
True
>>> np.is_busday(np.datetime64('2011-07-16'))  # a Saturday
False
>>> np.is_busday(np.datetime64('2011-07-16'), weekmask="Sat Sun")
True
>>> a = np.arange(np.datetime64('2011-07-11'), np.datetime64('2011-07-18'))
>>> np.is_busday(a)
array([ True,  True,  True,  True,  True, False, False], dtype='bool')
```

**np.busday_count():**

To find how many valid days there are in a specified range of datetime64 dates, use `busday_count`.

Example
>>> np.busday_count(np.datetime64('2011-07-11'), np.datetime64('2011-07-18'))
5
>>> np.busday_count(np.datetime64('2011-07-18'), np.datetime64('2011-07-11'))
-5

If you have an array of datetime64 day values, and you want a count of how many of them are valid dates, you can do this:

Example

```python
>>> a = np.arange(np.datetime64('2011-07-11'), np.datetime64('2011-07-18'))
>>> np.count_nonzero(np.is_busday(a))
5
```

Custom Weekmasks

Here are several examples of custom weekmask values. These examples specify the “busday” default of Monday through Friday being valid days.

Some examples:

```python
# Positional sequences; positions are Monday through Sunday.
# Length of the sequence must be exactly 7.
weekmask = [1, 1, 1, 1, 1, 0, 0]
# list or other sequence; 0 == invalid day, 1 == valid day
weekmask = "1111100"
# string '0' == invalid day, '1' == valid day
weekmask = "Mon Tue Wed Thu Fri"
# any amount of whitespace is allowed; abbreviations are case-sensitive.
weekmask = "MonTue Wed Thu Fri"
```

1.9.5 Differences Between 1.6 and 1.7 Datetimes

The NumPy 1.6 release includes a more primitive datetime data type than 1.7. This section documents many of the changes that have taken place.

String Parsing

The datetime string parser in NumPy 1.6 is very liberal in what it accepts, and silently allows invalid input without raising errors. The parser in NumPy 1.7 is quite strict about only accepting ISO 8601 dates, with a few convenience extensions. 1.6 always creates microsecond (us) units by default, whereas 1.7 detects a unit based on the format of the string. Here is a comparison.:

```python
# NumPy 1.6.1
>>> np.datetime64('1979-03-22')
1979-03-22 00:00:00
# NumPy 1.7.0
>>> np.datetime64('1979-03-22')
numpy.datetime64('1979-03-22')

# NumPy 1.6.1, unit default microseconds
>>> np.datetime64('1979-03-22').dtype
dtype('datetime64[us]')
```
# NumPy 1.7.0, unit of days detected from string
>>> np.datetime64('1979-03-22').dtype
dtype('<M8[D]')

# NumPy 1.6.1, ignores invalid part of string
>>> np.datetime64('1979-03-2corruptedstring')
1979-03-02 00:00:00
# NumPy 1.7.0, raises error for invalid input
>>> np.datetime64('1979-03-2corruptedstring')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: Error parsing datetime string "1979-03-2corruptedstring" at position 8

# NumPy 1.6.1, 'nat' produces today's date
>>> np.datetime64('nat')
2012-04-30 00:00:00
# NumPy 1.7.0, 'nat' produces not-a-time
>>> np.datetime64('nat')
numpy.datetime64('NaT')

# NumPy 1.6.1, 'garbage' produces today's date
>>> np.datetime64('garbage')
2012-04-30 00:00:00
# NumPy 1.7.0, 'garbage' raises an exception
>>> np.datetime64('garbage')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: Error parsing datetime string "garbage" at position 0

# NumPy 1.6.1, can't specify unit in scalar constructor
>>> np.datetime64('1979-03-22T19:00', 'h')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: function takes at most 1 argument (2 given)
# NumPy 1.7.0, unit in scalar constructor
>>> np.datetime64('1979-03-22T19:00', 'h')
numpy.datetime64('1979-03-22T19:00-0500','h')

# NumPy 1.6.1, reads ISO 8601 strings w/o TZ as UTC
>>> np.array(['1979-03-22T19:00'], dtype='M8[h]')
array([1979-03-22 19:00:00], dtype=datetime64[h])
# NumPy 1.7.0, reads ISO 8601 strings w/o TZ as local (ISO specifies this)
>>> np.array(['1979-03-22T19:00'], dtype='M8[h]')
array(['1979-03-22T19-0500'], dtype='datetime64[h]')

# NumPy 1.6.1, doesn't parse all ISO 8601 strings correctly
>>> np.array(['1979-03-22T12'], dtype='M8[h]')
array(['1979-03-22 00:00:00'], dtype=datetimetime64[h])
# NumPy 1.7.0, handles this case correctly
>>> np.array(['1979-03-22T12'], dtype='M8[h]')
array(['1979-03-22T12-0500'], dtype='datetime64[h]')
# NumPy 1.6.1, doesn't parse all ISO 8601 strings correctly
>>> np.array(['1979-03-22T12'], dtype='M8[h]')
array(['1979-03-22 12:00:00'], dtype=datetimetime64[h])
# NumPy 1.7.0, handles this case correctly
>>> np.array(['1979-03-22T12'], dtype='M8[h]')
array(['1979-03-22T12-0500'], dtype='datetime64[h]')
Unit Conversion

The 1.6 implementation of datetime does not convert between units correctly:

```python
# NumPy 1.6.1, the representation value is untouched
>>> np.array(['1979-03-22'], dtype='M8[D]')
array(['1979-03-22 00:00:00'], dtype=object)
>>> np.array(['1979-03-22'], dtype='M8[D]').astype('M8[M]')
array([2250-08-01 00:00:00], dtype=datetime64[M])
# NumPy 1.7.0, the representation is scaled accordingly
>>> np.array(['1979-03-22'], dtype='M8[D]')
array(['1979-03-22'], dtype=datetime64[D])
>>> np.array(['1979-03-22'], dtype='M8[D]').astype('M8[M]')
array(['1979-03'], dtype=datetime64[M])
```

Datetime Arithmetic

The 1.6 implementation of datetime only works correctly for a small subset of arithmetic operations. Here we show some simple cases:

```python
# NumPy 1.6.1, produces invalid results if units are incompatible
>>> a = np.array(['1979-03-22T12'], dtype='M8[h]')
>>> b = np.array([3*60], dtype='m8[m]')
>>> a + b
array([1970-01-01 00:00:00.080988], dtype=datetime64[us])
# NumPy 1.7.0, promotes to higher-resolution unit
>>> a = np.array(['1979-03-22T12'], dtype='M8[h]')
>>> b = np.array([3*60], dtype='m8[m]')
>>> a + b
array(['1979-03-22T15:00-0500'], dtype=datetime64[m])
# NumPy 1.6.1, arithmetic works if everything is microseconds
>>> a = np.array(['1979-03-22T12:00'], dtype='M8[us]')
>>> b = np.array([3*60*60*1000000], dtype='m8[us]')
>>> a + b
array(['1979-03-22 15:00:00'], dtype=datetime64[us])
# NumPy 1.7.0
>>> a = np.array(['1979-03-22T12:00'], dtype='M8[us]')
>>> b = np.array([3*60*60*1000000], dtype='m8[us]')
>>> a + b
array(['1979-03-22T15:00:00.000000-0500'], dtype=datetime64[us])
```
A universal function (or \textit{ufunc} for short) is a function that operates on \textit{ndarrays} in an element-by-element fashion, supporting \textit{array broadcasting}, \textit{type casting}, and several other standard features. That is, a ufunc is a “vectorized” wrapper for a function that takes a fixed number of scalar inputs and produces a fixed number of scalar outputs.

In Numpy, universal functions are instances of the \texttt{numpy.ufunc} class. Many of the built-in functions are implemented in compiled C code, but \texttt{ufunc} instances can also be produced using the \texttt{frompyfunc} factory function.

\section*{2.1 Broadcasting}

Each universal function takes array inputs and produces array outputs by performing the core function element-wise on the inputs. Standard broadcasting rules are applied so that inputs not sharing exactly the same shapes can still be usefully operated on. Broadcasting can be understood by four rules:

1. All input arrays with \texttt{ndim} smaller than the input array of largest \texttt{ndim}, have 1’s prepended to their shapes.
2. The size in each dimension of the output shape is the maximum of all the input sizes in that dimension.
3. An input can be used in the calculation if its size in a particular dimension either matches the output size in that dimension, or has value exactly 1.
4. If an input has a dimension size of 1 in its shape, the first data entry in that dimension will be used for all calculations along that dimension. In other words, the stepping machinery of the \texttt{ufunc} will simply not step along that dimension (the \texttt{stride} will be 0 for that dimension).

Broadcasting is used throughout NumPy to decide how to handle disparately shaped arrays; for example, all arithmetic operations (+, −, ∗, ...) between \textit{ndarrays} broadcast the arrays before operation. A set of arrays is called “broadcastable” to the same shape if the above rules produce a valid result, \textit{i.e.}, one of the following is true:

1. The arrays all have exactly the same shape.
2. The arrays all have the same number of dimensions and the length of each dimensions is either a common length or 1.
3. The arrays that have too few dimensions can have their shapes prepended with a dimension of length 1 to satisfy property 2.

\textbf{Example}

If \texttt{a.shape} is (5,1), \texttt{b.shape} is (1,6), \texttt{c.shape} is (6,) and \texttt{d.shape} is () so that \texttt{d} is a scalar, then \texttt{a}, \texttt{b}, \texttt{c}, and \texttt{d} are all broadcastable to dimension (5,6); and

- \texttt{a} acts like a (5,6) array where \texttt{a[:,0]} is broadcast to the other columns,
- \texttt{b} acts like a (5,6) array where \texttt{b[0,:]} is broadcast to the other rows,
- \texttt{c} acts like a (1,6) array and therefore like a (5,6) array where \texttt{c[:]} is broadcast to every row, and finally,
2.2 Output type determination

The output of the ufunc (and its methods) is not necessarily an ndarray, if all input arguments are not ndarrays. All output arrays will be passed to the __array_prepare__ and __array_wrap__ methods of the input (besides ndarrays, and scalars) that defines it and has the highest __array_priority__ of any other input to the universal function. The default __array_priority__ of the ndarray is 0.0, and the default __array_priority__ of a subtype is 1.0. Matrices have __array_priority__ equal to 10.0.

All ufuncs can also take output arguments. If necessary, output will be cast to the data-type(s) of the provided output array(s). If a class with a __array__ method is used for the output, results will be written to the object returned by __array__. Then, if the class also has an __array_prepare__ method, it is called so metadata may be determined based on the context of the ufunc (the context consisting of the ufunc itself, the arguments passed to the ufunc, and the ufunc domain.) The array object returned by __array_prepare__ is passed to the ufunc for computation. Finally, if the class also has an __array_wrap__ method, the returned ndarray result will be passed to that method just before passing control back to the caller.

2.3 Use of internal buffers

Internally, buffers are used for misaligned data, swapped data, and data that has to be converted from one data type to another. The size of internal buffers is settable on a per-thread basis. There can be up to \(2(n_{\text{inputs}} + n_{\text{outputs}})\) buffers of the specified size created to handle the data from all the inputs and outputs of a ufunc. The default size of a buffer is 10,000 elements. Whenever buffer-based calculation would be needed, but all input arrays are smaller than the buffer size, those misbehaved or incorrectly-typed arrays will be copied before the calculation proceeds. Adjusting the size of the buffer may therefore alter the speed at which ufunc calculations of various sorts are completed. A simple interface for setting this variable is accessible using the function

\[
\text{setbufsize}(\text{size}) \quad \text{Set the size of the buffer used in ufuncs.}
\]

\[
\text{numpy.setbufsize}(\text{size})
\]

Set the size of the buffer used in ufuncs.

**Parameters**

- **size**: int
  
  Size of buffer.

2.4 Error handling

Universal functions can trip special floating-point status registers in your hardware (such as divide-by-zero). If available on your platform, these registers will be regularly checked during calculation. Error handling is controlled on a per-thread basis, and can be configured using the functions

\[
\text{seterr}([\text{all, divide, over, under, invalid}]) \quad \text{Set how floating-point errors are handled.}
\]

\[
\text{seterrcall}(\text{func})
\]

Set the floating-point error callback function or log object.

\[
\text{numpy.seterr}(\text{all}=\text{None}, \text{divide}=\text{None}, \text{over}=\text{None}, \text{under}=\text{None}, \text{invalid}=\text{None})
\]
Set how floating-point errors are handled.

Note that operations on integer scalar types (such as `int16`) are handled like floating point, and are affected by these settings.

**Parameters**
  - Set treatment for all types of floating-point errors at once:
    - ignore: Take no action when the exception occurs.
    - warn: Print a `RuntimeWarning` (via the Python `warnings` module).
    - raise: Raise a `FloatingPointError`.
    - call: Call a function specified using the `seterrcall` function.
    - print: Print a warning directly to `stdout`.
    - log: Record error in a Log object specified by `seterrcall`.
  - The default is not to change the current behavior.
  - Treatment for division by zero.
  - Treatment for floating-point overflow.
  - Treatment for floating-point underflow.
  - Treatment for invalid floating-point operation.

**Returns**
- **old_settings**: dict
  - Dictionary containing the old settings.

**See also**
- `seterrcall`
  - Set a callback function for the ‘call’ mode.
- `geterr`, `geterrcall`, `errstate`

**Notes**
The floating-point exceptions are defined in the IEEE 754 standard [1]:
- Division by zero: infinite result obtained from finite numbers.
- Overflow: result too large to be expressed.
- Underflow: result so close to zero that some precision was lost.
- Invalid operation: result is not an expressible number, typically indicates that a NaN was produced.
Examples

```python
>>> old_settings = np.seterr(all='ignore')  # seterr to known value
>>> np.seterr(over='raise')
{'over': 'ignore', 'divide': 'ignore', 'invalid': 'ignore',
 'under': 'ignore'}
>>> np.seterr(**old_settings)  # reset to default
{'over': 'raise', 'divide': 'ignore', 'invalid': 'ignore', 'under': 'ignore'}

```nnumpy.int16(32000) * np.int16(3)
30464
```nnumpy.int16(32000) * np.int16(3)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
FloatingPointError: overflow encountered in short_scalars
```
```nnumpy.seterrcall(func)
Set the floating-point error callback function or log object.
```
```There are two ways to capture floating-point error messages. The first is to set the error-handler to ‘call’, using
seterr. Then, set the function to call using this function.
```
```The second is to set the error-handler to ‘log’, using seterr. Floating-point errors then trigger a call to the
‘write’ method of the provided object.
```
```Parameters
  func : callable f(err, flag) or object with write method
Function to call upon floating-point errors (‘call’-mode) or object whose ‘write’ method
is used to log such message (‘log’-mode).
```
```The call function takes two arguments. The first is the type of error (one of “divide”,
“over”, “under”, or “invalid”), and the second is the status flag. The flag is a byte, whose
least-significant bits indicate the status:
```
```[0 0 0 0 invalid over under invalid]
In other words, flags = divide + 2*over + 4*under + 8*invalid.
```
```If an object is provided, its write method should take one argument, a string.
```
```Returns
  h : callable, log instance or None
  The old error handler.
```
```See also:
seterr, geterr, geterrcall
```
Examples

Callback upon error:

```python
>>> def err_handler(type, flag):
...     print "Floating point error ($s), with flag $s" % (type, flag)
...

>>> saved_handler = np.seterrcall(err_handler)
>>> save_err = np.seterr(all='call')

>>> np.array([1, 2, 3]) / 0.0
Floating point error (divide by zero), with flag 1
array([ Inf, Inf, Inf])

>>> np.seterrcall(saved_handler)
<function err_handler at 0x...>
>>> np.seterr(**save_err)
{'over': 'call', 'divide': 'call', 'invalid': 'call', 'under': 'call'}
```

Log error message:

```python
>>> class Log(object):
...     def write(self, msg):
...         print "LOG: $s" % msg
...

>>> log = Log()
>>> saved_handler = np.seterrcall(log)
>>> save_err = np.seterr(all='log')

>>> np.array([1, 2, 3]) / 0.0
LOG: Warning: divide by zero encountered in divide
array([ Inf, Inf, Inf])

>>> np.seterrcall(saved_handler)
<_main__.Log object at 0x...>
>>> np.seterr(**save_err)
{'over': 'log', 'divide': 'log', 'invalid': 'log', 'under': 'log'}
```

2.5 Casting Rules

Note: In NumPy 1.6.0, a type promotion API was created to encapsulate the mechanism for determining output types. See the functions `result_type`, `promote_types`, and `min scalar type` for more details.

At the core of every ufunc is a one-dimensional strided loop that implements the actual function for a specific type combination. When a ufunc is created, it is given a static list of inner loops and a corresponding list of type signatures over which the ufunc operates. The ufunc machinery uses this list to determine which inner loop to use for a particular case. You can inspect the `.types` attribute for a particular ufunc to see which type combinations have a defined inner loop and which output type they produce (character codes are used in said output for brevity).

Casting must be done on one or more of the inputs whenever the ufunc does not have a core loop implementation for the input types provided. If an implementation for the input types cannot be found, then the algorithm searches for an implementation with a type signature to which all of the inputs can be cast “safely.” The first one it finds in its internal
list of loops is selected and performed, after all necessary type casting. Recall that internal copies during ufuncs (even for casting) are limited to the size of an internal buffer (which is user settable).

**Note:** Universal functions in NumPy are flexible enough to have mixed type signatures. Thus, for example, a universal function could be defined that works with floating-point and integer values. See `ldexp` for an example.

By the above description, the casting rules are essentially implemented by the question of when a data type can be cast “safely” to another data type. The answer to this question can be determined in Python with a function call: `can_cast(fromtype, totype)`. The Figure below shows the results of this call for the 24 internally supported types on the author’s 64-bit system. You can generate this table for your system with the code given in the Figure.

**Figure**

Code segment showing the “can cast safely” table for a 32-bit system.

```python
>>> def print_table(ntypes):
...     print 'X',
...     for char in ntypes:
...         print char,
...     print
...     for row in ntypes:
...         print row,
...         for col in ntypes:
...             print int(np.can_cast(row, col)),
...     print

>>> print_table(np.typecodes['All'])
X ? b h i l q p B H I L Q P e f d g F D G S U V O M m
? 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
b 0 1 1 1 1 1 1 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0
h 0 0 1 1 1 1 1 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0
i 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 1 1 0 1 1 1 1 1 1 0
l 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 1 1 0 1 1 1 1 1 1 0
q 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 1 1 0 1 1 1 1 1 1 0
p 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 1 1 0 1 1 1 1 1 1 0
B 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
H 0 0 0 1 1 1 1 0 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 0
I 0 0 0 0 1 1 1 0 0 1 1 1 1 0 0 1 1 0 1 1 1 1 1 1 0
L 0 0 0 0 0 0 0 0 0 1 1 1 0 0 1 1 0 1 1 1 1 1 1 1 0
Q 0 0 0 0 0 0 0 0 0 1 1 1 0 0 1 1 0 1 1 1 1 1 1 1 0
P 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0 1 1 0 1 1 1 1 1 1 0
e 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 0
f 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 0
d 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 0
g 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0
F 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0
D 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0
G 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0
S 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0
U 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0
V 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
O 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
M 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
m 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
```

You should note that, while included in the table for completeness, the ‘S’, ‘U’, and ‘V’ types cannot be operated on by ufuncs. Also, note that on a 32-bit system the integer types may have different sizes, resulting in a slightly altered table.

Mixed scalar-array operations use a different set of casting rules that ensure that a scalar cannot “upcast” an array.
unless the scalar is of a fundamentally different kind of data (i.e., under a different hierarchy in the data-type hierarchy) than the array. This rule enables you to use scalar constants in your code (which, as Python types, are interpreted accordingly in ufuncs) without worrying about whether the precision of the scalar constant will cause upcasting on your large (small precision) array.

2.6 Overriding Ufunc behavior

Classes (including ndarray subclasses) can override how ufuncs act on them by defining certain special methods. For details, see Standard array subclasses.

2.7 ufunc

2.7.1 Optional keyword arguments

All ufuncs take optional keyword arguments. Most of these represent advanced usage and will not typically be used.

`out`

New in version 1.6.

The first output can provided as either a positional or a keyword parameter.

`where`

New in version 1.7.

Accepts a boolean array which is broadcast together with the operands. Values of True indicate to calculate the ufunc at that position, values of False indicate to leave the value in the output alone.

`casting`

New in version 1.6.

Provides a policy for what kind of casting is permitted. For compatibility with previous versions of NumPy, this defaults to ‘unsafe’. May be ‘no’, ‘equiv’, ‘safe’, ‘same_kind’, or ‘unsafe’. See can_cast for explanations of the parameter values.

In a future version of numpy, this argument will default to ‘same_kind’. As part of this transition, starting in version 1.7, ufuncs will produce a DeprecationWarning for calls which are allowed under the ‘unsafe’ rules, but not under the ‘same_kind’ rules.

`order`

New in version 1.6.

Specifies the calculation iteration order/memory layout of the output array. Defaults to ‘K’. ‘C’ means the output should be C-contiguous, ‘F’ means F-contiguous, ‘A’ means F-contiguous if the inputs are F-contiguous and not also not C-contiguous, C-contiguous otherwise, and ‘K’ means to match the element ordering of the inputs as closely as possible.

`dtype`

New in version 1.6.

Overrides the dtype of the calculation and output arrays. Similar to sig.

subok
New in version 1.6.

Defaults to true. If set to false, the output will always be a strict array, not a subtype.

**sig**

Either a data-type, a tuple of data-types, or a special signature string indicating the input and output types of a ufunc. This argument allows you to provide a specific signature for the 1-d loop to use in the underlying calculation. If the loop specified does not exist for the ufunc, then a TypeError is raised. Normally, a suitable loop is found automatically by comparing the input types with what is available and searching for a loop with data-types to which all inputs can be cast safely. This keyword argument lets you bypass that search and choose a particular loop. A list of available signatures is provided by the `types` attribute of the ufunc object.

**extobj**

A list of length 1, 2, or 3 specifying the ufunc buffer-size, the error mode integer, and the error callback function. Normally, these values are looked up in a thread-specific dictionary. Passing them here circumvents that look up and uses the low-level specification provided for the error mode. This may be useful, for example, as an optimization for calculations requiring many ufunc calls on small arrays in a loop.

### 2.7.2 Attributes

There are some informational attributes that universal functions possess. None of the attributes can be set.

| __doc__   | A docstring for each ufunc. The first part of the docstring is dynamically generated from the number of outputs, the name, and the number of inputs. The second part of the docstring is provided at creation time and stored with the ufunc. |
| ___name___ | The name of the ufunc. |

- `ufunc.nin` The number of inputs.
- `ufunc.nout` The number of outputs.
- `ufunc.nargs` The number of arguments.
- `ufunc.ntypes` The number of types.
- `ufunc.types` Returns a list with types grouped input->output.
- `ufunc.identity` The identity value.

#### Examples

```python
>>> np.add.nin
2
>>> np.multiply.nin
2
>>> np.power.nin
2
>>> np.exp.nin
1
```

- `ufunc.nout` The number of outputs.

Data attribute containing the number of arguments the ufunc treats as output.
**Notes**

Since all ufuncs can take output arguments, this will always be (at least) 1.

**Examples**

```python
>>> np.add.nout
1
>>> np.multiply.nout
1
>>> np.power.nout
1
>>> np.exp.nout
1
```

**ufunc.nargs**

The number of arguments.

Data attribute containing the number of arguments the ufunc takes, including optional ones.

**Notes**

Typically this value will be one more than what you might expect because all ufuncs take the optional “out” argument.

**Examples**

```python
>>> np.add.nargs
3
>>> np.multiply.nargs
3
>>> np.power.nargs
3
>>> np.exp.nargs
2
```

**ufunc.ntypes**

The number of types.

The number of numerical NumPy types - of which there are 18 total - on which the ufunc can operate.

**See also:**

numpy.ufunc.types

**Examples**

```python
>>> np.add.ntypes
18
>>> np.multiply.ntypes
18
>>> np.power.ntypes
17
>>> np.exp.ntypes
7
>>> np.remainder.ntypes
14
```

**ufunc.types**

Returns a list with types grouped input->output.
Data attribute listing the data-type “Domain-Range” groupings the ufunc can deliver. The data-types are given using the character codes.

See also:

numpy.ufunc.ntypes

Examples

```python
gtype = np.add.types
['??->?', 'bb->b', 'BB->B', 'hh->h', 'HH->H', 'ii->i', 'II->I', 'll->l',
'LL->L', 'qq->q', 'QQ->Q', 'ff->f', 'dd->d', 'gg->g', 'FF->F', 'DD->D',
'GG->G', 'OO->O']
```

```python
gtype = np.multiply.types
['??->?', 'bb->b', 'BB->B', 'hh->h', 'HH->H', 'ii->i', 'II->I', 'll->l',
'LL->L', 'qq->q', 'QQ->Q', 'ff->f', 'dd->d', 'gg->g', 'FF->F', 'DD->D',
'GG->G', 'OO->O']
```

```python
gtype = np.power.types
['bb->b', 'BB->B', 'hh->h', 'HH->H', 'ii->i', 'II->I', 'll->l', 'LL->L',
'qq->q', 'QQ->Q', 'ff->f', 'dd->d', 'gg->g', 'FF->F', 'DD->D', 'GG->G',
'OO->O']
```

```python
gtype = np.exp.types
['f->f', 'd->d', 'g->g', 'F->F', 'D->D', 'G->G', 'O->O']
```

```python
gtype = np.remainder.types
['bb->b', 'BB->B', 'hh->h', 'HH->H', 'ii->i', 'II->I', 'll->l', 'LL->L',
'qq->q', 'QQ->Q', 'ff->f', 'dd->d', 'gg->g', 'FF->F', 'DD->D', 'GG->G',
'OO->O']
```

ufunc.identity
The identity value.

Data attribute containing the identity element for the ufunc, if it has one. If it does not, the attribute value is None.

Examples

```python
gtype = np.add.identity
0
```

```python
gtype = np.multiply.identity
1
```

```python
gtype = np.power.identity
1
```

```python
gtype = print np.exp.identity
None
```

2.7.3 Methods

All ufuncs have four methods. However, these methods only make sense on ufuncs that take two input arguments and return one output argument. Attempting to call these methods on other ufuncs will cause a ValueError. The reduce-like methods all take an axis keyword and a dtype keyword, and the arrays must all have dimension >= 1. The axis keyword specifies the axis of the array over which the reduction will take place and may be negative, but must be an integer. The dtype keyword allows you to manage a very common problem that arises when naively using {op}.reduce. Sometimes you may have an array of a certain data type and wish to add up all of its elements, but the result does not fit into the data type of the array. This commonly happens if you have an array of single-byte integers. The dtype keyword allows you to alter the data type over which the reduction takes place (and therefore the type of
the output). Thus, you can ensure that the output is a data type with precision large enough to handle your output. The responsibility of altering the reduce type is mostly up to you. There is one exception: if no `dtype` is given for a reduction on the “add” or “multiply” operations, then if the input type is an integer (or Boolean) data-type and smaller than the size of the `int_` data type, it will be internally upcast to the `int_` (or `uint`) data-type.

Ufuncs also have a fifth method that allows in place operations to be performed using fancy indexing. No buffering is used on the dimensions where fancy indexing is used, so the fancy index can list an item more than once and the operation will be performed on the result of the previous operation for that item.

<table>
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<th>Method</th>
<th>Description</th>
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<tbody>
<tr>
<td><code>ufunc.reduce</code></td>
<td>Reduces <code>a</code>'s dimension by one, by applying ufunc along one axis.</td>
</tr>
<tr>
<td><code>ufunc.accumulate</code></td>
<td>Accumulate the result of applying the operator to all elements.</td>
</tr>
<tr>
<td><code>ufunc.reduceat</code></td>
<td>Performs a (local) reduce with specified slices over a single axis.</td>
</tr>
<tr>
<td><code>ufunc.outer</code></td>
<td>Apply the ufunc <code>op</code> to all pairs (a, b) with a in A and b in B.</td>
</tr>
<tr>
<td><code>ufunc.at</code></td>
<td>Performs unbuffered in place operation on operand ‘a’ for elements specified by fancy indexing.</td>
</tr>
</tbody>
</table>

```
ufunc.reduce(a[, axis, dtype, out, keepdims])
```

Reduces `a`'s dimension by one, by applying ufunc along one axis.

Let \(a.\text{shape} = (N_0, ..., N_i, ..., N_{M-1})\). Then \(\text{ufunc.reduce}(a, \text{axis} = i)[k_0, ..., k_{i-1}, k_{i+1}, ..., k_{M-1}]\) = the result of iterating \(j\) over \(\text{range}(N_i)\), cumulatively applying ufunc to each \(a[k_0, ..., k_{i-1}, j, k_{i+1}, ..., k_{M-1}]\). For a one-dimensional array, reduce produces results equivalent to:

```python
r = op.identity  # op = ufunc
for i in range(len(a)):
    r = op(r, a[i])
return r
```

For example, `add.reduce()` is equivalent to `sum()`.

**Parameters**

- `a`: array_like
  
The array to act on.

- `axis`: None or int or tuple of ints, optional
  
  Axis or axes along which a reduction is performed. The default (`axis = 0`) is perform a reduction over the first dimension of the input array. `axis` may be negative, in which case it counts from the last to the first axis.

  New in version 1.7.0.

  If this is `None`, a reduction is performed over all the axes. If this is a tuple of ints, a reduction is performed on multiple axes, instead of a single axis or all the axes as before.

  For operations which are either not commutative or not associative, doing a reduction over multiple axes is not well-defined. The ufuncs do not currently raise an exception in this case, but will likely do so in the future.

- `dtype`: data-type code, optional
  
  The type used to represent the intermediate results. Defaults to the data-type of the output array if this is provided, or the data-type of the input array if no output array is provided.

- `out`: ndarray, optional
  
  A location into which the result is stored. If not provided, a freshly-allocated array is returned.
**keepdims** : bool, optional

If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *arr*.

New in version 1.7.0.

**Returns**

- **r** : ndarray

  The reduced array. If *out* was supplied, *r* is a reference to it.

**Examples**

```python
>>> np.multiply.reduce([2, 3, 5])
30
```

A multi-dimensional array example:

```python
>>> X = np.arange(8).reshape((2,2,2))
>>> X
array([[[0, 1],
        [2, 3]],
       [[4, 5],
        [6, 7]]])
```

```python
>>> np.add.reduce(X, 0)
array([[ 4,  6],
       [ 8, 10]])
```

```python
>>> np.add.reduce(X)  # confirm: default axis value is 0
array([[ 4,  6],
       [ 8, 10]])
```

```python
>>> np.add.reduce(X, 1)
array([[ 2,  4],
       [10, 12]])
```

```python
>>> np.add.reduce(X, 2)
array([[ 1,  5],
       [ 9, 13]])
```

ufunc.accumulate(*array*, axis=0, dtype=None, out=None)

Accumulate the result of applying the operator to all elements.

For a one-dimensional array, accumulate produces results equivalent to:

```python
r = np.empty(len(A))
t = op.identity  # op = the ufunc being applied to A's elements
for i in range(len(A)):
    t = op(t, A[i])
return r
```

For example, add.accumulate() is equivalent to np.cumsum().

For a multi-dimensional array, accumulate is applied along only one axis (axis zero by default; see Examples below) so repeated use is necessary if one wants to accumulate over multiple axes.

**Parameters**

- **array** : array_like

  The array to act on.

- **axis** : int, optional

  The axis along which to apply the accumulation; default is zero.
**dtype**: data-type code, optional

The data-type used to represent the intermediate results. Defaults to the data-type of the output array if such is provided, or the the data-type of the input array if no output array is provided.

**out**: ndarray, optional

A location into which the result is stored. If not provided a freshly-allocated array is returned.

**Returns**

- **r**: ndarray

  The accumulated values. If `out` was supplied, `r` is a reference to `out`.

**Examples**

1-D array examples:

```python
gt. np.add.accumulate([2, 3, 5])
array([ 2, 5, 10])
gt. np.multiply.accumulate([2, 3, 5])
array([ 2, 6, 30])
```

2-D array examples:

```python
gt. I = np.eye(2)
gt. I
array([[ 1., 0.],
       [ 0., 1.]])
```

Accumulate along axis 0 (rows), down columns:

```python
gt. np.add.accumulate(I, 0)
array([[ 1., 0.],
       [ 1., 1.]])
gt. np.add.accumulate(I)  # no axis specified = axis zero
array([[ 1., 0.],
       [ 1., 1.]])
```

Accumulate along axis 1 (columns), through rows:

```python
gt. np.add.accumulate(I, 1)
array([[ 1., 1.],
       [ 0., 1.]])
```

**ufunc.reduceat** *(a, indices, axis=0, dtype=None, out=None)*

Performs a (local) reduce with specified slices over a single axis.

For `i` in `range(len(indices))`, `reduceat` computes `ufunc.reduce(a[indices[i]:indices[i+1]])`, which becomes the i-th generalized “row” parallel to `axis` in the final result (i.e., in a 2-D array, for example, if `axis = 0`, it becomes the i-th row, but if `axis = 1`, it becomes the i-th column). There are three exceptions to this:

- when `i = len(indices) - 1` (so for the last index), `indices[i+1]` = `a.shape[axis]`.
- if `indices[i] >= indices[i + 1]`, the i-th generalized “row” is simply `a[indices[i]]`.
- if `indices[i] >= len(a) or indices[i] < 0`, an error is raised.

The shape of the output depends on the size of `indices`, and may be larger than `a` (this happens if `len(indices) > a.shape[axis]`).

---

2.7. ufunc
Parameters

\(a\) : array_like

The array to act on.

\(\text{indices}\) : array_like

Paired indices, comma separated (not colon), specifying slices to reduce.

\(\text{axis}\) : int, optional

The axis along which to apply the reduceat.

\(\text{dtype}\) : data-type code, optional

The type used to represent the intermediate results. Defaults to the data type of the output array if this is provided, or the data type of the input array if no output array is provided.

\(\text{out}\) : ndarray, optional

A location into which the result is stored. If not provided a freshly-allocated array is returned.

Returns

\(r\) : ndarray

The reduced values. If \(\text{out}\) was supplied, \(r\) is a reference to \(\text{out}\).

Notes

A descriptive example:

If \(a\) is 1-D, the function \(\text{ufunc.accumulate}(a)\) is the same as \(\text{ufunc.reduceat}(a, \text{indices})[:, 2]\) where \(\text{indices}\) is \(\text{range(len(array) - 1)}\) with a zero placed in every other element: \(\text{indices} = \text{zeros}(2 \times \text{len(a)} - 1), \text{indices}[1::2] = \text{range(1, len(a))}\).

Don’t be fooled by this attribute’s name: \(\text{reduceat}(a)\) is not necessarily smaller than \(a\).

Examples

To take the running sum of four successive values:

```python
>>> np.add.reduceat(np.arange(8), [0, 4, 1, 5, 2, 6, 3, 7])[:2]
array([ 6, 10, 14, 18])
```

A 2-D example:

```python
>>> x = np.linspace(0, 15, 16).reshape(4, 4)
>>> x
array([[ 0.,  1.,  2.,  3.],
       [ 4.,  5.,  6.,  7.],
       [ 8.,  9., 10., 11.],
       [12., 13., 14., 15.]]])
```

# reduce such that the result has the following five rows:
# [row1 + row2 + row3]
# [row4]
# [row2]
# [row3]
# [row1 + row2 + row3 + row4]
NumPy Reference, Release 1.9.2

```python
>>> np.add.reduceat(x, [0, 3, 1, 2, 0])
array([[ 12.,  15.,  18.,  21.],
       [ 12.,  13.,  14.,  15.],
       [  4.,   5.,   6.,   7.],
       [  8.,   9.,  10.,  11.],
       [ 24.,  28.,  32.,  36.]]

# reduce such that result has the following two columns:
# [col1 * col2 * col3, col4]

>>> np.multiply.reduceat(x, [0, 3], 1)
array([[  0.,   3.],
       [ 120.,   7.],
       [ 720.,  11.],
       [2184.,  15.]]

ufunc.outer(A, B)
Apply the ufunc op to all pairs (a, b) with a in A and b in B.

Let M = A.ndim, N = B.ndim. Then the result, C, of op.outer(A, B) is an array of dimension M + N such that:

\[ C[i_0, ..., i_{M-1}, j_0, ..., j_{N-1}] = op(A[i_0, ..., i_{M-1}], B[j_0, ..., j_{N-1}]) \]

For A and B one-dimensional, this is equivalent to:

```python
r = empty(len(A), len(B))
for i in range(len(A)):
    for j in range(len(B)):
        r[i, j] = op(A[i], B[j])  # op = ufunc in question
```

Parameters
- A : array_like
  First array
- B : array_like
  Second array

Returns
- r : ndarray
  Output array

See also:
- numpy.outer

Examples
```python
>>> np.multiply.outer([1, 2, 3], [4, 5, 6])
array([[  4.,   5.,   6.],
       [  8.,  10.,  12.],
       [ 12.,  15.,  18.]]

A multi-dimensional example:
```
B = np.array([[1, 2, 3, 4]])
B.shape
(1, 4)
C = np.multiply.outer(A, B)
C.shape; C
(2, 3, 1, 4)
array([[[ 1, 2, 3, 4]],
       [[ 2, 4, 6, 8]],
       [[ 3, 6, 9, 12]]],
       [[ 4, 8, 12, 16]],
       [[ 5, 10, 15, 20]],
       [[ 6, 12, 18, 24]])

ufunc.at(a, indices, b=None)
Performs unbuffered in place operation on operand ‘a’ for elements specified by ‘indices’. For addition ufunc, this method is equivalent to a[indices] += b, except that results are accumulated for elements that are indexed more than once. For example, a[[0,0]] += 1 will only increment the first element once because of buffering, whereas add.at(a, [0,0], 1) will increment the first element twice.

New in version 1.8.0.

Parameters
a : array_like
   The array to perform in place operation on.

indices : array_like or tuple
   Array like index object or slice object for indexing into first operand. If first operand has multiple dimensions, indices can be a tuple of array like index objects or slice objects.

b : array_like
   Second operand for ufuncs requiring two operands. Operand must be broadcastable over first operand after indexing or slicing.

Examples
Set items 0 and 1 to their negative values:
>>> a = np.array([1, 2, 3, 4])
>>> np.negative.at(a, [0, 1])
>>> print(a)
array([-1, -2, 3, 4])

Increment items 0 and 1, and increment item 2 twice:
>>> a = np.array([1, 2, 3, 4])
>>> np.add.at(a, [0, 1, 2, 2], 1)
>>> print(a)
array([2, 3, 5, 4])

Add items 0 and 1 in first array to second array, and store results in first array:
>>> a = np.array([1, 2, 3, 4])
>>> b = np.array([1, 2])
>>> np.add.at(a, [0, 1], b)
>>> print(a)
array([2, 4, 3, 4])
Warning: A reduce-like operation on an array with a data-type that has a range “too small” to handle the result will silently wrap. One should use `dtype` to increase the size of the data-type over which reduction takes place.

2.8 Available ufuncs

There are currently more than 60 universal functions defined in `numpy` on one or more types, covering a wide variety of operations. Some of these ufuncs are called automatically on arrays when the relevant infix notation is used (e.g., `add(a, b)` is called internally when `a + b` is written and `a or b` is an `ndarray`). Nevertheless, you may still want to use the ufunc call in order to use the optional output argument(s) to place the output(s) in an object (or objects) of your choice.

Recall that each ufunc operates element-by-element. Therefore, each ufunc will be described as if acting on a set of scalar inputs to return a set of scalar outputs.

Note: The ufunc still returns its output(s) even if you use the optional output argument(s).

2.8.1 Math operations

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>add(x1, x2[, out])</code></td>
<td>Add arguments element-wise.</td>
</tr>
<tr>
<td><code>subtract(x1, x2[, out])</code></td>
<td>Subtract arguments, element-wise.</td>
</tr>
<tr>
<td><code>multiply(x1, x2[, out])</code></td>
<td>Multiply arguments element-wise.</td>
</tr>
<tr>
<td><code>divide(x1, x2[, out])</code></td>
<td>Divide arguments element-wise.</td>
</tr>
<tr>
<td><code>logaddexp(x1, x2[, out])</code></td>
<td>Logarithm of the sum of exponentiations of the inputs.</td>
</tr>
<tr>
<td><code>logaddexp2(x1, x2[, out])</code></td>
<td>Logarithm of the sum of exponentiations of the inputs in base-2.</td>
</tr>
<tr>
<td><code>true_divide(x1, x2[, out])</code></td>
<td>Returns a true division of the inputs, element-wise.</td>
</tr>
<tr>
<td><code>floor_divide(x1, x2[, out])</code></td>
<td>Return the largest integer smaller or equal to the division of the inputs.</td>
</tr>
<tr>
<td><code>negative(x[, out])</code></td>
<td>Numerical negative, element-wise.</td>
</tr>
<tr>
<td><code>power(x1, x2[, out])</code></td>
<td>First array elements raised to powers from second array, element-wise.</td>
</tr>
<tr>
<td><code>remainder(x1, x2[, out])</code></td>
<td>Return element-wise remainder of division.</td>
</tr>
<tr>
<td><code>mod(x1, x2[, out])</code></td>
<td>Return element-wise remainder of division.</td>
</tr>
<tr>
<td><code>fmod(x1, x2[, out])</code></td>
<td>Return the element-wise remainder of division.</td>
</tr>
<tr>
<td><code>absolute(x[, out])</code></td>
<td>Calculate the absolute value element-wise.</td>
</tr>
<tr>
<td><code>rint(x[, out])</code></td>
<td>Round elements of the array to the nearest integer.</td>
</tr>
<tr>
<td><code>sign(x[, out])</code></td>
<td>Returns an element-wise indication of the sign of a number.</td>
</tr>
<tr>
<td><code>conj(x[, out])</code></td>
<td>Return the complex conjugate, element-wise.</td>
</tr>
<tr>
<td><code>exp(x[, out])</code></td>
<td>Calculate the exponential of all elements in the input array.</td>
</tr>
<tr>
<td><code>exp2(x[, out])</code></td>
<td>Calculate (2^p) for all (p) in the input array.</td>
</tr>
<tr>
<td><code>log(x[, out])</code></td>
<td>Natural logarithm, element-wise.</td>
</tr>
<tr>
<td><code>log2(x[, out])</code></td>
<td>Base-2 logarithm of (x).</td>
</tr>
<tr>
<td><code>log10(x[, out])</code></td>
<td>Return the base 10 logarithm of the input array, element-wise.</td>
</tr>
<tr>
<td><code>expm1(x[, out])</code></td>
<td>Calculate (\exp (x) - 1) for all elements in the array.</td>
</tr>
<tr>
<td><code>log1p(x[, out])</code></td>
<td>Return the natural logarithm of one plus the input array, element-wise.</td>
</tr>
<tr>
<td><code>sqrt(x[, out])</code></td>
<td>Return the positive square-root of an array, element-wise.</td>
</tr>
<tr>
<td><code>square(x[, out])</code></td>
<td>Return the element-wise square of the input.</td>
</tr>
<tr>
<td><code>reciprocal(x[, out])</code></td>
<td>Return the reciprocal of the argument, element-wise.</td>
</tr>
<tr>
<td><code>ones_like(a[, dtype, order, subok])</code></td>
<td>Return an array of ones with the same shape and type as a given array.</td>
</tr>
</tbody>
</table>

Tip: The optional output arguments can be used to help you save memory for large calculations. If your arrays are
large, complicated expressions can take longer than absolutely necessary due to the creation and (later) destruction of temporary calculation spaces. For example, the expression \( G = a \times b + c \) is equivalent to \( t1 = A \times B; \ G = T1 + C; \ \text{del} \ t1 \). It will be more quickly executed as \( G = A \times B; \ \text{add}(G, C, G) \) which is the same as \( G = A \times B; \ G += C \).

### 2.8.2 Trigonometric functions

All trigonometric functions use radians when an angle is called for. The ratio of degrees to radians is \( 180^\circ / \pi \).

- **sin**\( (x[, \text{out}]) \)**: Trigonometric sine, element-wise.
- **cos**\( (x[, \text{out}]) \)**: Cosine element-wise.
- **tan**\( (x[, \text{out}]) \)**: Compute tangent element-wise.
- **arcsin**\( (x[, \text{out}]) \)**: Inverse sine, element-wise.
- **arccos**\( (x[, \text{out}]) \)**: Trigonometric inverse cosine, element-wise.
- **arctan**\( (x[, \text{out}]) \)**: Trigonometric inverse tangent, element-wise.
- **arctan2**\( (x1, x2[, \text{out}]) \)**: Element-wise arc tangent of \( x1/x2 \) choosing the quadrant correctly.
- **hypot**\( (x1, x2[, \text{out}]) \)**: Given the “legs” of a right triangle, return its hypotenuse.
- **sinh**\( (x[, \text{out}]) \)**: Hyperbolic sine, element-wise.
- **cosh**\( (x[, \text{out}]) \)**: Hyperbolic cosine, element-wise.
- **tanh**\( (x[, \text{out}]) \)**: Compute hyperbolic tangent element-wise.
- **arcsinh**\( (x[, \text{out}]) \)**: Inverse hyperbolic sine element-wise.
- **arccosh**\( (x[, \text{out}]) \)**: Inverse hyperbolic cosine, element-wise.
- **arctanh**\( (x[, \text{out}]) \)**: Inverse hyperbolic tangent element-wise.
- **deg2rad**\( (x[, \text{out}]) \)**: Convert angles from degrees to radians.
- **rad2deg**\( (x[, \text{out}]) \)**: Convert angles from radians to degrees.

### 2.8.3 Bit-twiddling functions

These functions all require integer arguments and they manipulate the bit-pattern of those arguments.

- **bitwise_and**\( (x1, x2[, \text{out}]) \)**: Compute the bit-wise AND of two arrays element-wise.
- **bitwise_or**\( (x1, x2[, \text{out}]) \)**: Compute the bit-wise OR of two arrays element-wise.
- **bitwise_xor**\( (x1, x2[, \text{out}]) \)**: Compute the bit-wise XOR of two arrays element-wise.
- **invert**\( (x[, \text{out}]) \)**: Compute bit-wise inversion, or bit-wise NOT, element-wise.
- **left_shift**\( (x1, x2[, \text{out}]) \)**: Shift the bits of an integer to the left.
- **right_shift**\( (x1, x2[, \text{out}]) \)**: Shift the bits of an integer to the right.

### 2.8.4 Comparison functions

- **greater**\( (x1, x2[, \text{out}]) \)**: Return the truth value of \( (x1 > x2) \) element-wise.
- **greater_equal**\( (x1, x2[, \text{out}]) \)**: Return the truth value of \( (x1 \geq x2) \) element-wise.
- **less**\( (x1, x2[, \text{out}]) \)**: Return the truth value of \( (x1 < x2) \) element-wise.
- **less_equal**\( (x1, x2[, \text{out}]) \)**: Return the truth value of \( (x1 \leq x2) \) element-wise.
- **not_equal**\( (x1, x2[, \text{out}]) \)**: Return \( (x1 \neq x2) \) element-wise.
- **equal**\( (x1, x2[, \text{out}]) \)**: Return \( (x1 = x2) \) element-wise.
Warning: Do not use the Python keywords and and or to combine logical array expressions. These keywords will test the truth value of the entire array (not element-by-element as you might expect). Use the bitwise operators & and | instead.

```
logical_and(x1, x2[, out])  Compute the truth value of x1 AND x2 element-wise.
logical_or(x1, x2[, out])  Compute the truth value of x1 OR x2 element-wise.
logical_xor(x1, x2[, out]) Compute the truth value of x1 XOR x2, element-wise.
logical_not(x[, out])      Compute the truth value of NOT x element-wise.
```

Warning: The bit-wise operators & and | are the proper way to perform element-by-element array comparisons. Be sure you understand the operator precedence: 
\((a > 2) \& (a < 5)\) is the proper syntax because 
\(2 \& a\) will result in an error due to the fact that \(2 \& a\) is evaluated first.

```
maximum(x1, x2[, out])    Element-wise maximum of array elements.
```

Tip: The Python function max() will find the maximum over a one-dimensional array, but it will do so using a slower sequence interface. The reduce method of the maximum ufunc is much faster. Also, the max() method will not give answers you might expect for arrays with greater than one dimension. The reduce method of minimum also allows you to compute a total minimum over an array.

```
minimum(x1, x2[, out])    Element-wise minimum of array elements.
```

Warning: the behavior of maximum(a, b) is different than that of max(a, b). As a ufunc, maximum(a, b) performs an element-by-element comparison of a and b and chooses each element of the result according to which element in the two arrays is larger. In contrast, max(a, b) treats the objects a and b as a whole, looks at the (total) truth value of a > b and uses it to return either a or b (as a whole). A similar difference exists between minimum(a, b) and min(a, b).

```
fmax(x1, x2[, out])        Element-wise maximum of array elements.
fmin(x1, x2[, out])        Element-wise minimum of array elements.
```

### 2.8.5 Floating functions

Recall that all of these functions work element-by-element over an array, returning an array output. The description details only a single operation.

```
isreal(x)                  Returns a bool array, where True if input element is real.
iscomplex(x)               Returns a bool array, where True if input element is complex.
isfinite(x[, out])         Test element-wise for finiteness (not infinity or not Not a Number).
isinf(x[, out])             Test element-wise for positive or negative infinity.
isnan(x[, out])            Test element-wise for NaN and return result as a boolean array.
signbit(x[, out])          Returns element-wise True where signbit is set (less than zero).
copysign(x1, x2[, out])    Change the sign of x1 to that of x2, element-wise.
nextafter(x1, x2[, out])   Return the next floating-point value after x1 towards x2, element-wise.
modf(x[, out1, out2])      Return the fractional and integral parts of an array, element-wise.
ldexp(x1, x2[, out])       Returns x1 * 2**x2, element-wise.
```

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Table 2.13 – continued from previous page

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>frexp(x[, out1, out2])</code></td>
<td>Decompose the elements of x into mantissa and twos exponent.</td>
</tr>
<tr>
<td><code>fmod(x1, x2[, out])</code></td>
<td>Return the element-wise remainder of division.</td>
</tr>
<tr>
<td><code>floor(x[, out])</code></td>
<td>Return the floor of the input, element-wise.</td>
</tr>
<tr>
<td><code>ceil(x[, out])</code></td>
<td>Return the ceiling of the input, element-wise.</td>
</tr>
<tr>
<td><code>trunc(x[, out])</code></td>
<td>Return the truncated value of the input, element-wise.</td>
</tr>
</tbody>
</table>
In this chapter routine docstrings are presented, grouped by functionality. Many docstrings contain example code, which demonstrates basic usage of the routine. The examples assume that NumPy is imported with:

```python
>>> import numpy as np
```

A convenient way to execute examples is the `%doctest_mode` mode of IPython, which allows for pasting of multi-line examples and preserves indentation.

### 3.1 Array creation routines

See also:

*Array creation*

#### 3.1.1 Ones and zeros

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>empty(shape[, dtype, order])</code></td>
<td>Return a new array of given shape and type, without initializing entries.</td>
</tr>
<tr>
<td><code>empty_like(a[, dtype, order, subok])</code></td>
<td>Return a new array with the same shape and type as a given array.</td>
</tr>
<tr>
<td><code>eye(N[, M, k, dtype])</code></td>
<td>Return a 2-D array with ones on the diagonal and zeros elsewhere.</td>
</tr>
<tr>
<td><code>identity(n[, dtype])</code></td>
<td>Return the identity array.</td>
</tr>
<tr>
<td><code>ones(shape[, dtype, order])</code></td>
<td>Return a new array of given shape and type, filled with ones.</td>
</tr>
<tr>
<td><code>ones_like(a[, dtype, order, subok])</code></td>
<td>Return an array of ones with the same shape and type as a given array.</td>
</tr>
<tr>
<td><code>zeros(shape[, dtype, order])</code></td>
<td>Return a new array of given shape and type, filled with zeros.</td>
</tr>
<tr>
<td><code>zeros_like(a[, dtype, order, subok])</code></td>
<td>Return an array of zeros with the same shape and type as a given array.</td>
</tr>
<tr>
<td><code>full(shape, fill_value[, dtype, order])</code></td>
<td>Return a new array of given shape and type, filled with <code>fill_value</code>.</td>
</tr>
<tr>
<td><code>full_like(a, fill_value[, dtype, order, subok])</code></td>
<td>Return a full array with the same shape and type as a given array.</td>
</tr>
</tbody>
</table>

```python
numpy.empty(shape, dtype=float, order='C')
```

Return a new array of given shape and type, without initializing entries.

**Parameters**

- `shape` : int or tuple of int
  - Shape of the empty array

- `dtype` : data-type, optional
  - Desired output data-type.

- `order` : {‘C’, ‘F’}, optional
Whether to store multi-dimensional data in C (row-major) or Fortran (column-major) order in memory.

**Returns**

out : ndarray

Array of uninitialized (arbitrary) data with the given shape, dtype, and order.

**See also:**

`empty_like`, `zeros`, `ones`

**Notes**

`empty`, unlike `zeros`, does not set the array values to zero, and may therefore be marginally faster. On the other hand, it requires the user to manually set all the values in the array, and should be used with caution.

**Examples**

```python
def main():
    print(np.empty((2, 2)))
    print(np.empty((2, 2), dtype=int))
```

```bash
>>> np.empty([2, 2])
array([[ -9.74499359e+001, 6.69583040e-309],
       [ 2.13182611e-314, 3.06959433e-309]]) #random

>>> np.empty([2, 2], dtype=int)
array([[ -1073741821, -1067949133],
       [ 496041986, 19249760]]) #random
```

**Parameters**

- **a**: array_like
  - The shape and data-type of `a` define these same attributes of the returned array.

- **dtype**: data-type, optional
  - New in version 1.6.0.
  - Overrides the data type of the result.

- **order**: {‘C’, ‘F’, ‘A’, or ‘K’}, optional
  - New in version 1.6.0.
  - Overrides the memory layout of the result. ‘C’ means C-order, ‘F’ means F-order, ‘A’ means ‘F’ if `a` is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of `a` as closely as possible.

- **subok**: bool, optional.
  - If True, then the newly created array will use the sub-class type of ‘a’, otherwise it will be a base-class array. Defaults to True.

**Returns**

out : ndarray

Array of uninitialized (arbitrary) data with the same shape and type as `a`.

**See also:**

`ones_like`

Return an array of ones with shape and type of input.
zeros_like
Return an array of zeros with shape and type of input.

empty
Return a new uninitialized array.

ones
Return a new array setting values to one.

zeros
Return a new array setting values to zero.

Notes
This function does not initialize the returned array; to do that use zeros_like or ones_like instead. It may be marginally faster than the functions that do set the array values.

Examples
>>> a = ([1,2,3], [4,5,6])  # a is array-like
>>> np.empty_like(a)
array([[-1073741821, -1073741821, 3],
      [ 0, 0, -1073741821]])

>>> a = np.array([[1., 2., 3.],
                 [4., 5., 6.]])
>>> np.empty_like(a)
array([[ -2.00000715e+000, 1.48219694e-323, -2.00000572e+000],
       [ 4.38791518e-305, -2.00000715e+000, 4.17269252e-309]])

numpy.eye(N, M=None, k=0, dtype=<type 'float'>)
Return a 2-D array with ones on the diagonal and zeros elsewhere.

Parameters
N : int
   Number of rows in the output.

M : int, optional
   Number of columns in the output. If None, defaults to N.

k : int, optional
   Index of the diagonal: 0 (the default) refers to the main diagonal, a
   positive value refers to an upper diagonal, and a negative value to a
   lower diagonal.

dtype : data-type, optional
   Data-type of the returned array.

Returns
I : ndarray of shape (N,M)
   An array where all elements are equal to zero, except for the k-th
diagonal, whose values are equal to one.

See also:

identity
(almost) equivalent function

diag
diagonal 2-D array from a 1-D array specified by the user.
Examples

```python
>>> np.eye(2, dtype=int)
array([[1, 0],
       [0, 1]])
```

```python
>>> np.eye(3, k=1)
array([[ 0., 1., 0.],
       [ 0., 0., 1.],
       [ 0., 0., 0.]]
```

`numpy.identity(n, dtype=None)`

Return the identity array.

The identity array is a square array with ones on the main diagonal.

**Parameters**

- `n` : int
  
  Number of rows (and columns) in $n \times n$ output.

- `dtype` : data-type, optional
  
  Data-type of the output. Defaults to `float`.

**Returns**

- `out` : ndarray
  
  $n \times n$ array with its main diagonal set to one, and all other elements 0.

Examples

```python
>>> np.identity(3)
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]]
```

`numpy.ones(shape, dtype=None, order='C')`

Return a new array of given shape and type, filled with ones.

**Parameters**

- `shape` : int or sequence of ints
  
  Shape of the new array, e.g., $(2, 3)$ or $2$.

- `dtype` : data-type, optional
  
  The desired data-type for the array, e.g., `numpy.int8`. Default is `numpy.float64`.

- `order` : {'C', 'F'}, optional
  
  Whether to store multidimensional data in C- or Fortran-contiguous (row- or column-wise) order in memory.

**Returns**

- `out` : ndarray
  
  Array of ones with the given shape, dtype, and order.

See also:

- `zeros`, `ones_like`
Examples

```python
>>> np.ones(5)
array([ 1., 1., 1., 1., 1.])

>>> np.ones((5,), dtype=np.int)
array([1, 1, 1, 1, 1])

>>> np.ones((2, 1))
array([[ 1.],
       [ 1.]])

>>> s = (2,2)
>>> np.ones(s)
array([[ 1., 1.],
       [ 1., 1.]])
```

numpy.ones_like(a, dtype=None, order='K', subok=True)

Return an array of ones with the same shape and type as a given array.

Parameters

- **a**: array_like
  The shape and data-type of a define these same attributes of the returned array.

- **dtype**: data-type, optional
  New in version 1.6.0.
  Overrides the data type of the result.

- **order**: {'C', 'F', 'A', or 'K'}, optional
  New in version 1.6.0.
  Overrides the memory layout of the result. ‘C’ means C-order, ‘F’ means F-order, ‘A’ means ‘F’ if a is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of a as closely as possible.

- **subok**: bool, optional.
  If True, then the newly created array will use the sub-class type of ‘a’, otherwise it will be a base-class array. Defaults to True.

Returns

- **out**: ndarray
  Array of ones with the same shape and type as a.

See also:

- **zeros_like**
  Return an array of zeros with shape and type of input.

- **empty_like**
  Return an empty array with shape and type of input.

- **zeros**
  Return a new array setting values to zero.

- **ones**
  Return a new array setting values to one.
empty
Return a new uninitialized array.

Examples
>>> x = np.arange(6)
>>> x = x.reshape((2, 3))
array([[ 0,  1,  2],
       [ 3,  4,  5]])
>>> np.ones_like(x)
array([[ 1,  1,  1],
       [ 1,  1,  1]])

numpy.zeros (shape, dtype=float, order='C')
Return a new array of given shape and type, filled with zeros.

Parameters
shape : int or sequence of ints
Shape of the new array, e.g., (2, 3) or 2.
dtype : data-type, optional
The desired data-type for the array, e.g., numpy.int8. Default is numpy.float64.
order : {'C', 'F'}, optional
Whether to store multidimensional data in C- or Fortran-contiguous (row- or column-wise) order in memory.

Returns
out : ndarray
Array of zeros with the given shape, dtype, and order.

See also:
zeros_like
Return an array of zeros with shape and type of input.
ones_like
Return an array of ones with shape and type of input.
empty_like
Return an empty array with shape and type of input.
ones
Return a new array setting values to one.
empty
Return a new uninitialized array.
Examples

```python
>>> np.zeros(5)
array([ 0., 0., 0., 0., 0.])

>>> np.zeros((5,), dtype=numpy.int)
array([0, 0, 0, 0, 0])

>>> np.zeros((2, 1))
array([[ 0.],
       [ 0.]]

>>> s = (2,2)
>>> np.zeros(s)
array([[ 0., 0.],
       [ 0., 0.]]

>>> np.zeros((2,), dtype=[('x', 'i4'), ('y', 'i4')])
# custom dtype
array([(0, 0), (0, 0)],
      dtype=[('x', '<i4'), ('y', '<i4')]
```

`numpy.zeros_like(a, dtype=None, order='K', subok=True)`

Return an array of zeros with the same shape and type as a given array.

**Parameters**

- `a`: array_like
  - The shape and data-type of `a` define these same attributes of the returned array.

- `dtype`: data-type, optional
  - New in version 1.6.0.
  - Overrides the data type of the result.

- `order`: {'C', 'F', 'A', or 'K'}, optional
  - New in version 1.6.0.
  - Overrides the memory layout of the result. ‘C’ means C-order, ‘F’ means F-order, ‘A’ means ‘F’ if `a` is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of `a` as closely as possible.

- `subok`: bool, optional.
  - If True, then the newly created array will use the sub-class type of ‘a’, otherwise it will be a base-class array. Defaults to True.

**Returns**

- `out`: ndarray
  - Array of zeros with the same shape and type as `a`.

**See also:**

- `ones_like`
  - Return an array of ones with shape and type of input.

- `empty_like`
  - Return an empty array with shape and type of input.

- `zeros`
  - Return a new array setting values to zero.
ones
Return a new array setting values to one.

empty
Return a new uninitialized array.

Examples
>>> x = np.arange(6)
>>> x = x.reshape((2, 3))
>>> x
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.zeros_like(x)
array([[0, 0, 0],
       [0, 0, 0]])

>>> y = np.arange(3, dtype=np.float)
>>> y
array([ 0., 1., 2.])
>>> np.zeros_like(y)
array([ 0., 0., 0.])

numpy.full(shape, fill_value, dtype=None, order='C')
Return a new array of given shape and type, filled with fill_value.

Parameters
   shape : int or sequence of ints
           Shape of the new array, e.g., (2, 3) or 2.
   fill_value : scalar
           Fill value.
   dtype : data-type, optional
           The desired data-type for the array, e.g., numpy.int8. Default is is chosen as np.array(fill_value).dtype.
   order : {'C', 'F'}, optional
           Whether to store multidimensional data in C- or Fortran-contiguous (row- or column-wise) order in memory.

Returns
   out : ndarray
           Array of fill_value with the given shape, dtype, and order.

See also:
zeros_like
Return an array of zeros with shape and type of input.

ones_like
Return an array of ones with shape and type of input.

empty_like
Return an empty array with shape and type of input.

full_like
Fill an array with shape and type of input.
zeros
Return a new array setting values to zero.

ones
Return a new array setting values to one.

empty
Return a new uninitialized array.

Examples
>>> np.full((2, 2), np.inf)
array([[inf, inf],
       [inf, inf]])

>>> np.full((2, 2), 10, dtype=np.int)
array([[10, 10],
       [10, 10]])

def numpy.full_like(a, fill_value, dtype=None, order='K', subok=True)
Return a full array with the same shape and type as a given array.

Parameters
- a: array_like
  The shape and data-type of a define these same attributes of the returned array.
- fill_value: scalar
  Fill value.
- dtype: data-type, optional
  Overrides the data type of the result.
- order: {'C', 'F', 'A', or 'K'}, optional
  Overrides the memory layout of the result. 'C' means C-order, 'F' means F-order, 'A'
  means 'F' if a is Fortran contiguous, 'C' otherwise. 'K' means match the layout of a as
  closely as possible.
- subok: bool, optional
  If True, then the newly created array will use the sub-class type of 'a', otherwise it will
  be a base-class array. Defaults to True.

Returns
- out: ndarray
  Array of fill_value with the same shape and type as a.

See also:
zeros_like
Return an array of zeros with shape and type of input.
ones_like
Return an array of ones with shape and type of input.
empty_like
Return an empty array with shape and type of input.
zeros
Return a new array setting values to zero.
ones
Return a new array setting values to one.

empty
Return a new uninitialized array.

full
Fill a new array.

Examples
>>> x = np.arange(6, dtype=np.int)
>>> np.full_like(x, 1)
array([1, 1, 1, 1, 1, 1])
>>> np.full_like(x, 0.1)
array([0, 0, 0, 0, 0, 0])
>>> np.full_like(x, 0.1, dtype=np.double)
array([0.1, 0.1, 0.1, 0.1, 0.1, 0.1])
>>> np.full_like(x, np.nan, dtype=np.double)
array([nan, nan, nan, nan, nan, nan])

>>> y = np.arange(6, dtype=np.double)
>>> np.full_like(y, 0.1)
array([0.1, 0.1, 0.1, 0.1, 0.1, 0.1])

3.1.2 From existing data

array(object[, dtype, copy, order, subok, ndmin])
Create an array.

Parameters
object : array_like
An array, any object exposing the array interface, an object whose __array__ method returns an array, or any (nested) sequence.

dtype : data-type, optional
The desired data-type for the array. If not given, then the type will be determined as the minimum type required to hold the objects in the sequence. This argument can only be used to 'upcast' the array. For downcasting, use the .astype(t) method.

copy : bool, optional
If true (default), then the object is copied. Otherwise, a copy will only be made if __array__ returns a copy, if obj is a nested sequence, or if a copy is needed to satisfy any of the other requirements (dtype, order, etc.).

**order**: {'C', 'F', 'A'}, optional

Specify the order of the array. If order is ‘C’ (default), then the array will be in C-contiguous order (last-index varies the fastest). If order is ‘F’, then the returned array will be in Fortran-contiguous order (first-index varies the fastest). If order is ‘A’, then the returned array may be in any order (either C-, Fortran-contiguous, or even discontiguous).

**subok**: bool, optional

If True, then sub-classes will be passed-through, otherwise the returned array will be forced to be a base-class array (default).

**ndmin**: int, optional

Specifies the minimum number of dimensions that the resulting array should have. Ones will be pre-pended to the shape as needed to meet this requirement.

**Returns**

**out**: ndarray

An array object satisfying the specified requirements.

**See also:**

empty, empty_like, zeros, zeros_like, ones, ones_like, fill

**Examples**

```python
>>> np.array([1, 2, 3])
array([1, 2, 3])
```

Upcasting:

```python
>>> np.array([1, 2, 3.0])
array([ 1., 2., 3.])
```

More than one dimension:

```python
>>> np.array([[1, 2], [3, 4]])
array([[1, 2],
       [3, 4]])
```

Minimum dimensions 2:

```python
>>> np.array([1, 2, 3], ndmin=2)
array([[1, 2, 3]])
```

Type provided:

```python
>>> np.array([1, 2, 3], dtype=complex)
array([ 1.+0.j, 2.+0.j, 3.+0.j])
```

Data-type consisting of more than one element:

```python
>>> x = np.array([[1,2],(3,4)],dtype=[('a','<i4'),('b','<i4')])
>>> x['a']
array([1, 3])
```
Creating an array from sub-classes:

```python
>>> np.array(np.mat('1 2; 3 4'))
array([[1, 2],
       [3, 4]])

>>> np.array(np.mat('1 2; 3 4'), subok=True)
matrix([[1, 2],
         [3, 4]])
```

```
numpy.asarray(a, dtype=None, order=None)

Convert the input to an array.

Parameters
a : array_like
    Input data, in any form that can be converted to an array. This includes lists, lists of
tuples, tuples, tuples of tuples, tuples of lists and ndarrays.

dtype : data-type, optional
    By default, the data-type is inferred from the input data.

order : {'C', 'F'}, optional
    Whether to use row-major ('C') or column-major ('F' for FORTRAN) memory repre-
sentation. Defaults to 'C'.

Returns
out : ndarray
    Array interpretation of a. No copy is performed if the input is already an ndarray. If a
is a subclass of ndarray, a base class ndarray is returned.

See also:

asanyarray
    Similar function which passes through subclasses.

ascontiguousarray
    Convert input to a contiguous array.

asfarray
    Convert input to a floating point ndarray.

asfortranarray
    Convert input to an ndarray with column-major memory order.

asarray_chkfinite
    Similar function which checks input for NaNs and Infs.

fromiter
    Create an array from an iterator.

fromfunction
    Construct an array by executing a function on grid positions.

Examples
Convert a list into an array:
>>> a = [1, 2]
>>> np.asarray(a)
array([1, 2])

Existing arrays are not copied:

>>> a = np.array([1, 2])
>>> np.asarray(a) is a
True

If dtype is set, array is copied only if dtype does not match:

>>> a = np.array([1, 2], dtype=np.float32)
>>> np.asarray(a, dtype=np.float32) is a
True
>>> np.asarray(a, dtype=np.float64) is a
False

Contrary to asanyarray, ndarray subclasses are not passed through:

>>> issubclass(np.matrix, np.ndarray)
True
>>> a = np.matrix([[1, 2]])
>>> np.asarray(a) is a
False
>>> np.asanyarray(a) is a
True

```
3.1. Array creation routines
```

```
numpy.asanyarray(a, dtype=None, order=None)
Convert the input to an ndarray, but pass ndarray subclasses through.

Parameters

a : array_like
Input data, in any form that can be converted to an array. This includes scalars, lists,
lists of tuples, tuples, tuples of tuples, tuples of lists, and ndarrays.

dtype : data-type, optional
By default, the data-type is inferred from the input data.

order : {'C', 'F'}, optional
Whether to use row-major ('C') or column-major ('F') memory representation. Defaults
to 'C'.

Returns

out : ndarray or an ndarray subclass
Array interpretation of a. If a is an ndarray or a subclass of ndarray, it is returned as-is
and no copy is performed.

See also:

asarray
Similar function which always returns ndarrays.
ascontiguousarray
Convert input to a contiguous array.
asfarray
Convert input to a floating point ndarray.
```
asfortranarray
Convert input to an ndarray with column-major memory order.

asarray_chkfinite
Similar function which checks input for NaNs and Infs.

fromiter
Create an array from an iterator.

fromfunction
Construct an array by executing a function on grid positions.

Examples
Convert a list into an array:

```python
>>> a = [1, 2]
>>> np.asanyarray(a)
array([1, 2])
```

Instances of ndarray subclasses are passed through as-is:

```python
>>> a = np.matrix([1, 2])
>>> np.asanyarray(a) is a
True
```

numpy.ascontiguousarray(a, dtype=None)
Return a contiguous array in memory (C order).

Parameters
- a : array_like
  Input array.
- dtype : str or dtype object, optional
  Data-type of returned array.

Returns
- out : ndarray
  Contiguous array of same shape and content as a, with type dtype if specified.

See also:

asfortranarray
Convert input to an ndarray with column-major memory order.

require
Return an ndarray that satisfies requirements.

ndarray.flags
Information about the memory layout of the array.

Examples
```python
>>> x = np.arange(6).reshape(2,3)
>>> np.ascontiguousarray(x, dtype=np.float32)
array([[ 0.,  1.,  2.],
       [ 3.,  4.,  5.]], dtype=float32)
>>> x.flags['C_CONTIGUOUS']
True
```
numpy.asmatrix(data, dtype=None)

Interpret the input as a matrix.

Unlike matrix, asmatrix does not make a copy if the input is already a matrix or an ndarray. Equivalent to matrix(data, copy=False).

Parameters

- **data**: array_like
  Input data.

Returns

- **mat**: matrix
  *data* interpreted as a matrix.

Examples

```python
>>> x = np.array([[1, 2], [3, 4]])

>>> m = np.asmatrix(x)

>>> x[0,0] = 5

>>> m
matrix([[5, 2],
        [3, 4]])
```

numpy.copy(a, order='K')

Return an array copy of the given object.

Parameters

- **a**: array_like
  Input data.

- **order**: {'C', 'F', 'A', 'K'}, optional
  Controls the memory layout of the copy. ‘C’ means C-order, ‘F’ means F-order, ‘A’ means ‘F’ if a is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of a as closely as possible. (Note that this function and :meth:ndarray.copy are very similar, but have different default values for their order= arguments.)

Returns

- **arr**: ndarray
  Array interpretation of a.

Notes

This is equivalent to

```python
>>> np.array(a, copy=True)
```

Examples

Create an array `x`, with a reference `y` and a copy `z`:

```python
>>> x = np.array([1, 2, 3])

>>> y = x

>>> z = np.copy(x)
```

Note that, when we modify `x`, `y` changes, but not `z`:  

3.1. Array creation routines
>>> x[0] = 10
>>> x[0] == y[0]
True
>>> x[0] == z[0]
False

numpy.frombuffer (buffer, dtype=float, count=-1, offset=0)
Interpret a buffer as a 1-dimensional array.

Parameters

buffer : buffer_like
An object that exposes the buffer interface.

dtype : data-type, optional
Data-type of the returned array; default: float.

count : int, optional
Number of items to read. -1 means all data in the buffer.

offset : int, optional
Start reading the buffer from this offset; default: 0.

Notes
If the buffer has data that is not in machine byte-order, this should be specified as part of the
data-type, e.g.:

```python
>>> dt = np.dtype(int)
>>> dt = dt.newbyteorder('>')
>>> np.frombuffer(buf, dtype=dt)
```

The data of the resulting array will not be byteswapped, but will be interpreted correctly.

Examples

```python
>>> s = 'hello world'
>>> np.frombuffer(s, dtype='S1', count=5, offset=6)
array(['w', 'o', 'r', 'l', 'd'],
      dtype='|S1')
```

numpy.fromfile (file, dtype=float, count=-1, sep=' ')
Construct an array from data in a text or binary file.

A highly efficient way of reading binary data with a known data-type, as well as parsing simply formatted
text files. Data written using the tofile method can be read using this function.

Parameters

file : file or str
Open file object or filename.

dtype : data-type
Data type of the returned array. For binary files, it is used to determine the size and
byte-order of the items in the file.

count : int
Number of items to read. -1 means all items (i.e., the complete file).

sep : str
Separator between items if file is a text file. Empty ("") separator means the file should be treated as binary. Spaces (" ") in the separator match zero or more whitespace characters. A separator consisting only of spaces must match at least one whitespace.

See also:

load, save, ndarray.tofile

loadtxt

More flexible way of loading data from a text file.

Notes

Do not rely on the combination of tofile and fromfile for data storage, as the binary files generated are are not platform independent. In particular, no byte-order or data-type information is saved. Data can be stored in the platform independent .npy format using save and load instead.

Examples

Construct an ndarray:

```python
>>> dt = np.dtype([('time', [('min', int), ('sec', int)]), ...
                   ('temp', float))
>>> x = np.zeros((1,), dtype=dt)
>>> x['time']['min'] = 10; x['temp'] = 98.25
>>> x
array([(10, 0), 98.25],
      dtype=[('time', [('min', '<i4'), ('sec', '<i4')]), ('temp', '<f8')])
```

Save the raw data to disk:

```python
>>> import os
>>> fname = os.tmpnam()
>>> x.tofile(fname)
```

Read the raw data from disk:

```python
>>> np.fromfile(fname, dtype=dt)
array([(10, 0), 98.25],
      dtype=[('time', [('min', '<i4'), ('sec', '<i4')]), ('temp', '<f8')])
```

The recommended way to store and load data:

```python
>>> np.save(fname, x)
>>> np.load(fname + '.npy')
array([(10, 0), 98.25],
      dtype=[('time', [('min', '<i4'), ('sec', '<i4')]), ('temp', '<f8')])
```

NumPy.fromfunction (function, shape, **kwargs)

Construct an array by executing a function over each coordinate.

The resulting array therefore has a value fn(x, y, z) at coordinate (x, y, z).

Parameters

function : callable

The function is called with N parameters, where N is the rank of shape. Each parameter represents the coordinates of the array varying along a specific axis. For example, if shape were (2, 2), then the parameters in turn be (0, 0), (0, 1), (1, 0), (1, 1).

shape : (N,) tuple of ints

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Shape of the output array, which also determines the shape of the coordinate arrays passed to function.

dtype: data-type, optional

Data-type of the coordinate arrays passed to function. By default, dtype is float.

Returns

fromfunction: any

The result of the call to function is passed back directly. Therefore the shape of fromfunction is completely determined by function. If function returns a scalar value, the shape of fromfunction would match the shape parameter.

See also:

indices, meshgrid

Notes

Keywords other than dtype are passed to function.

Examples

```python
>>> np.fromfunction(lambda i, j: i == j, (3, 3), dtype=int)
array([[True, False, False],
       [False, True, False],
       [False, False, True]], dtype=bool)
```

```python
>>> np.fromfunction(lambda i, j: i + j, (3, 3), dtype=int)
array([[0, 1, 2],
       [1, 2, 3],
       [2, 3, 4]])
```

numpy.fromiter(iterable, dtype, count=-1)

Create a new 1-dimensional array from an iterable object.

Parameters

iterable: iterable object

An iterable object providing data for the array.

dtype: data-type

The data-type of the returned array.

count: int, optional

The number of items to read from iterable. The default is -1, which means all data is read.

Returns

out: ndarray

The output array.

Notes

Specify count to improve performance. It allows fromiter to pre-allocate the output array, instead of resizing it on demand.
Examples

```python
def iterable = (x*x for x in range(5))
np.fromiter(iterable, np.float)
array([ 0., 1., 4., 9., 16.])
```

```
numpy.fromstring(string, dtype=float, count=-1, sep='')
```

A new 1-D array initialized from raw binary or text data in a string.

**Parameters**

- `string`: str
  A string containing the data.

- `dtype`: data-type, optional
  The data type of the array; default: float. For binary input data, the data must be in exactly this format.

- `count`: int, optional
  Read this number of `dtype` elements from the data. If this is negative (the default), the count will be determined from the length of the data.

- `sep`: str, optional
  If not provided or, equivalently, the empty string, the data will be interpreted as binary data; otherwise, as ASCII text with decimal numbers. Also in this latter case, this argument is interpreted as the string separating numbers in the data; extra whitespace between elements is also ignored.

**Returns**

- `arr`: ndarray
  The constructed array.

**Raises**

- `ValueError`
  If the string is not the correct size to satisfy the requested `dtype` and `count`.

**See also:**

- `frombuffer`, `fromfile`, `fromiter`

Examples

```python
>>> np.fromstring('0102', dtype=np.uint8)
array([1, 2], dtype=uint8)
```

```python
>>> np.fromstring('1 2', dtype=int, sep=' ')
array([1, 2])
```

```python
>>> np.fromstring('1, 2', dtype=int, sep=',')
array([1, 2])
```

```python
>>> np.fromstring('\x01\x02\x03\x04\x05', dtype=np.uint8, count=3)
array([1, 2, 3], dtype=uint8)
```

```
numpy.loadtxt(fname, dtype=<type 'float'>, comments='%', delimiter=None, converters=None, skiprows=0, usecols=None, unpack=False, ndmin=0)
```

Load data from a text file.

Each row in the text file must have the same number of values.

**Parameters**

- `fname`: file or str
File, filename, or generator to read. If the filename extension is .gz or .bz2, the file is first decompressed. Note that generators should return byte strings for Python 3k.

dtype : data-type, optional

Data-type of the resulting array; default: float. If this is a record data-type, the resulting array will be 1-dimensional, and each row will be interpreted as an element of the array. In this case, the number of columns used must match the number of fields in the data-type.

comments : str, optional

The character used to indicate the start of a comment; default: ‘#’.

delimiter : str, optional

The string used to separate values. By default, this is any whitespace.

converters : dict, optional

A dictionary mapping column number to a function that will convert that column to a float. E.g., if column 0 is a date string: converters = {0: datestr2num}. Converters can also be used to provide a default value for missing data (but see also genfromtxt): converters = {3: lambda s: float(s.strip() or 0)}. Default: None.

skiprows : int, optional

Skip the first skiprows lines; default: 0.

usecols : sequence, optional

Which columns to read, with 0 being the first. For example, usecols = (1,4,5) will extract the 2nd, 5th and 6th columns. The default, None, results in all columns being read.

unpack : bool, optional

If True, the returned array is transposed, so that arguments may be unpacked using x, y, z = loadtxt(...). When used with a record data-type, arrays are returned for each field. Default is False.

ndmin : int, optional

The returned array will have at least ndmin dimensions. Otherwise mono-dimensional axes will be squeezed. Legal values: 0 (default), 1 or 2.

New in version 1.6.0.

**Returns**

out : ndarray

Data read from the text file.

See also:

load, fromstring, fromregex

genfromtxt

Load data with missing values handled as specified.

scipy.io.loadmat

reads MATLAB data files
Notes
This function aims to be a fast reader for simply formatted files. The genfromtxt function provides more sophisticated handling of, e.g., lines with missing values.

Examples

```python
>>> from StringIO import StringIO  # StringIO behaves like a file object
>>> c = StringIO("0 1
2 3")
>>> np.loadtxt(c)
array([[ 0., 1.],
       [ 2., 3.]])

>>> d = StringIO("M 21 72
F 35 58")
>>> np.loadtxt(d, dtype={'names': ('gender', 'age', 'weight'),
...                      'formats': ('S1', 'i4', 'f4')})
array([('M', 21, 72.0), ('F', 35, 58.0)],
      dtype=[('gender', '|S1'), ('age', '<i4'), ('weight', '<f4')])

>>> c = StringIO("1,0,2
3,0,4")
>>> x, y = np.loadtxt(c, delimiter=',', usecols=(0, 2), unpack=True)
>>> x
array([ 1., 3.])
>>> y
array([ 2., 4.])
```

3.1.3 Creating record arrays (numpy.rec)

Note: `numpy.rec` is the preferred alias for `numpy.core.records`.

```python
core.records.array(obj, dtype, shape,...)  # Construct a record array from a wide-variety of objects.
core.records.fromarrays(arrayList[, dtype, ...])  # create a record array from a (flat) list of arrays
core.records.fromrecords(recList[, dtype, ...])  # create a recarray from a list of records in text form
core.records.fromstring(datastring[, dtype, ...])  # Create an (read-only) record array from binary data contained in
core.records.fromfile(fd[, dtype, shape,...])  # If file is a string then that file is opened
```
create a recarray from a list of records in text form

The data in the same field can be heterogeneous, they will be promoted to the highest data type. This method is intended for creating smaller record arrays. If used to create large array without formats defined

```
>> r=fromrecords([(2,3.,'abc')]*100000)
```  
it can be slow.

If formats is None, then this will auto-detect formats. Use list of tuples rather than list of lists for faster processing.

```
>>> r=np.core.records.fromrecords([(456,'dbe',1.2),(2,'de',1.3)],
... names='col1,col2,col3')
```

```
>>> print r[0]
(456, 'dbe', 1.2)
```

```
>>> r.col1
array([456, 2])
```

```
>>> r.col2
chararray(['dbe', 'de'],
          dtype='|S3')
```

```
>>> import pickle
>>> print pickle.loads(pickle.dumps(r))
[(456, 'dbe', 1.2) (2, 'de', 1.3)]
```

```
numpy.core.records.fromstring(datastring, dtype=None, shape=None, offset=0, formats=None,
... names=None, titles=None, aligned=False, byteorder=None)
```  
create a (read-only) record array from binary data contained in a string

```
numpy.core.records.fromfile(fd, dtype=None, shape=None, offset=0, formats=None,
... names=None, titles=None, aligned=False, byteorder=None)
```  
Create an array from binary file data

If file is a string then that file is opened, else it is assumed to be a file object.

```
>>> from tempfile import TemporaryFile
>>> a = np.empty(10,dtype='f8,i4,a5')
>>> a[5] = (0.5,10,'abcde')
>>> fd=TemporaryFile()
>>> a = a.newbyteorder('<')
>>> a.tofile(fd)
>>> fd.seek(0)
>>> r=np.core.records.fromfile(fd, formats='f8,i4,a5', shape=10,
... byteorder='<')
```

```
>>> print r[5]
(0.5, 10, 'abcde')
```

```
>>> r.shape
(10,)
```

### 3.1.4 Creating character arrays (numpy.char)

**Note:** numpy.char is the preferred alias for numpy.core.defchararray.

```
core.defchararray.array(obj[, itemsize, ...])  Create a chararray.
```

Continued on next page
**Table 3.4 – continued from previous page**

```
core.defchararray.asarray(obj[, itemsize, ...])  Convert the input to a chararray, copying the data only if necessary.
```

```
numpy.core.defchararray.array(obj, itemsize=None, copy=True, unicode=None, order=None)

Create a chararray.

**Note:** This class is provided for numarray backward-compatibility. New code (not concerned with numarray compatibility) should use arrays of type `string_` or `unicode_` and use the free functions in `numpy.char` for fast vectorized string operations instead.

Versus a regular Numpy array of type `str` or `unicode`, this class adds the following functionality:

1. values automatically have whitespace removed from the end when indexed
2. comparison operators automatically remove whitespace from the end when comparing values
3. vectorized string operations are provided as methods (e.g. `str.endswith`) and infix operators (e.g. `+`, `*`, `%)

**Parameters**

- **obj :** array of str or unicode-like
- **itemsize :** int, optional
  
  *itemsize* is the number of characters per scalar in the resulting array. If *itemsize* is None, and *obj* is an object array or a Python list, the *itemsize* will be automatically determined. If *itemsize* is provided and *obj* is of type str or unicode, then the *obj* string will be chunked into *itemsize* pieces.
- **copy :** bool, optional
  
  If true (default), then the object is copied. Otherwise, a copy will only be made if __array__ returns a copy, if *obj* is a nested sequence, or if a copy is needed to satisfy any of the other requirements (*itemsize*, `unicode`, `order`, etc.).
- **unicode :** bool, optional
  
  When true, the resulting chararray can contain Unicode characters, when false only 8-bit characters. If `unicode` is `None` and `obj` is one of the following:
  
  - a chararray,
  - an ndarray of type `str` or `unicode`
  - a Python str or unicode object,
  
  then the unicode setting of the output array will be automatically determined.
- **order :** `{‘C’, ‘F’, ‘A’}`, optional
  
  Specify the order of the array. If order is ‘C’ (default), then the array will be in C-contiguous order (last-index varies the fastest). If order is ‘F’, then the returned array will be in Fortran-contiguous order (first-index varies the fastest). If order is ‘A’, then the returned array may be in any order (either C-, Fortran-contiguous, or even discontiguous).

```
numpy.core.defchararray.asarray(obj, itemsize=None, unicode=None, order=None)

Convert the input to a chararray, copying the data only if necessary.

Versus a regular Numpy array of type `str` or `unicode`, this class adds the following functionality:

1. values automatically have whitespace removed from the end when indexed

---

3.1. Array creation routines
2. Comparison operators automatically remove whitespace from the end when comparing values.

3. Vectorized string operations are provided as methods (e.g. `str.endswith`) and infix operators (e.g. `+`, `*`, `%`)

**Parameters**

- `obj`: array of str or unicode-like
- `itemsize`: int, optional
  
  *itemsize* is the number of characters per scalar in the resulting array. If `itemsize` is None, and `obj` is an object array or a Python list, the `itemsize` will be automatically determined. If `itemsize` is provided and `obj` is of type str or unicode, then the `obj` string will be chunked into `itemsize` pieces.

- `unicode`: bool, optional
  
  When true, the resulting `chararray` can contain Unicode characters, when false only 8-bit characters. If `unicode` is `None` and `obj` is one of the following:
  
  - a `chararray`,
  - an ndarray of type `str` or `unicode`
  - a Python str or unicode object,

  then the unicode setting of the output array will be automatically determined.

- `order`: {'C', 'F'}, optional
  
  Specify the order of the array. If order is `C` (default), then the array will be in C-contiguous order (last-index varies the fastest). If order is `F`, then the returned array will be in Fortran-contiguous order (first-index varies the fastest).

### 3.1.5 Numerical ranges

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<th>Function</th>
<th>Description</th>
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<td><code>arange</code></td>
<td>Return evenly spaced values within a given interval.</td>
</tr>
<tr>
<td><code>linspace</code></td>
<td>Return evenly spaced numbers over a specified interval.</td>
</tr>
<tr>
<td><code>logspace</code></td>
<td>Return numbers spaced evenly on a log scale.</td>
</tr>
<tr>
<td><code>meshgrid</code></td>
<td>Return coordinate matrices from coordinate vectors.</td>
</tr>
<tr>
<td><code>ndgrid</code></td>
<td><code>nd_grid</code> instance which returns a dense multi-dimensional “meshgrid”.</td>
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<td><code>ogrid</code></td>
<td><code>nd_grid</code> instance which returns an open multi-dimensional “meshgrid”.</td>
</tr>
</tbody>
</table>

**numpy.arange** ([`start`, `stop`, `step`, `dtype=\text{None}`])

Return evenly spaced values within a given interval.

Values are generated within the half-open interval `[start, stop)` (in other words, the interval including `start` but excluding `stop`). For integer arguments the function is equivalent to the Python built-in `range` function, but returns an ndarray rather than a list.

When using a non-integer step, such as 0.1, the results will often not be consistent. It is better to use `linspace` for these cases.

**Parameters**

- `start`: number, optional
  
  Start of interval. The interval includes this value. The default start value is 0.

- `stop`: number
End of interval. The interval does not include this value, except in some cases where step is not an integer and floating point round-off affects the length of out.

step : number, optional
Spacing between values. For any output out, this is the distance between two adjacent values, out[i+1] - out[i]. The default step size is 1. If step is specified, start must also be given.

dtype : dtype
The type of the output array. If dtype is not given, infer the data type from the other input arguments.

Returns
arange : ndarray
Array of evenly spaced values.

For floating point arguments, the length of the result is ceil((stop - start)/step). Because of floating point overflow, this rule may result in the last element of out being greater than stop.

See also:

linspace
Evenly spaced numbers with careful handling of endpoints.

ogrid
Arrays of evenly spaced numbers in N-dimensions.

mgrid
Grid-shaped arrays of evenly spaced numbers in N-dimensions.

Examples

```python
>>> np.arange(3)
array([0, 1, 2])
```

```
>>> np.arange(3.0)
array([ 0., 1., 2.])
```

```
>>> np.arange(3,7)
array([3, 4, 5, 6])
```

```
>>> np.arange(3,7,2)
array([3, 5])
```

numpy.linspace (start, stop, num=50, endpoint=True, retstep=False, dtype=None)

Return evenly spaced numbers over a specified interval.

Returns num evenly spaced samples, calculated over the interval [start, stop].

The endpoint of the interval can optionally be excluded.

Parameters

start : scalar
The starting value of the sequence.

stop : scalar
The end value of the sequence, unless endpoint is set to False. In that case, the sequence consists of all but the last of num + 1 evenly spaced samples, so that stop is excluded. Note that the step size changes when endpoint is False.

num : int, optional
Number of samples to generate. Default is 50.

endpoint : bool, optional

If True, stop is the last sample. Otherwise, it is not included. Default is True.

retstep : bool, optional

If True, return (samples, step), where step is the spacing between samples.

dtype : dtype, optional

The type of the output array. If dtype is not given, infer the data type from the other input arguments.

New in version 1.9.0.

Returns

samples : ndarray

There are num equally spaced samples in the closed interval [start, stop] or the half-open interval [start, stop) (depending on whether endpoint is True or False).

step : float

Only returned if retstep is True

Size of spacing between samples.

See also:

arange

Similar to linspace, but uses a step size (instead of the number of samples).

logspace

Samples uniformly distributed in log space.

Examples

```python
>>> np.linspace(2.0, 3.0, num=5)
array([ 2. , 2.25, 2.5 , 2.75, 3. ])
>>> np.linspace(2.0, 3.0, num=5, endpoint=False)
array([ 2. , 2.2, 2.4, 2.6, 2.8])
>>> np.linspace(2.0, 3.0, num=5, retstep=True)
(array([ 2. , 2.25, 2.5 , 2.75, 3. ]), 0.25)
```

Graphical illustration:

```python
>>> import matplotlib.pyplot as plt

>>> N = 8
>>> y = np.zeros(N)
>>> x1 = np.linspace(0, 10, N, endpoint=True)
>>> x2 = np.linspace(0, 10, N, endpoint=False)
>>> plt.plot(x1, y, 'o')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.plot(x2, y + 0.5, 'o')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.ylim([-0.5, 1])
(-0.5, 1)
>>> plt.show()
```
numpy.logspace

Return numbers spaced evenly on a log scale.

In linear space, the sequence starts at $base^{start}$ (base to the power of start) and ends with $base^{stop}$ (see endpoint below).

Parameters

- **start**: float
  
  $base^{start}$ is the starting value of the sequence.

- **stop**: float
  
  $base^{stop}$ is the final value of the sequence, unless endpoint is False. In that case, num + 1 values are spaced over the interval in log-space, of which all but the last (a sequence of length num) are returned.

- **num**: integer, optional
  
  Number of samples to generate. Default is 50.

- **endpoint**: boolean, optional
  
  If true, stop is the last sample. Otherwise, it is not included. Default is True.

- **base**: float, optional
  
  The base of the log space. The step size between the elements in \( \log_{base}(samples) \) is uniform. Default is 10.0.

- **dtype**: dtype
  
  The type of the output array. If dtype is not given, infer the data type from the other input arguments.

Returns

- **samples**: ndarray
  
  num samples, equally spaced on a log scale.

See also:
**arange**

Similar to linspace, with the step size specified instead of the number of samples. Note that, when used with a float endpoint, the endpoint may or may not be included.

**linspace**

Similar to logspace, but with the samples uniformly distributed in linear space, instead of log space.

**Notes**

Logspace is equivalent to the code

```python
>>> y = np.linspace(start, stop, num=num, endpoint=endpoint)
... >>> power(base, y).astype(dtype)
...```

**Examples**

```python
>>> np.logspace(2.0, 3.0, num=4)
array([ 100. , 215.443469 , 464.15888336, 1000. ])
>>> np.logspace(2.0, 3.0, num=4, endpoint=False)
array([ 100.0000000 , 177.82794106, 316.22776602, 562.34132519])
>>> np.logspace(2.0, 3.0, num=4, base=2.0)
array([ 4. , 5.0396842 , 6.34960421, 8. , 10. , 19.42630361, 31.38428377, 50. , 81. , 125.66370614, 200. , 331.15452036, 512. ])
```

Graphical illustration:

```python
>>> import matplotlib.pyplot as plt
>>> N = 10
>>> x1 = np.logspace(0.1, 1, N, endpoint=True)
>>> x2 = np.logspace(0.1, 1, N, endpoint=False)
>>> y = np.zeros(N)
>>> plt.plot(x1, y, 'o')
... <<matplotlib.lines.Line2D object at 0x...>>
>>> plt.plot(x2, y + 0.5, 'o')
... <<matplotlib.lines.Line2D object at 0x...>>
>>> plt.ylim([-0.5, 1])
(-0.5, 1)
>>> plt.show()
```
numpy.meshgrid(*xi, **kwargs)

Return coordinate matrices from coordinate vectors.

Make N-D coordinate arrays for vectorized evaluations of N-D scalar/vector fields over N-D grids, given one-dimensional coordinate arrays x1, x2,..., xn.

Changed in version 1.9: 1-D and 0-D cases are allowed.

Parameters

x1, x2,..., xn : array_like

1-D arrays representing the coordinates of a grid.

indexing : {'xy', 'ij'}, optional

Cartesian ('xy', default) or matrix ('ij') indexing of output. See Notes for more details.

New in version 1.7.0.

sparse : bool, optional

If True a sparse grid is returned in order to conserve memory. Default is False.

New in version 1.7.0.

copy : bool, optional

If False, a view into the original arrays are returned in order to conserve memory. Default is True. Please note that sparse=False, copy=False will likely return non-contiguous arrays. Furthermore, more than one element of a broadcast array may refer to a single memory location. If you need to write to the arrays, make copies first.

New in version 1.7.0.

Returns

X1, X2,..., XN : ndarray

For vectors x1, x2,..., xn with lengths Ni=len(xi), return (N1, N2, N3,...Nn) shaped arrays if indexing='ij' or (N2, N1, N3,...Nn) shaped arrays if indexing='xy' with the elements of xi repeated to fill the matrix along the first dimension for x1, the second for x2 and so on.

See also:

index_tricks.mgrid

Construct a multi-dimensional “meshgrid” using indexing notation.

index_tricks.ogrid

Construct an open multi-dimensional “meshgrid” using indexing notation.

Notes

This function supports both indexing conventions through the indexing keyword argument. Giving the string ‘ij’ returns a meshgrid with matrix indexing, while ‘xy’ returns a meshgrid with Cartesian indexing. In the 2-D case with inputs of length M and N, the outputs are of shape (N, M) for ‘xy’ indexing and (M, N) for ‘ij’ indexing. In the 3-D case with inputs of length M, N and P, outputs are of shape (N, M, P) for ‘xy’ indexing and (M, N, P) for ‘ij’ indexing. The difference is illustrated by the following code snippet:

```python
xv, yv = meshgrid(x, y, sparse=False, indexing='ij')
for i in range(nx):
    for j in range(ny):
        # treat xv[i,j], yv[i,j]
```

```python
xv, yv = meshgrid(x, y, sparse=False, indexing='xy')
```

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for i in range(nx):
    for j in range(ny):
        # treat xv[j,i], yv[j,i]

In the 1-D and 0-D case, the indexing and sparse keywords have no effect.

Examples

```python
>>> nx, ny = (3, 2)
>>> x = np.linspace(0, 1, nx)
>>> y = np.linspace(0, 1, ny)
>>> xv, yv = meshgrid(x, y)
>>> xv
array([[ 0. , 0.5, 1. ],
       [ 0. , 0.5, 1. ]])
>>> yv
array([[ 0. , 0. , 0. ],
       [ 1. , 1. , 1. ]])
>>> xv, yv = meshgrid(x, y, sparse=True)  # make sparse output arrays
>>> xv
array([[ 0. ],
       [ 1. ]])
>>> yv
array([[ 0.],
       [ 1.])
```

`meshgrid` is very useful to evaluate functions on a grid.

```python
>>> x = np.arange(-5, 5, 0.1)
>>> y = np.arange(-5, 5, 0.1)
>>> xx, yy = meshgrid(x, y, sparse=True)
>>> z = np.sin(xx**2 + yy**2) / (xx**2 + yy**2)
>>> h = plt.contourf(x,y,z)
```

```
>>> numpy.mgrid = <numpy.lib.index_tricks.nd_grid object at 0x41607cec>
nd_grid instance which returns a dense multi-dimensional “meshgrid”.

An instance of `numpy.lib.index_tricks.nd_grid` which returns an dense (or fleshed out) mesh-grid when indexed, so that each returned argument has the same shape. The dimensions and number of the output arrays are equal to the number of indexing dimensions. If the step length is not a complex number, then the stop is not inclusive.

However, if the step length is a complex number (e.g. 5j), then the integer part of its magnitude is interpreted as specifying the number of points to create between the start and stop values, where the stop value is inclusive.

Returns

mesh-grid `ndarrays` all of the same dimensions

See also:

- `numpy.lib.index_tricks.nd_grid`
  - class of `ogrid` and `mgrid` objects
- `ogrid`
  - like `mgrid` but returns open (not fleshed out) mesh grids
- `r_
  - array concatenator
Examples

```python
>>> np.mgrid[0:5,0:5]
array([[0, 0, 0, 0, 0],
       [1, 1, 1, 1, 1],
       [2, 2, 2, 2, 2],
       [3, 3, 3, 3, 3],
       [4, 4, 4, 4, 4]],
       [[0, 1, 2, 3, 4],
       [0, 1, 2, 3, 4],
       [0, 1, 2, 3, 4],
       [0, 1, 2, 3, 4],
       [0, 1, 2, 3, 4]])
```

```python
>>> np.mgrid[-1:1:5j]
array([-1. , -0.5, 0. , 0.5, 1. ])
```

`numpy.ogrid = <numpy.lib.index_tricks.nd_grid object at 0x41607d4c>`

`nd_grid` instance which returns an open multi-dimensional “meshgrid”.

An instance of `numpy.lib.index_tricks.nd_grid` which returns an open (i.e. not fleshed out) meshgrid when indexed, so that only one dimension of each returned array is greater than 1. The dimension and number of the output arrays are equal to the number of indexing dimensions. If the step length is not a complex number, then the stop is not inclusive.

However, if the step length is a `complex number` (e.g. 5j), then the integer part of its magnitude is interpreted as specifying the number of points to create between the start and stop values, where the stop value is inclusive.

**Returns**

mesh-grid `ndarrays` with only one dimension ≠ 1

See also:

`np.lib.index_tricks.nd_grid`

class of `ogrid` and `mgrid` objects

`mgrid`

like `ogrid` but returns dense (or fleshed out) mesh grids

`r_`

array concatenator

Examples

```python
>>> from numpy import ogrid

```  

```python
>>> ogrid[-1:1:5j]
array([-1. , -0.5, 0. , 0.5, 1. ])
```

```python
>>> ogrid[0:5,0:5]
[array([[0],
       [1],
       [2],
       [3],
       [4]]), array([[0, 1, 2, 3, 4]])]
```

### 3.1.6 Building matrices

<table>
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<th>Function</th>
<th>Description</th>
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<td><code>diag(v[, k])</code></td>
<td>Extract a diagonal or construct a diagonal array.</td>
</tr>
<tr>
<td><code>diagflat(v[, k])</code></td>
<td>Create a two-dimensional array with the flattened input as a diagonal.</td>
</tr>
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<table>
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<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td><code>tril(N [, M, k, dtype])</code></td>
<td>An array with ones at and below the given diagonal and zeros elsewhere.</td>
</tr>
<tr>
<td><code>tril(m [, k])</code></td>
<td>Lower triangle of an array.</td>
</tr>
<tr>
<td><code>triu(m [, k])</code></td>
<td>Upper triangle of an array.</td>
</tr>
<tr>
<td><code>vander(x [, N, increasing])</code></td>
<td>Generate a Vandermonde matrix.</td>
</tr>
</tbody>
</table>

```
import numpy as np

# Extract a diagonal or construct a diagonal array.

# See the more detailed documentation for numpy.diag if you use this function to extract a diagonal and
# wish to write to the resulting array; whether it returns a copy or a view depends on what version of numpy you
# are using.

Parameters
v : array_like
    If v is a 2-D array, return a copy of its k-th diagonal. If v is a 1-D array, return a 2-D
    array with v on the k-th diagonal.

k : int, optional
    Diagonal in question. The default is 0. Use k>0 for diagonals above the main diagonal,
    and k<0 for diagonals below the main diagonal.

Returns
out : ndarray
    The extracted diagonal or constructed diagonal array.

See also:

diagonal
Return specified diagonals.

diagflat
Create a 2-D array with the flattened input as a diagonal.

trace
Sum along diagonals.

triu
Upper triangle of an array.

tril
Lower triangle of an array.

Examples

>>> x = np.arange(9).reshape((3,3))
>>> x
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])

>>> np.diag(x)
array([0, 4, 8])

>>> np.diag(x, k=1)
array([1, 5])

>>> np.diag(x, k=-1)
array([3, 7])
```
>>> np.diag(np.diag(x))
array([[0, 0, 0],
[0, 4, 0],
[0, 0, 8]])

numpy.diagflat(v, k=0)
Create a two-dimensional array with the flattened input as a diagonal.

Parameters
- **v**: array_like
  Input data, which is flattened and set as the k-th diagonal of the output.
- **k**: int, optional
  Diagonal to set; 0, the default, corresponds to the “main” diagonal, a positive (negative) k giving the number of the diagonal above (below) the main.

Returns
- **out**: ndarray
  The 2-D output array.

See also:
- **diag**: MATLAB work-alike for 1-D and 2-D arrays.
- **diagonal**: Return specified diagonals.
- **trace**: Sum along diagonals.

Examples
>>> np.diagflat([[1,2], [3,4]])
array([[0, 0, 0, 0],
[0, 2, 0, 0],
[0, 0, 3, 0],
[0, 0, 0, 4]])

>>> np.diagflat([1,2], 1)
array([[0, 1, 0],
[0, 0, 2],
[0, 0, 0]])

numpy.tri(N, M=None, k=0, dtype=<type 'float'>)
An array with ones at and below the given diagonal and zeros elsewhere.

Parameters
- **N**: int
  Number of rows in the array.
- **M**: int, optional
  Number of columns in the array. By default, M is taken equal to N.
- **k**: int, optional
  The sub-diagonal at and below which the array is filled. k = 0 is the main diagonal, while k < 0 is below it, and k > 0 is above. The default is 0.
**dtype**: dtype, optional

Data type of the returned array. The default is float.

**Returns**

- **tri**: ndarray of shape (N, M)

  Array with its lower triangle filled with ones and zero elsewhere; in other words
  \(T[i,j] = 1\) for \(i \leq j + k\), 0 otherwise.

**Examples**

```python
>>> np.tri(3, 5, 2, dtype=int)
array([[1, 1, 1, 0, 0],
       [1, 1, 1, 1, 0],
       [1, 1, 1, 1, 1]])
```

```python
>>> np.tri(3, 5, -1)
array([[ 0., 0., 0., 0., 0.],
       [ 1., 0., 0., 0., 0.],
       [ 1., 1., 0., 0., 0.]])
```

**numpy.tri(m, k=0)**

Lower triangle of an array.

Return a copy of an array with elements above the \(k\)-th diagonal zeroed.

**Parameters**

- **m**: array_like, shape (M, N)
  
  Input array.

- **k**: int, optional
  
  Diagonal above which to zero elements. \(k = 0\) (the default) is the main diagonal, \(k < 0\) is below it and \(k > 0\) is above.

**Returns**

- **tri**: ndarray, shape (M, N)

  Lower triangle of \(m\), of same shape and data-type as \(m\).

**See also:**

**triu**

same thing, only for the upper triangle

**Examples**

```python
>>> np.triu([[1,2,3],[4,5,6],[7,8,9],[10,11,12]], -1)
array([[ 0., 0., 0.],
       [ 4., 0., 0.],
       [ 7., 8., 0.],
       [10., 11., 12.]])
```

**numpy.triu(m, k=0)**

Upper triangle of an array.

Return a copy of a matrix with the elements below the \(k\)-th diagonal zeroed.

Please refer to the documentation for **tril** for further details.

**See also:**
tril
lower triangle of an array

Examples

```python
gtriu([[1, 2, 3], [4, 5, 6], [7, 8, 9], [10, 11, 12]], -1)
array([[ 1,  2,  3],
       [ 4,  5,  6],
       [ 0,  8,  9],
       [ 0,  0, 12]])
```

```python
np.vander(x, N=None, increasing=False)
Generate a Vandermonde matrix.
The columns of the output matrix are powers of the input vector. The order of the powers is determined by the increasing boolean argument. Specifically, when increasing is False, the i-th output column is the input vector raised element-wise to the power of N - i - 1. Such a matrix with a geometric progression in each row is named for Alexandre-Theophile Vandermonde.

**Parameters**

- `x`: array_like
  1-D input array.
- `N`: int, optional
  Number of columns in the output. If `N` is not specified, a square array is returned (N = len(x)).
- `increasing`: bool, optional
  Order of the powers of the columns. If True, the powers increase from left to right, if False (the default) they are reversed.

**Returns**

- `out`: ndarray
  Vandermonde matrix. If increasing is False, the first column is x^(N-1), the second x^(N-2) and so forth. If increasing is True, the columns are x^0, x^1, ..., x^(N-1).

**See also:**

polynomial.polynomial.polyvander

**Examples**

```python
x = np.array([1, 2, 3, 5])
N = 3
np.vander(x, N)
array([[ 1,  1,  1],
       [ 4,  2,  1],
       [ 9,  3,  1],
       [25,  5,  1]])
```

```python
np.column_stack([x**(N-1-i) for i in range(N)])
array([[ 1,  1,  1],
       [ 4,  2,  1],
       [ 9,  3,  1],
       [25,  5,  1]])
```
```python
>>> x = np.array([1, 2, 3, 5])
>>> np.vander(x)
array([[ 1,  1,  1,  1],
       [ 8,  4,  2,  1],
       [27,  9,  3,  1],
       [125, 25,  5,  1]])
>>> np.vander(x, increasing=True)
array([[ 1,  1,  1,  1],
       [ 1,  2,  4,  8],
       [ 1,  3,  9, 27],
       [ 1,  5, 25, 125]])
```

The determinant of a square Vandermonde matrix is the product of the differences between the values of the input vector:

```python
>>> np.linalg.det(np.vander(x))
48.000000000000043
>>> (5-3)*(5-2)*(5-1)*(3-2)*(3-1)*(2-1)
48
```

### 3.1.7 The Matrix class

```
mat(data[, dtype]) Interprets the input as a matrix.
bmat(obj[, ldict, gdict]) Build a matrix object from a string, nested sequence, or array.
```

#### numpy.mat(data, dtype=None)
Interpret the input as a matrix.

Unlike `matrix`, `asmatrix` does not make a copy if the input is already a matrix or an ndarray. Equivalent to `matrix(data, copy=False)`.

**Parameters**
- **data**: array_like
  - Input data.

**Returns**
- **mat**: matrix
  - *data* interpreted as a matrix.

**Examples**

```python
>>> x = np.array([[1, 2], [3, 4]])
>>> m = np.asmatrix(x)
>>> x[0,0] = 5

>>> m
matrix([[5, 2],
        [3, 4]])
```

#### numpy.bmat(obj, ldict=None, gdict=None)
Build a matrix object from a string, nested sequence, or array.
Parameters

**obj** : str or array_like

Input data. Names of variables in the current scope may be referenced, even if *obj* is a string.

Returns

**out** : matrix

Returns a matrix object, which is a specialized 2-D array.

See also:

matrix

Examples

```python
>>> A = np.mat('1 1; 1 1')
>>> B = np.mat('2 2; 2 2')
>>> C = np.mat('3 4; 5 6')
>>> D = np.mat('7 8; 9 0')

All the following expressions construct the same block matrix:

```python
>>> np.bmat([[A, B], [C, D]])
matrix([[1, 1, 2, 2],
        [1, 1, 2, 2],
        [3, 4, 7, 8],
        [5, 6, 9, 0]])
``` 

```python
>>> np.bmat(np.r_[np.c_[A, B], np.c_[C, D]])
matrix([[1, 1, 2, 2],
        [1, 1, 2, 2],
        [3, 4, 7, 8],
        [5, 6, 9, 0]])
``` 

```python
>>> np.bmat('A,B; C,D')
matrix([[1, 1, 2, 2],
        [1, 1, 2, 2],
        [3, 4, 7, 8],
        [5, 6, 9, 0]])
``` 

3.2 Array manipulation routines

3.2.1 Basic operations

```python
numpy.copyto(dst, src[, casting, where])  
Copies values from one array to another, broadcasting as necessary.
``` 

*Parameters*

- **dst** : ndarray
  The array into which values are copied.
src : array_like

The array from which values are copied.

casting : {'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional

Controls what kind of data casting may occur when copying.

- 'no' means the data types should not be cast at all.
- 'equiv' means only byte-order changes are allowed.
- 'safe' means only casts which can preserve values are allowed.
- 'same_kind' means only safe casts or casts within a kind, like float64 to float32, are allowed.
- 'unsafe' means any data conversions may be done.

where : array_like of bool, optional

A boolean array which is broadcasted to match the dimensions of dst, and selects elements to copy from src to dst wherever it contains the value True.

### 3.2.2 Changing array shape

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
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<tr>
<td>reshape(a, newshape[, order])</td>
<td>Gives a new shape to an array without changing its data.</td>
</tr>
<tr>
<td>ravel(a[, order])</td>
<td>Return a flattened array.</td>
</tr>
<tr>
<td>ndarray.flat</td>
<td>A 1-D iterator over the array.</td>
</tr>
<tr>
<td>ndarray.flatten([order])</td>
<td>Return a copy of the array collapsed into one dimension.</td>
</tr>
</tbody>
</table>

```python
numpy.reshape(a, newshape, order='C')
```

Gives a new shape to an array without changing its data.

**Parameters**

- **a** : array_like
  
  Array to be reshaped.

- **newshape** : int or tuple of ints
  
  The new shape should be compatible with the original shape. If an integer, then the result will be a 1-D array of that length. One shape dimension can be -1. In this case, the value is inferred from the length of the array and remaining dimensions.

- **order** : {'C', 'F', 'A'}, optional
  
  Read the elements of a using this index order, and place the elements into the reshaped array using this index order. ‘C’ means to read / write the elements using C-like index order, with the last axis index changing fastest, back to the first axis index changing slowest. ‘F’ means to read / write the elements using Fortran-like index order, with the first index changing fastest, and the last index changing slowest. Note that the ‘C’ and ‘F’ options take no account of the memory layout of the underlying array, and only refer to the order of indexing. ‘A’ means to read / write the elements in Fortran-like index order if a is Fortran contiguous in memory, C-like order otherwise.

**Returns**

- **reshaped_array** : ndarray
  
  This will be a new view object if possible; otherwise, it will be a copy. Note there is no guarantee of the memory layout (C- or Fortran- contiguous) of the returned array.
See also:

\texttt{ndarray.reshape}

Equivalent method.

Notes

It is not always possible to change the shape of an array without copying the data. If you want an error to be raise if the data is copied, you should assign the new shape to the shape attribute of the array:

```python
g = np.zeros((10, 2))
# A transpose make the array non-contiguous
>>> b = g.T
# Taking a view makes it possible to modify the shape without modifying the
# initial object.
>>> c = b.view()
```  

```python
>>> c.shape = (20)
AttributeError: incompatible shape for a non-contiguous array
```

The \texttt{order} keyword gives the index ordering both for \textit{fetching} the values from \textit{a}, and then \textit{placing} the values into the output array. For example, let’s say you have an array:

```python
g = np.arange(6).reshape((3, 2))
```  

You can think of reshaping as first raveling the array (using the given index order), then inserting the elements from the raveled array into the new array using the same kind of index ordering as was used for the raveling.

```python
>>> np.reshape(a, (2, 3)) # C-like index ordering
array([[0, 1, 2],
        [3, 4, 5]])
```  

```python
>>> np.reshape(np.ravel(a), (2, 3)) # equivalent to C ravel then C reshape
array([[0, 1, 2],
        [3, 4, 5]])
```  

```python
>>> np.reshape(a, (2, 3), order='F') # Fortran-like index ordering
array([[0, 4, 3],
        [2, 1, 5]])
```  

```python
>>> np.reshape(np.ravel(a, order='F'), (2, 3), order='F')
array([[0, 4, 3],
        [2, 1, 5]])
```

Examples

```python
>>> a = np.arange([1, 2, 3])
>>> np.reshape(a, 6)
array([1, 2, 3, 4, 5, 6])
```  

```python
>>> np.reshape(a, 6, order='F')
array([1, 4, 2, 5, 3, 6])
```  

```python
>>> np.reshape(a, (3, -1)) # the unspecified value is inferred to be 2
array([[1, 2],
        [3, 4],
        [5, 6]])
```

\texttt{numpy.ravel}(\textit{a, order='C'}

Return a flattened array.

3.2. Array manipulation routines 503
A 1-D array, containing the elements of the input, is returned. A copy is made only if needed.

Parameters

- `a` : array_like
  Input array. The elements in `a` are read in the order specified by `order`, and packed as a 1-D array.

- `order` : {'C', 'F', 'A', 'K'}, optional
  The elements of `a` are read using this index order. ‘C’ means to index the elements in C-like order, with the last axis index changing fastest, back to the first axis index changing slowest. ‘F’ means to index the elements in Fortran-like index order, with the first index changing fastest, and the last index changing slowest. Note that the ‘C’ and ‘F’ options take no account of the memory layout of the underlying array, and only refer to the order of axis indexing. ‘A’ means to read the elements in Fortran-like index order if `a` is Fortran contiguous in memory, C-like order otherwise. ‘K’ means to read the elements in the order they occur in memory, except for reversing the data when strides are negative. By default, ‘C’ index order is used.

Returns

- `1d_array` : ndarray
  Output of the same dtype as `a`, and of shape `(a.size,)`.

See also:

- `ndarray.flat`
  1-D iterator over an array.

- `ndarray.flatten`
  1-D array copy of the elements of an array in row-major order.

Notes

In C-like (row-major) order, in two dimensions, the row index varies the slowest, and the column index the quickest. This can be generalized to multiple dimensions, where row-major order implies that the index along the first axis varies slowest, and the index along the last quickest. The opposite holds for Fortran-like, or column-major, index ordering.

Examples

It is equivalent to `reshape(-1, order=order)`.

```python
>>> x = np.array([[1, 2, 3], [4, 5, 6]])
>>> print np.ravel(x)
[1 2 3 4 5 6]

>>> print x.reshape(-1)
[1 2 3 4 5 6]

>>> print np.ravel(x, order='F')
[1 4 2 5 3 6]

When order is ‘A’, it will preserve the array’s ‘C’ or ‘F’ ordering:

```
When order is ‘K’, it will preserve orderings that are neither ‘C’ nor ‘F’, but won’t reverse axes:

```python
>>> a = np.arange(3[::-1]); a
array([2, 1, 0])
>>> a.ravel(order='C')
a.ravel([2, 1, 0])
>>> a.ravel(order='K')
a.ravel([2, 1, 0])
```

```python
>>> a = np.arange(12).reshape(2,3,2).swapaxes(1,2); a
array([[[ 0, 2, 4],
        [ 1, 3, 5]],
       [[ 6, 8, 10],
        [ 7, 9, 11]]])
>>> a.ravel(order='C')
a.ravel([ 0, 2, 4, 1, 3, 5, 6, 8, 10, 7, 9, 11])
>>> a.ravel(order='K')
a.ravel([ 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11])
```

**ndarray.flat**

A 1-D iterator over the array.

This is a `numpy.flatiter` instance, which acts similarly to, but is not a subclass of, Python’s built-in iterator object.

**See also:**

`flatten`

Return a copy of the array collapsed into one dimension.

`flatiter`

**Examples**

```python
>>> x = np.arange(1, 7).reshape(2, 3)
```

```python
>>> x
array([[1, 2, 3],
        [4, 5, 6]])
```

```python
>>> x.flat[3]
4
>>> x.T
array([[1, 4],
        [2, 5],
        [3, 6]])
```

```python
>>> x.T.flat[3]
5
>>> type(x.flat)
type('numpy.flatiter')
```

An assignment example:

```python
>>> x.flat = 3; x
array([[3, 3, 3],
        [3, 3, 3]])
```

```python
>>> x.flat[[1,4]] = 1; x
array([[3, 1, 3],
        [3, 1, 3]])
```

**ndarray.flatten** *(order='C')*

Return a copy of the array collapsed into one dimension.
Parameters
   order : {'C', 'F', 'A'}, optional
   Whether to flatten in C (row-major), Fortran (column-major) order, or preserve the
   C/Fortran ordering from a. The default is 'C'.

Returns
   y : ndarray
   A copy of the input array, flattened to one dimension.

See also:
   ravel
   Return a flattened array.
   flat
   A 1-D flat iterator over the array.

Examples
>>> a = np.array([[1, 2], [3, 4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])

3.2.3 Transpose-like operations

<table>
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<th>rollaxis(a, axis[, start])</th>
<th>Roll the specified axis backwards, until it lies in a given position.</th>
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<td>swapaxes(a, axis1, axis2)</td>
<td>Interchange two axes of an array.</td>
</tr>
<tr>
<td>ndarray.T</td>
<td>Same as self.transpose(), except that self is returned if self.ndim &lt; 2.</td>
</tr>
<tr>
<td>transpose(a[, axes])</td>
<td>Permute the dimensions of an array.</td>
</tr>
</tbody>
</table>

numpy.rollaxis(a, axis[, start=0])
Roll the specified axis backwards, until it lies in a given position.

Parameters
   a : ndarray
   Input array.
   axis : int
   The axis to roll backwards. The positions of the other axes do not change relative to one
   another.
   start : int, optional
   The axis is rolled until it lies before this position. The default, 0, results in a “complete”
   roll.

Returns
   res : ndarray
   Output array.

See also:
**roll**

Roll the elements of an array by a number of positions along a given axis.

**Examples**

```python
>>> a = np.ones((3,4,5,6))
>>> np.rollaxis(a, 3, 1).shape
(3, 6, 4, 5)
>>> np.rollaxis(a, 2).shape
(5, 3, 4, 6)
>>> np.rollaxis(a, 1, 4).shape
(3, 5, 6, 4)
```

**numpy.swapaxes** *(a, axis1, axis2)*

Interchange two axes of an array.

**Parameters**

- **a**: array_like
  - Input array.
- **axis1**: int
  - First axis.
- **axis2**: int
  - Second axis.

**Returns**

- **a_swapped**: ndarray
  - If `a` is an ndarray, then a view of `a` is returned; otherwise a new array is created.

**Examples**

```python
>>> x = np.array([[1,2,3]])
>>> np.swapaxes(x,0,1)
array([[1],
       [2],
       [3]])

>>> x = np.array([[[0,1],[2,3]],[[4,5],[6,7]]])
>>> x
array([[[0, 1],
        [2, 3]],
       [[4, 5],
        [6, 7]]])

>>> np.swapaxes(x,0,2)
array([[[0, 4],
        [2, 6]],
       [[1, 5],
        [3, 7]]])
```

**ndarray.T**

Same as `self.transpose()`, except that `self` is returned if `self.ndim < 2.`
Examples

```python
>>> x = np.array([[1., 2.], [3., 4.]])
>>> x
array([[ 1.,  2.],
    [ 3.,  4.]])
>>> x.T
array([[ 1.,  3.],
    [ 2.,  4.]])
```

```
numpy.transpose(a, axes=None)
```

Permute the dimensions of an array.

**Parameters**

- **a**: array_like
  - Input array.

- **axes**: list of ints, optional
  - By default, reverse the dimensions, otherwise permute the axes according to the values given.

**Returns**

- **p**: ndarray
  - `a` with its axes permuted. A view is returned whenever possible.

**See also:**

doarray

**Examples**

```python
>>> x = np.arange(4).reshape((2,2))
>>> x
array([[0, 1],
    [2, 3]])
>>> np.transpose(x)
array([[0, 2],
    [1, 3]])
```

```python
>>> x = np.ones((1, 2, 3))
```

```python
>>> np.transpose(x, (1, 0, 2)).shape
(2, 1, 3)
```

### 3.2.4 Changing number of dimensions

<table>
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<td><code>atleast_1d</code>(<em>arys)</em></td>
<td>Convert inputs to arrays with at least one dimension.</td>
</tr>
<tr>
<td><code>atleast_2d</code>(<em>arys)</em></td>
<td>View inputs as arrays with at least two dimensions.</td>
</tr>
<tr>
<td><code>atleast_3d</code>(<em>arys)</em></td>
<td>View inputs as arrays with at least three dimensions.</td>
</tr>
<tr>
<td><code>broadcast</code></td>
<td>Produce an object that mimics broadcasting.</td>
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</tbody>
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<table>
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<tr>
<th>Function</th>
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<tbody>
<tr>
<td>broadcast_arrays</td>
<td>Broadcast any number of arrays against each other.</td>
</tr>
<tr>
<td>expand_dims</td>
<td>Expand the shape of an array.</td>
</tr>
<tr>
<td>squeeze</td>
<td>Remove single-dimensional entries from the shape of an array.</td>
</tr>
</tbody>
</table>

**numpy.atleast_1d(*arys)**

Convert inputs to arrays with at least one dimension.

Scalar inputs are converted to 1-dimensional arrays, whilst higher-dimensional inputs are preserved.

**Parameters**

arys1, arys2, ... : array_like

One or more input arrays.

**Returns**

ret : ndarray

An array, or sequence of arrays, each with a.ndim >= 1. Copies are made only if necessary.

**See also:**

atleast_2d, atleast_3d

**Examples**

```python
>>> np.atleast_1d(1.0)
array([1.])

>>> x = np.arange(9.0).reshape(3, 3)
>>> np.atleast_1d(x)
array([[0., 1., 2.],
       [3., 4., 5.],
       [6., 7., 8.]])
```

**numpy.atleast_2d(*arys)**

View inputs as arrays with at least two dimensions.

**Parameters**

arys1, arys2, ... : array_like

One or more array-like sequences. Non-array inputs are converted to arrays. Arrays that already have two or more dimensions are preserved.

**Returns**

res, res2, ... : ndarray

An array, or tuple of arrays, each with a.ndim >= 2. Copies are avoided where possible, and views with two or more dimensions are returned.

**See also:**

atleast_1d, atleast_3d
Examples

```python
>>> np.atleast_2d(3.0)
array([[ 3.]])

>>> x = np.arange(3.0)
>>> np.atleast_2d(x)
array([[ 0., 1., 2.]])
>>> np.atleast_2d(x).base is x
True

>>> np.atleast_2d(1, [1, 2], [[1, 2]])
[array([[1]]), array([[1, 2]]), array([[1, 2]])]
```

```python
def numpy.atleast_3d(*arys)
    View inputs as arrays with at least three dimensions.

Parameters
arys1, arys2, ... : array_like
    One or more array-like sequences. Non-array inputs are converted to arrays. Arrays
    that already have three or more dimensions are preserved.

Returns
res1, res2, ... : ndarray
    An array, or tuple of arrays, each with a.ndim >= 3. Copies are avoided where
    possible, and views with three or more dimensions are returned. For example, a 1-D
    array of shape (N,) becomes a view of shape (1, N, 1), and a 2-D array of shape
    (M, N) becomes a view of shape (M, N, 1).

See also:

atleast_1d, atleast_2d
```

Examples

```python
>>> np.atleast_3d(3.0)
array([[[ 3.]]])

>>> x = np.arange(3.0)
>>> np.atleast_3d(x).shape
(1, 3, 1)

>>> x = np.arange(12.0).reshape(4,3)
>>> np.atleast_3d(x).shape
(4, 3, 1)
>>> np.atleast_3d(x).base is x
True

>>> for arr in np.atleast_3d([1, 2], [[1, 2]], [[[1, 2]]]):
...     print(arr, arr.shape
...
[[[1]
  [2]]] (1, 2, 1)
[[[1]
  [2]]] (1, 2, 1)
[[[1 2]]] (1, 1, 2)
```

```python
class numpy.broadcast
    Produce an object that mimics broadcasting.
```
Parameters
in1, in2, ... : array_like

Input parameters.

Returns
b : broadcast object

Broadcast the input parameters against one another, and return an object that encapsulates the result. Amongst others, it has shape and nd properties, and may be used as an iterator.

Examples
Manually adding two vectors, using broadcasting:

```python
>>> x = np.array([[1], [2], [3]])
>>> y = np.array([4, 5, 6])
>>> b = np.broadcast(x, y)

>>> out = np.empty(b.shape)
>>> out.flat = [u+v for (u,v) in b]

array([[ 5.,  6.,  7.],
       [ 6.,  7.,  8.],
       [ 7.,  8.,  9.]])
```

Compare against built-in broadcasting:

```python
>>> x + y
array([[5, 6, 7],
       [6, 7, 8],
       [7, 8, 9]])
```

Attributes

- **index**  current index in broadcasted result
- **iters**  tuple of iterators along self's “components.”
- **shape**  Shape of broadcasted result.
- **size**  Total size of broadcasted result.

Examples

```python
>>> x = np.array([[1], [2], [3]])
>>> y = np.array([4, 5, 6])
>>> b = np.broadcast(x, y)

>>> b.index
0

>>> b.iters
[(1, 4), (1, 5), (1, 6)]

>>> b.index
3
```

broadcast.index  current index in broadcasted result

broadcast.iters  tuple of iterators along self's “components.”
Returns a tuple of `numpy.flatiter` objects, one for each “component” of self.

See also:

`numpy.flatiter`

**Examples**

```python
g = np.array([1, 2, 3])
y = np.array([[4], [5], [6]])
b = np.broadcast(g, y)
row, col = b.iters
row.next(), col.next()
(1, 4)
```

**broadcast.shape**

Shape of broadcasted result.

**Examples**

```python
g = np.array([1, 2, 3])
y = np.array([[4], [5], [6]])
b = np.broadcast(g, y)
b.shape
(3, 3)
```

**broadcast.size**

Total size of broadcasted result.

**Examples**

```python
g = np.array([1, 2, 3])
y = np.array([[4], [5], [6]])
b = np.broadcast(g, y)
b.size
9
```

**Methods**

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<th>Description</th>
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<td><code>x.next()</code> -&gt; the next value, or raise StopIteration</td>
</tr>
<tr>
<td><code>reset()</code></td>
<td>Reset the broadcasted result’s iterator(s).</td>
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**broadcast.next**

`x.next()` -> the next value, or raise StopIteration

**broadcast.reset**

Reset the broadcasted result’s iterator(s).

**Parameters**

- None

**Returns**

- None

**Examples**

```python
g = np.array([1, 2, 3])
y = np.array([[4], [5], [6]])
b = np.broadcast(g, y)
```
```python
>>> b.index
0
>>> b.next(), b.next(), b.next()
((1, 4), (2, 4), (3, 4))
>>> b.index
3
>>> b.reset()
>>> b.index
0

callable

numpy.broadcast_arrays(*args)
Broadcast any number of arrays against each other.

Parameters

`*args` : array_likes

The arrays to broadcast.

Returns

broadcasted : list of arrays

These arrays are views on the original arrays. They are typically not contiguous. Furthermore, more than one element of a broadcasted array may refer to a single memory location. If you need to write to the arrays, make copies first.

Examples

```python
>>> x = np.array([[1, 2, 3]])
>>> y = np.array([[1], [2], [3]])
>>> np.broadcast_arrays(x, y)
[array([[1, 2, 3],
        [1, 2, 3],
        [1, 2, 3]]), array([[1, 1, 1],
        [2, 2, 2],
        [3, 3, 3]])]
```

Here is a useful idiom for getting contiguous copies instead of non-contiguous views.

```python
>>> [np.array(a) for a in np.broadcast_arrays(x, y)]
[array([[1, 2, 3],
        [1, 2, 3],
        [1, 2, 3]]), array([[1, 1, 1],
        [2, 2, 2],
        [3, 3, 3]])]
```

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```
Output array. The number of dimensions is one greater than that of the input array.

See also:
doc.indexing, atleast_1d, atleast_2d, atleast_3d

Examples

```python
>>> x = np.array([1,2])
>>> x.shape
(2,)
```

The following is equivalent to `x[np.newaxis, :]` or `x[np.newaxis]`:

```python
>>> y = np.expand_dims(x, axis=0)
>>> y
array([[1, 2]])
>>> y.shape
(1, 2)
```

```python
>>> y = np.expand_dims(x, axis=1)  # Equivalent to `x[:, newaxis]`
>>> y
array([[1],
       [2]])
>>> y.shape
(2, 1)
```

Note that some examples may use `None` instead of `np.newaxis`. These are the same objects:

```python
>>> np.newaxis is None
True
```

numpy.squeeze(a, axis=None)

Remove single-dimensional entries from the shape of an array.

Parameters
- **a**: array_like
  - Input data.
- **axis**: None or int or tuple of ints, optional
  - New in version 1.7.0.
  - Selects a subset of the single-dimensional entries in the shape. If an axis is selected with shape entry greater than one, an error is raised.

Returns
- **squeezed**: ndarray
  - The input array, but with all or a subset of the dimensions of length 1 removed. This is always `a` itself or a view into `a`.

Examples

```python
>>> x = np.array([[[0], [1], [2]]])
>>> x.shape
(1, 3, 1)
```

```python
>>> np.squeeze(x).shape
(3,)
```

```python
>>> np.squeeze(x, axis=(2,)).shape
(1, 3)
```
3.2.5 Changing kind of array

<table>
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</tr>
<tr>
<td>require(a[, dtype, requirements])</td>
<td>Return an ndarray of the provided type that satisfies requirements.</td>
</tr>
</tbody>
</table>

**numpy.asarray(a[, dtype=None, order=None])**

Convert the input to an array.

**Parameters**

- **a**: array_like
  
  Input data, in any form that can be converted to an array. This includes lists, lists of tuples, tuples of tuples, tuples of lists and ndarrays.

- **dtype**: data-type, optional
  
  By default, the data-type is inferred from the input data.

- **order**: {'C', 'F'}, optional
  
  Whether to use row-major ('C') or column-major ('F' for FORTRAN) memory representation. Defaults to ‘C’.

**Returns**

- **out**: ndarray
  
  Array interpretation of a. No copy is performed if the input is already an ndarray. If a is a subclass of ndarray, a base class ndarray is returned.

**See also:**

- **asanyarray**
  
  Similar function which passes through subclasses.

- **ascontiguousarray**
  
  Convert input to a contiguous array.

- **asfarray**
  
  Convert input to a floating point ndarray.

- **asfortranarray**
  
  Convert input to an ndarray with column-major memory order.

- **asarray_chkfinite**
  
  Similar function which checks input for NaNs and Infs.

- **fromiter**
  
  Create an array from an iterator.

- **fromfunction**
  
  Construct an array by executing a function on grid positions.
Examples

Convert a list into an array:

```python
globals()['Examples']
```

Existing arrays are not copied:

```python
globals()['Examples']
```

If `dtype` is set, array is copied only if dtype does not match:

```python
globals()['Examples']
```

Contrary to `asanyarray`, ndarray subclasses are not passed through:

```python
globals()['Examples']
```

numpy.asanyarray(a, dtype=None, order=None)

Convert the input to an ndarray, but pass ndarray subclasses through.

Parameters

- `a` : array_like
  Input data, in any form that can be converted to an array. This includes scalars, lists, lists of tuples, tuples, tuples of tuples, tuples of lists, and ndarrays.

- `dtype` : data-type, optional
  By default, the data-type is inferred from the input data.

- `order` : {'C', 'F'}, optional
  Whether to use row-major (‘C’) or column-major (‘F’) memory representation. Defaults to ‘C’.

Returns

- `out` : ndarray or an ndarray subclass
  Array interpretation of `a`. If `a` is an ndarray or a subclass of ndarray, it is returned as-is and no copy is performed.

See also:

- `asarray`
  Similar function which always returns ndarrays.

- `ascontiguousarray`
  Convert input to a contiguous array.
asfarray
Convert input to a floating point ndarray.

asfortranarray
Convert input to an ndarray with column-major memory order.

asarray_chkfinite
Similar function which checks input for NaNs and Infs.

fromiter
Create an array from an iterator.

fromfunction
Construct an array by executing a function on grid positions.

Examples
Convert a list into an array:

```python
>>> a = [1, 2]
>>> np.asanyarray(a)
array([1, 2])
```

Instances of ndarray subclasses are passed through as-is:

```python
>>> a = np.matrix([[1, 2]])
>>> np.asanyarray(a) is a
True
```

numpy.asmatrix(data, dtype=None)
Interpret the input as a matrix.

Unlike matrix, asmatrix does not make a copy if the input is already a matrix or an ndarray. Equivalent to matrix(data, copy=False).

Parameters
- data : array_like
  Input data.

Returns
- mat : matrix
  data interpreted as a matrix.

Examples

```python
>>> x = np.array([[1, 2], [3, 4]])

>>> m = np.asmatrix(x)

>>> x[0, 0] = 5

>>> m
matrix([[5, 2],
        [3, 4]])
```

numpy.asfarray(a, dtype=<type 'numpy.float64'>)
Return an array converted to a float type.

Parameters
- a : array_like
The input array.

**dtype**: str or dtype object, optional

Float type code to coerce input array a. If dtype is one of the ‘int’ dtypes, it is replaced with float64.

**Returns**

**out**: ndarray

The input a as a float ndarray.

**Examples**

```python
code
>>> np.asfarray([2, 3])
anarray([ 2., 3.])
>>> np.asfarray([2, 3], dtype='float')
anarray([ 2., 3.])
>>> np.asfarray([2, 3], dtype='int8')
anarray([ 2., 3.])
```

numpy.asfortranarray(a, dtype=None)

Return an array laid out in Fortran order in memory.

**Parameters**

- **a**: array_like
  - Input array.
- **dtype**: str or dtype object, optional
  - By default, the data-type is inferred from the input data.

**Returns**

- **out**: ndarray
  - The input a in Fortran, or column-major, order.

**See also:**

- **ascontiguousarray**
  - Convert input to a contiguous (C order) array.
- **asanyarray**
  - Convert input to an ndarray with either row or column-major memory order.
- **require**
  - Return an ndarray that satisfies requirements.
- **ndarray.flags**
  - Information about the memory layout of the array.

**Examples**

```python
code
>>> x = np.arange(6).reshape(2,3)
>>> y = np.asfortranarray(x)
>>> x.flags['F_CONTIGUOUS']
False
>>> y.flags['F_CONTIGUOUS']
True
```

numpy.ascontiguousarray(a, dtype=None)

Return a contiguous array in memory (C order).
Parameters

- **a**: array_like
  
  Input array.

- **dtype**: str or dtype object, optional
  
  Data-type of returned array.

Returns

- **out**: ndarray
  
  Contiguous array of same shape and content as a, with type dtype if specified.

See also:

- `asfortranarray`
  
  Convert input to an ndarray with column-major memory order.

- `require`
  
  Return an ndarray that satisfies requirements.

- `ndarray.flags`
  
  Information about the memory layout of the array.

Examples

```python
>>> x = np.arange(6).reshape(2, 3)
>>> np.ascontiguousarray(x, dtype=np.float32)
array([[ 0.,  1.,  2.],
       [ 3.,  4.,  5.]], dtype=float32)
>>> x.flags['C_CONTIGUOUS']
True
```

`numpy.asarray_chkfinite(a, dtype=None, order=None)`

Convert the input to an array, checking for NaNs or Infs.

Parameters

- **a**: array_like
  
  Input data, in any form that can be converted to an array. This includes lists, lists of tuples, tuples of tuples, tuples of lists and ndarrays. Success requires no NaNs or Infs.

- **dtype**: data-type, optional
  
  By default, the data-type is inferred from the input data.

- **order**: {'C', 'F'}, optional
  
  Whether to use row-major ('C') or column-major ('FORTRAN') memory representation. Defaults to ‘C’.

Returns

- **out**: ndarray
  
  Array interpretation of a. No copy is performed if the input is already an ndarray. If a is a subclass of ndarray, a base class ndarray is returned.

 Raises

- `ValueError`
  
  Raises ValueError if a contains NaN (Not a Number) or Inf (Infinity).

See also:
asarray
Create and array.

asanyarray
Similar function which passes through subclasses.

ascontiguousarray
Convert input to a contiguous array.

asfarray
Convert input to a floating point ndarray.

asfortranarray
Convert input to an ndarray with column-major memory order.

fromiter
Create an array from an iterator.

fromfunction
Construct an array by executing a function on grid positions.

Examples
Convert a list into an array. If all elements are finite asarray_chkfinite is identical to asarray.

```python
>>> a = [1, 2]
>>> np.asarray_chkfinite(a, dtype=float)
array([1., 2.])
```

Raises ValueError if array_like contains Nans or Infs.

```python
>>> a = [1, 2, np.inf]
>>> try:
...   np.asarray_chkfinite(a)
... except ValueError:
...   print('ValueError')
... ValueError
```

numpy.asscalar(a)
Convert an array of size 1 to its scalar equivalent.

Parameters
a : ndarray
Input array of size 1.

Returns
out : scalar
Scalar representation of a. The output data type is the same type returned by the input’s item method.

Examples
```python
>>> np.asscalar(np.array([24]))
24
```

numpy.require(a, dtype=None, requirements=None)
Return an ndarray of the provided type that satisfies requirements.

This function is useful to be sure that an array with the correct flags is returned for passing to compiled code (perhaps through ctypes).
Parameters

- **a**: array_like
  The object to be converted to a type-and-requirement-satisfying array.

- **dtype**: data-type
  The required data-type, the default data-type is float64).

- **requirements**: str or list of str
  The requirements list can be any of the following
  - ‘F_CONTIGUOUS’ (‘F’) - ensure a Fortran-contiguous array
  - ‘C_CONTIGUOUS’ (‘C’) - ensure a C-contiguous array
  - ‘ALIGNED’ (‘A’) - ensure a data-type aligned array
  - ‘WRITEABLE’ (‘W’) - ensure a writable array
  - ‘OWNDATA’ (‘O’) - ensure an array that owns its own data

See also:

- **asarray**
  Convert input to an ndarray.

- **asanyarray**
  Convert to an ndarray, but pass through ndarray subclasses.

- **ascontiguousarray**
  Convert input to a contiguous array.

- **asfortranarray**
  Convert input to an ndarray with column-major memory order.

- **ndarray.flags**
  Information about the memory layout of the array.

Notes

The returned array will be guaranteed to have the listed requirements by making a copy if needed.

Examples

```python
>>> x = np.arange(6).reshape(2,3)
>>> x.flags
  C_CONTIGUOUS : True
  F_CONTIGUOUS : False
  OWNDATA : False
  WRITEABLE : True
  ALIGNED : True
  UPDATEIFCOPY : False

>>> y = np.require(x, dtype=np.float32, requirements=['A', 'O', 'W', 'F'])
>>> y.flags
  C_CONTIGUOUS : False
  F_CONTIGUOUS : True
  OWNDATA : True
  WRITEABLE : True
  ALIGNED : True
  UPDATEIFCOPY : False
```

3.2. Array manipulation routines
3.2.6 Joining arrays

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<td>Stack arrays in sequence depth wise (along third axis).</td>
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<tr>
<td>hstack</td>
<td>Stack arrays in sequence horizontally (column wise).</td>
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<tr>
<td>vstack</td>
<td>Stack arrays in sequence vertically (row wise).</td>
</tr>
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</table>

numpy.column_stack(tup)
Stack 1-D arrays as columns into a 2-D array.

Take a sequence of 1-D arrays and stack them as columns to make a single 2-D array. 2-D arrays are stacked as-is, just like with hstack. 1-D arrays are turned into 2-D columns first.

Parameters
- **tup**: sequence of 1-D or 2-D arrays.
  Arrays to stack. All of them must have the same first dimension.

Returns
- **stacked**: 2-D array
  The array formed by stacking the given arrays.

See also:
- hstack, vstack, concatenate

Examples

```python
>>> a = np.array((1, 2, 3))
>>> b = np.array((2, 3, 4))
>>> np.column_stack((a, b))
array([[1, 2],
       [2, 3],
       [3, 4]])
```

numpy.concatenate((a1, a2, ...), axis=0)
Join a sequence of arrays together.

Parameters
- **a1, a2, ...**: sequence of array_like
  The arrays must have the same shape, except in the dimension corresponding to axis (the first, by default).
- **axis**: int, optional
  The axis along which the arrays will be joined. Default is 0.

Returns
- **res**: ndarray
  The concatenated array.

See also:
- ma.concatenate
  Concatenate function that preserves input masks.
array_split
Split an array into multiple sub-arrays of equal or near-equal size.

split
Split array into a list of multiple sub-arrays of equal size.

hsplit
Split array into multiple sub-arrays horizontally (column wise)

vsplit
Split array into multiple sub-arrays vertically (row wise)

dsplit
Split array into multiple sub-arrays along the 3rd axis (depth).

hstack
Stack arrays in sequence horizontally (column wise)

vstack
Stack arrays in sequence vertically (row wise)

dstack
Stack arrays in sequence depth wise (along third dimension)

Notes
When one or more of the arrays to be concatenated is a MaskedArray, this function will return a MaskedArray object instead of an ndarray, but the input masks are not preserved. In cases where a MaskedArray is expected as input, use the ma.concatenate function from the masked array module instead.

Examples
>>> a = np.array([[1, 2], [3, 4]])
>>> b = np.array([[5, 6]])
>>> np.concatenate((a, b), axis=0)
array([[1, 2],
       [3, 4],
       [5, 6]])
>>> np.concatenate((a, b.T), axis=1)
array([[1, 2, 5],
       [3, 4, 6]])

This function will not preserve masking of MaskedArray inputs.

>>> a = np.ma.arange(3)
>>> a[1] = np.ma.masked
>>> b = np.arange(2, 5)
>>> a
masked_array(data = [0 -- 2],
             mask = [False True False],
             fill_value = 999999)
>>> b
array([2, 3, 4])
>>> np.concatenate([a, b])
masked_array(data = [0 1 2 2 3 4],
             mask = False,
             fill_value = 999999)
>>> np.ma.concatenate([a, b])
masked_array(data = [0 -- 2 2 3 4],
             mask = [False True False False False],
             fill_value = 999999)
numpy.dstack(tup)
Stack arrays in sequence depth wise (along third axis).

Takes a sequence of arrays and stack them along the third axis to make a single array. Rebuilds arrays divided by dsplit. This is a simple way to stack 2D arrays (images) into a single 3D array for processing.

Parameters
   tup : sequence of arrays

   Arrays to stack. All of them must have the same shape along all but the third axis.

Returns
   stacked : ndarray

   The array formed by stacking the given arrays.

See also:

vstack
Stack along first axis.

hstack
Stack along second axis.

concatenate
Join arrays.

dsplit
Split array along third axis.

Examples

>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.dstack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])

>>> a = np.array([[1],[2],[3]])
>>> b = np.array([[2],[3],[4]])
>>> np.dstack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])

numpy.hstack(tup)
Stack arrays in sequence horizontally (column wise).

Take a sequence of arrays and stack them horizontally to make a single array. Rebuild arrays divided by hsplit.

Parameters
   tup : sequence of ndarrays

   All arrays must have the same shape along all but the second axis.

Returns
   stacked : ndarray
The array formed by stacking the given arrays.

See also:

vstack
Stack arrays in sequence vertically (row wise).

dstack
Stack arrays in sequence depth wise (along third axis).

concatenate
Join a sequence of arrays together.

hstack
Split array along second axis.

Notes
Equivalent to np.concatenate(tup, axis=1)

Examples
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.hstack((a,b))
array([1, 2, 3, 2, 3, 4])

>>> a = np.array([[1],[2],[3]])
>>> b = np.array([[2],[3],[4]])
>>> np.hstack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])

numpy.vstack(tup)
Stack arrays in sequence vertically (row wise).

Take a sequence of arrays and stack them vertically to make a single array. Rebuild arrays divided by vsplit.

Parameters
tup : sequence of ndarrays
    Tuple containing arrays to be stacked. The arrays must have the same shape along all but the first axis.

Returns
stacked : ndarray
    The array formed by stacking the given arrays.

See also:

hstack
    Stack arrays in sequence horizontally (column wise).

dstack
    Stack arrays in sequence depth wise (along third dimension).

concatenate
    Join a sequence of arrays together.

vsplit
    Split array into a list of multiple sub-arrays vertically.
Notes

Equivalent to `np.concatenate(tup, axis=0)` if `tup` contains arrays that are at least 2-dimensional.

Examples

```python
>>> a = np.array([1, 2, 3])
>>> b = np.array([2, 3, 4])
>>> np.vstack((a,b))
array([[1, 2, 3],
       [2, 3, 4]])

>>> a = np.array([[1], [2], [3]])
>>> b = np.array([[2], [3], [4]])
>>> np.vstack((a,b))
array([[1],
       [2],
       [3],
       [2],
       [3],
       [4]])
```

3.2.7Splitting arrays

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</tbody>
</table>

```python
numpy.array_split(ary, indices_or_sections[, axis])
```

Split an array into multiple sub-arrays.

Please refer to the `split` documentation. The only difference between these functions is that `array_split` allows `indices_or_sections` to be an integer that does not equally divide the axis.

See also:

`split`

Split array into multiple sub-arrays of equal size.

Examples

```python
>>> x = np.arange(8.0)
>>> np.array_split(x, 3)
[array([ 0.,  1.,  2.]), array([ 3.,  4.,  5.]), array([ 6.,  7.])]
```

```python
numpy.dsplit(ary, indices_or_sections)
```

Split array into multiple sub-arrays along the 3rd axis (depth).

Please refer to the `split` documentation. `dsplit` is equivalent to `split` with `axis=2`, the array is always split along the third axis provided the array dimension is greater than or equal to 3.

See also:
**split**

Split an array into multiple sub-arrays of equal size.

**Examples**

```python
>>> x = np.arange(16.0).reshape(2, 2, 4)
>>> x
array([[[ 0.,  1.,  2.,  3.],
        [ 4.,  5.,  6.,  7.],
        [ 8.,  9., 10., 11.],
        [12., 13., 14., 15.]]])
```

```python
>>> np.dsplit(x, 2)
[array([[[ 0.,  1.],
        [ 4.,  5.],
        [ 8.,  9.],
        [12., 13.]]),
      array([[[ 2.,  3.],
        [ 6.,  7.],
        [10., 11.],
        [14., 15.]]])]
```

```python
>>> np.dsplit(x, np.array([3, 6]))
[array([[[ 0.,  1.,  2.],
        [ 4.,  5.,  6.],
        [ 8.,  9., 10.],
        [12., 13., 14.]]),
      array([[[ 3.],
        [ 7.],
        [11.],
        [15.]]],
      array([], dtype=float64)]
```

numpy.hsplit(ary, indices_or_sections)

Split an array into multiple sub-arrays horizontally (column-wise).

Please refer to the split documentation. hsplit is equivalent to split with axis=1, the array is always split along the second axis regardless of the array dimension.

**See also:**

**split**

Split an array into multiple sub-arrays of equal size.

**Examples**

```python
>>> x = np.arange(16.0).reshape(4, 4)
>>> x
array([[ 0.,  1.,  2.,  3.],
       [ 4.,  5.,  6.,  7.],
       [ 8.,  9., 10., 11.],
       [12., 13., 14., 15.]]])
```

```python
>>> np.hsplit(x, 2)
[array([[[ 0.,  1.],
        [ 4.,  5.],
        [ 8.,  9.],
        [12., 13.]]),
      array([[[ 2.,  3.],
        [ 6.,  7.],
        [10., 11.],
        [14., 15.]]])]
```
```python
>>> np.hsplit(x, np.array([3, 6]))
[array([[ 0., 1., 2.,
       4., 5., 6.,
       8., 9., 10.,
      12., 13., 14.]],
      dtype=float64),
array([[ 3.,
       7.],
      [11.,
      15.]],
      dtype=float64)),
array([], dtype=float64)]

With a higher dimensional array the split is still along the second axis.

```python
>>> x = np.arange(8.0).reshape(2, 2, 2)
>>> x
array([[[ 0.,  1.],
       [ 2.,  3.]],
       [[ 4.,  5.],
       [ 6.,  7.]]])
>>> np.hsplit(x, 2)
[array([[[ 0.,  1.]],
       [[ 2.,  3.]]]),
array([[[ 4.,  5.]],
       [[ 6.,  7.]]])]
```

numpy.split(ary, indices_or_sections, axis=0)
Split an array into multiple sub-arrays.

**Parameters**

- `ary` : ndarray
  Array to be divided into sub-arrays.

- `indices_or_sections` : int or 1-D array
  If `indices_or_sections` is an integer, N, the array will be divided into N equal arrays along `axis`. If such a split is not possible, an error is raised.

  If `indices_or_sections` is a 1-D array of sorted integers, the entries indicate where along `axis` the array is split. For example, `[2, 3]` would, for `axis=0`, result in
  - `ary[:2]`
  - `ary[2:3]`
  - `ary[3:]`

  If an index exceeds the dimension of the array along `axis`, an empty sub-array is returned correspondingly.

- `axis` : int, optional
  The axis along which to split, default is 0.

**Returns**

- `sub-arrays` : list of ndarrays
  A list of sub-arrays.

**Raises**

- `ValueError`
  If `indices_or_sections` is given as an integer, but a split does not result in equal division.
See also:

**array_split**
Split an array into multiple sub-arrays of equal or near-equal size. Does not raise an exception if an equal division cannot be made.

**hsplit**
Split array into multiple sub-arrays horizontally (column-wise).

**vsplit**
Split array into multiple sub-arrays vertically (row wise).

**dsplit**
Split array into multiple sub-arrays along the 3rd axis (depth).

**concatenate**
Join arrays together.

**hstack**
Stack arrays in sequence horizontally (column wise).

**vstack**
Stack arrays in sequence vertically (row wise).

**dstack**
Stack arrays in sequence depth wise (along third dimension).

**Examples**

```python
>>> x = np.arange(9.0)
>>> np.split(x, 3)
[array([ 0., 1., 2.]), array([ 3., 4., 5.]), array([ 6., 7., 8.])]

>>> x = np.arange(8.0)
>>> np.split(x, [3, 5, 6, 10])
[array([ 0., 1., 2.]),
 array([ 3., 4.]),
 array([ 5.]),
 array([ 6., 7.]),
 array([], dtype=float64)]
```

Numpy vsplit (ary, indices_or_sections)
Split an array into multiple sub-arrays vertically (row-wise).

Please refer to the split documentation. vsplit is equivalent to split with axis=0 (default), the array is always split along the first axis regardless of the array dimension.

See also:

**split**
Split an array into multiple sub-arrays of equal size.

**Examples**

```python
>>> x = np.arange(16.0).reshape(4, 4)
>>> x
array([[ 0.,  1.,  2.,  3.],
       [ 4.,  5.,  6.,  7.],
       [ 8.,  9., 10., 11.],
       [12., 13., 14., 15.]])
```
>>> np.vsplit(x, 2)
[array([[ 0.,  1.,  2.,  3.],
        [ 4.,  5.,  6.,  7.]]),
 array([[ 8.,  9., 10., 11.],
        [12., 13., 14., 15.]]))

>>> np.vsplit(x, np.array([3, 6]))
[array([[ 0.,  1.,  2.,  3.],
        [ 4.,  5.,  6.,  7.],
        [ 8.,  9., 10., 11.]]),
 array([[12., 13., 14., 15.]],
 array([], dtype=float64))

With a higher dimensional array the split is still along the first axis.

>>> x = np.arange(8.0).reshape(2, 2, 2)

>>> x
array([[[ 0.,  1.],
        [ 2.,  3.]],
       [[ 4.,  5.],
        [ 6.,  7.]]])

>>> np.vsplit(x, 2)
[array([[[ 0.,  1.],
        [ 2.,  3.]]],
 array([[[ 4.,  5.],
        [ 6.,  7.]]])]

3.2.8 Tiling arrays

```
tile(A, reps)
    Construct an array by repeating A the number of times given by reps.

repeat(a, repeats[, axis])
    Repeat elements of an array.
```

numpy.tile(A, reps)

Construct an array by repeating A the number of times given by reps.

If `reps` has length `d`, the result will have dimension of `max(d, A.ndim)`.

If `A.ndim < d`, `A` is promoted to be `d`-dimensional by prepending new axes. So a shape (3,) array is promoted to (1, 3) for 2-D replication, or shape (1, 1, 3) for 3-D replication. If this is not the desired behavior, promote `A` to `d`-dimensions manually before calling this function.

If `A.ndim > d`, `reps` is promoted to `A.ndim` by pre-pending 1’s to it. Thus for an `A` of shape (2, 3, 4, 5), a `reps` of (2, 2) is treated as (1, 1, 2, 2).

**Parameters**

- **A** : array_like
  The input array.

- **reps** : array_like
  The number of repetitions of `A` along each axis.

**Returns**

- **c** : ndarray
  The tiled output array.

**See also:**
**repeat**

Repeat elements of an array.

**Examples**

```python
>>> a = np.array([0, 1, 2])
>>> np.tile(a, 2)
array([0, 1, 2, 0, 1, 2])
>>> np.tile(a, (2, 2))
array([[0, 1, 2, 0, 1, 2],
       [0, 1, 2, 0, 1, 2]])
>>> np.tile(a, (2, 1, 2))
array([[[0, 1, 2, 0, 1, 2]],
       [[0, 1, 2, 0, 1, 2]]])

>>> b = np.array([[1, 2], [3, 4]])
>>> np.tile(b, 2)
array([[1, 2, 1, 2],
       [3, 4, 3, 4]])
>>> np.tile(b, (2, 1))
array([[1, 2],
       [3, 4],
       [1, 2],
       [3, 4]])
```

numpy.repeat(a, repeats, axis=None)

Repeat elements of an array.

**Parameters**

- **a**: array_like
  
  Input array.

- **repeats**: {int, array of ints}
  
  The number of repetitions for each element. repeats is broadcasted to fit the shape of the given axis.

- **axis**: int, optional
  
  The axis along which to repeat values. By default, use the flattened input array, and return a flat output array.

**Returns**

- **repeated_array**: ndarray
  
  Output array which has the same shape as a, except along the given axis.

**See also:**

tile

Tile an array.

**Examples**

```python
>>> x = np.array([[1, 2], [3, 4]])
>>> np.repeat(x, 2)
array([[1, 1, 2, 2, 3, 3, 4, 4]])
>>> np.repeat(x, 3, axis=1)
array([[1, 1, 1, 2, 2, 2],
       [3, 3, 3, 4, 4, 4]])
```
>>> np.repeat(x, [1, 2], axis=0)
array([[1, 2],
       [3, 4],
       [3, 4]])

3.2.9 Adding and removing elements

```
def delete(arr, obj[, axis])
Return a new array with sub-arrays along an axis deleted. For a one dimensional array, this returns those entries
not returned by arr[obj].

Parameters
  arr : array_like
    Input array.
  obj : slice, int or array of ints
    Indicate which sub-arrays to remove.
  axis : int, optional
    The axis along which to delete the subarray defined by obj. If axis is None, obj is
applied to the flattened array.

Returns
  out : ndarray
    A copy of arr with the elements specified by obj removed. Note that delete does not
occur in-place. If axis is None, out is a flattened array.

See also:

  insert
    Insert elements into an array.
  append
    Append elements at the end of an array.
```

Often it is preferable to use a boolean mask. For example:

```python
>>> mask = np.ones(len(arr), dtype=bool)
>>> mask[[0, 2, 4]] = False
>>> result = arr[mask, ...]
```

Is equivalent to `np.delete(arr, [0, 2, 4], axis=0)`, but allows further use of `mask`. 
Examples

```python
>>> arr = np.array([[1,2,3,4], [5,6,7,8], [9,10,11,12]])
>>> arr
array([[ 1,  2,  3,  4],
       [ 5,  6,  7,  8],
       [ 9, 10, 11, 12]])
>>> np.delete(arr, 1, 0)
array([[ 1,  2,  3,  4],
       [ 9, 10, 11, 12]])
>>> np.delete(arr, np.s_[:2], 1)
array([[ 2,  4],
       [ 6,  8],
       [10, 12]])
>>> np.delete(arr, [1,3,5], None)
array([ 1,  3,  5,  7,  8,  9, 10, 11, 12])
```

numpy.insert(arr, obj, values, axis=None)

Insert values along the given axis before the given indices.

**Parameters**
- **arr**: array_like
  Input array.
- **obj**: int, slice or sequence of ints
  Object that defines the index or indices before which values is inserted. New in version 1.8.0.
  Support for multiple insertions when obj is a single scalar or a sequence with one element (similar to calling insert multiple times).
- **values**: array_like
  Values to insert into arr. If the type of values is different from that of arr, values is converted to the type of arr. values should be shaped so that arr[...,obj,...] = values is legal.
- **axis**: int, optional
  Axis along which to insert values. If axis is None then arr is flattened first.

**Returns**
- **out**: ndarray
  A copy of arr with values inserted. Note that insert does not occur in-place: a new array is returned. If axis is None, out is a flattened array.

**See also:**
- **append**
  Append elements at the end of an array.
- **concatenate**
  Join a sequence of arrays together.
- **delete**
  Delete elements from an array.
**Notes**

Note that for higher dimensional inserts `obj=0` behaves very different from `obj=[0]` just like `arr[:,0,:] = values` is different from `arr[:,[0],:] = values`.

**Examples**

```python
>>> a = np.array([[1, 1], [2, 2], [3, 3]])
>>> a
array([[1, 1],
       [2, 2],
       [3, 3]])
>>> np.insert(a, 1, 5)
array([1, 5, 1, 2, 2, 3, 3])
>>> np.insert(a, 1, 5, axis=1)
array([[1, 5, 1],
       [2, 5, 2],
       [3, 5, 3]])
```

Difference between sequence and scalars: `>>> np.insert(a, [1], [[1],[2],[3]], axis=1) array([[1, 1, 1],
       [2, 2, 2],
       [3, 3, 3]])`

```python
>>> np.array_equal(np.insert(a, [1], [[1],[2],[3]], axis=1), np.insert(a, [1], [1, [2], [3]], axis=1))
True
```

```python
>>> b = a.flatten()
>>> b
array([1, 1, 2, 2, 3, 3])
>>> np.insert(b, [2, 2], [5, 6])
array([1, 1, 5, 6, 2, 2, 3, 3])
>>> np.insert(b, slice(2, 4), [5, 6])
array([1, 1, 5, 2, 6, 2, 3, 3])
>>> np.insert(b, [2, 2], [7.13, False]) # type casting
array([1, 1, 7, 0, 2, 2, 3, 3])
```

```python
>>> x = np.arange(8).reshape(2, 4)
>>> idx = (1, 3)
>>> np.insert(x, idx, 999, axis=1)
array([[ 0, 999,  1,  2, 999,  3],
       [ 4, 999,  5,  6, 999,  7]])
```

**Parameters**

- `arr` : array_like
  Values are appended to a copy of this array.

- `values` : array_like
  These values are appended to a copy of `arr`. It must be of the correct shape (the same shape as `arr`, excluding `axis`). If `axis` is not specified, `values` can be any shape and will be flattened before use.

- `axis` : int, optional
The axis along which values are appended. If axis is not given, both arr and values are flattened before use.

**Returns**

append : ndarray

A copy of arr with values appended to axis. Note that append does not occur in-place: a new array is allocated and filled. If axis is None, out is a flattened array.

**See also:**

*insert*

Insert elements into an array.

*delete*

Delete elements from an array.

**Examples**

```python
>>> np.append([1, 2, 3], [[4, 5, 6], [7, 8, 9]])
array([1, 2, 3, 4, 5, 6, 7, 8, 9])
```

When axis is specified, values must have the correct shape.

```python
>>> np.append([[1, 2, 3], [4, 5, 6]], [[7, 8, 9]], axis=0)
array([[1, 2, 3],
       [4, 5, 6],
       [7, 8, 9]])
```

```python
>>> np.append([[1, 2, 3], [4, 5, 6]], [[7, 8, 9]], axis=0)
Traceback (most recent call last):
...
ValueError: arrays must have same number of dimensions
```

**numpy.resize(a, new_shape)**

Return a new array with the specified shape.

If the new array is larger than the original array, then the new array is filled with repeated copies of a. Note that this behavior is different from a.resize(new_shape) which fills with zeros instead of repeated copies of a.

**Parameters**

- **a**: array_like

  Array to be resized.

- **new_shape**: int or tuple of int

  Shape of resized array.

**Returns**

reshaped_array : ndarray

The new array is formed from the data in the old array, repeated if necessary to fill out the required number of elements. The data are repeated in the order that they are stored in memory.

**See also:**

*ndarray.resize*

resize an array in-place.
Examples

```python
>>> a=np.array([[0,1],[2,3]])
>>> np.resize(a,(1,4))
array([[0, 1, 2, 3]])

numpy.trim_zeros(filt, trim='fb')
    Trim the leading and/or trailing zeros from a 1-D array or sequence.

Parameters

    filt : 1-D array or sequence
        Input array.
    trim : str, optional
        A string with ‘f’ representing trim from front and ‘b’ to trim from back. Default is ‘fb’, trim zeros from both front and back of the array.

Returns

    trimmed : 1-D array or sequence
        The result of trimming the input. The input data type is preserved.

Examples

```python
>>> a = np.array((0, 0, 0, 1, 2, 3, 0, 2, 1, 0))
>>> np.trim_zeros(a)
array([1, 2, 3, 0, 2, 1])
```

```
```
```python
>>> np.trim_zeros(a, 'b')
array([0, 0, 0, 1, 2, 3, 0, 2, 1])
```

The input data type is preserved, list/tuple in means list/tuple out.

```python
>>> np.trim_zeros([0, 1, 2, 0])
[1, 2]
```

numpy.unique(ar, return_index=False, return_inverse=False, return_counts=False)
    Find the unique elements of an array.

Returns the sorted unique elements of an array. There are three optional outputs in addition to the unique elements: the indices of the input array that give the unique values, the indices of the unique array that reconstruct the input array, and the number of times each unique value comes up in the input array.

Parameters

    ar : array_like
        Input array. This will be flattened if it is not already 1-D.
    return_index : bool, optional
        If True, also return the indices of ar that result in the unique array.
    return_inverse : bool, optional
        If True, also return the indices of the unique array that can be used to reconstruct ar.
    return_counts : bool, optional
New in version 1.9.0.

If True, also return the number of times each unique value comes up in \( ar \).

**Returns**

- **unique**: ndarray
  
The sorted unique values.

- **unique_indices**: ndarray, optional
  
The indices of the first occurrences of the unique values in the (flattened) original array. Only provided if `return_index` is True.

- **unique_inverse**: ndarray, optional
  
The indices to reconstruct the (flattened) original array from the unique array. Only provided if `return_inverse` is True.

- **unique_counts**: ndarray, optional
  
  New in version 1.9.0.
  
The number of times each of the unique values comes up in the original array. Only provided if `return_counts` is True.

**See also:**

- `numpy.lib.arraysetops`
  
  Module with a number of other functions for performing set operations on arrays.

**Examples**

```python
>>> np.unique([1, 1, 2, 2, 3, 3])
array([1, 2, 3])

>>> a = np.array([[1, 1], [2, 3]])
>>> np.unique(a)
array([1, 2, 3])
```

Return the indices of the original array that give the unique values:

```python
>>> a = np.array(['a', 'b', 'b', 'c', 'a'])
>>> u, indices = np.unique(a, return_index=True)

>>> u
array(['a', 'b', 'c'],
      dtype='|S1')

>>> indices
array([0, 1, 3])
```

Reconstruct the input array from the unique values:

```python
>>> a = np.array([1, 2, 6, 4, 2, 3, 2])
>>> u, indices = np.unique(a, return_inverse=True)

>>> u
array([1, 2, 3, 4, 6])

>>> indices
array([0, 1, 4, 3, 1, 2, 1])
```

---

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3.2.10 Rearranging elements

- `fliplr(m)` Flip array in the left/right direction.
- `flipud(m)` Flip array in the up/down direction.
- `reshape(a, newshape[, order])` Gives a new shape to an array without changing its data.
- `roll(a, shift[, axis])` Roll array elements along a given axis.
- `rot90(m[, k])` Rotate an array by 90 degrees in the counter-clockwise direction.

**numpy.fliplr(m)**

Flip array in the left/right direction.

Flip the entries in each row in the left/right direction. Columns are preserved, but appear in a different order than before.

**Parameters**

- `m`: array_like
  
  Input array, must be at least 2-D.

**Returns**

- `f`: ndarray
  
  A view of `m` with the columns reversed. Since a view is returned, this operation is \(O(1)\).

**See also:**

- `flipud`
  
  Flip array in the up/down direction.

- `rot90`
  
  Rotate array counterclockwise.

**Notes**

Equivalent to `A[:,::-1]`. Requires the array to be at least 2-D.

**Examples**

```python
>>> A = np.diag([1.,2.,3.])
>>> A
array([[ 1., 0., 0.],
       [ 0., 2., 0.],
       [ 0., 0., 3.]])
>>> np.fliplr(A)
array([[ 0., 0., 1.],
       [ 0., 2., 0.],
       [ 3., 0., 0.]])
```

```python
>>> A = np.random.randn(2,3,5)
>>> np.all(np.fliplr(A)==A[:,:,::-1,...])
True
```

**numpy.flipud(m)**

Flip array in the up/down direction.

Flip the entries in each column in the up/down direction. Rows are preserved, but appear in a different order than before.
Parameters

- **m**: array_like
  
  Input array.

Returns

- **out**: array_like
  
  A view of m with the rows reversed. Since a view is returned, this operation is \( O(1) \).

See also:

- `fliplr`
  
  Flip array in the left/right direction.

- `rot90`
  
  Rotate array counterclockwise.

Notes

Equivalent to \( A[::-1,...] \). Does not require the array to be two-dimensional.

Examples

```python
>>> A = np.diag([1.0, 2, 3])
>>> A
array([[ 1., 0., 0.],
       [ 0., 2., 0.],
       [ 0., 0., 3.]])
>>> np.flipud(A)
array([[ 0., 0., 3.],
       [ 0., 2., 0.],
       [ 1., 0., 0.]])
```

```python
>>> A = np.random.randn(2,3,5)
>>> np.all(np.flipud(A)==A[::-1,...])
True
```

```python
>>> np.flipud([1,2])
array([2, 1])
```

### numpy.reshape(a, newshape, order='C')

Gives a new shape to an array without changing its data.

Parameters

- **a**: array_like
  
  Array to be reshaped.

- **newshape**: int or tuple of ints
  
  The new shape should be compatible with the original shape. If an integer, then the result will be a 1-D array of that length. One shape dimension can be -1. In this case, the value is inferred from the length of the array and remaining dimensions.

- **order**: {'C', 'F', 'A'}, optional
  
  Read the elements of a using this index order, and place the elements into the reshaped array using this index order. 'C' means to read / write the elements using C-like index order, with the last axis index changing fastest, back to the first axis index changing slowest. 'F' means to read / write the elements using Fortran-like index order, with the first index changing fastest, and the last index changing slowest. Note that the 'C' and
‘F’ options take no account of the memory layout of the underlying array, and only refer to the order of indexing. ‘A’ means to read / write the elements in Fortran-like index order if \( a \) is Fortran contiguous in memory, C-like order otherwise.

Returns

\[ \text{reshaped} \text{\_array} : \text{ndarray} \]

This will be a new view object if possible; otherwise, it will be a copy. Note there is no guarantee of the memory layout (C- or Fortran-contiguous) of the returned array.

See also:

\[ \text{ndarray} \text{\_reshape} \]

Equivalent method.

Notes

It is not always possible to change the shape of an array without copying the data. If you want an error to be raise if the data is copied, you should assign the new shape to the shape attribute of the array:

```python
>>> a = np.zeros((10, 2))
# A transpose make the array non-contiguous
>>> b = a.T
# Taking a view makes it possible to modify the shape without modifying the
# initial object.
>>> c = b.view()
>>> c.shape = (20)
AttributeError: incompatible shape for a non-contiguous array
```

The order keyword gives the index ordering both for fetching the values from \( a \), and then placing the values into the output array. For example, let’s say you have an array:

```python
>>> a = np.arange(6).reshape((3, 2))
>>> a
array([[0, 1],
       [2, 3],
       [4, 5]])
```

You can think of reshaping as first raveling the array (using the given index order), then inserting the elements from the raveled array into the new array using the same kind of index ordering as was used for the raveling.

```python
>>> np.reshape(a, (2, 3)) # C-like index ordering
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.reshape(np.ravel(a), (2, 3)) # equivalent to C ravel then C reshape
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.reshape(a, (2, 3), order='F') # Fortran-like index ordering
array([[0, 4, 3],
       [2, 1, 5]])
>>> np.reshape(np.ravel(a, order='F'), (2, 3), order='F')
array([[0, 4, 3],
       [2, 1, 5]])
```

Examples

```python
>>> a = np.array([[1,2,3], [4,5,6]])
>>> np.reshape(a, 6)
array([1, 2, 3, 4, 5, 6])
```
numpy.reshape(a, 6, order='F')
array([1, 4, 2, 5, 3, 6])

numpy.reshape(a, (3,-1))  # the unspecified value is inferred to be 2
array([[1, 2],
        [3, 4],
        [5, 6]])

numpy.roll(a, shift, axis=None)
Roll array elements along a given axis.
Elements that roll beyond the last position are re-introduced at the first.

Parameters
  a : array_like
    Input array.
  shift : int
    The number of places by which elements are shifted.
  axis : int, optional
    The axis along which elements are shifted. By default, the array is flattened before shifting, after which the original shape is restored.

Returns
  res : ndarray
    Output array, with the same shape as a.

See also:
  rollaxis
    Roll the specified axis backwards, until it lies in a given position.

Examples

>>> x = np.arange(10)
>>> np.roll(x, 2)
array([8, 9, 0, 1, 2, 3, 4, 5, 6, 7])

>>> x2 = np.reshape(x, (2,5))
>>> x2
array([[0, 1, 2, 3, 4],
        [5, 6, 7, 8, 9]])

>>> np.roll(x2, 1)
array([[9, 0, 1, 2, 3],
        [4, 5, 6, 7, 8]])

>>> np.roll(x2, 1, axis=0)
array([[5, 6, 7, 8, 9],
        [0, 1, 2, 3, 4]])

>>> np.roll(x2, 1, axis=1)
array([[4, 0, 1, 2, 3],
        [9, 5, 6, 7, 8]])

numpy.rot90(m, k=1)
Rotate an array by 90 degrees in the counter-clockwise direction.
The first two dimensions are rotated; therefore, the array must be at least 2-D.
Parameters

\( m \) : array_like

Array of two or more dimensions.

\( k \) : integer

Number of times the array is rotated by 90 degrees.

Returns

\( y \) : ndarray

Rotated array.

See also:

\texttt{fliplr}

Flip an array horizontally.

\texttt{flipud}

Flip an array vertically.

Examples

```python
>>> m = np.array([[1, 2], [3, 4]], int)
>>> m
array([[ 1,  2],
       [ 3,  4]])
>>> np.rot90(m)
array([[ 2,  4],
       [ 1,  3]])
>>> np.rot90(m, 2)
array([[ 4,  3],
       [ 2,  1]])
```

3.3 Binary operations

3.3.1 Elementwise bit operations

```python
numpy.bitwise_and(x1, x2[, out]) = <ufunc 'bitwise_and'>
```

Computes the bit-wise AND of the underlying binary representation of the integers in the input arrays. This ufunc implements the C/Python operator &.

Parameters

\( x1, x2 \) : array_like

Only integer and boolean types are handled.
Returns

out : array_like

Result.

See also:

logical_and, bitwise_or, bitwise_xor

binary_repr

Return the binary representation of the input number as a string.

Examples

The number 13 is represented by 00001101. Likewise, 17 is represented by 00010001. The bit-wise AND of 13 and 17 is therefore 00000000, or 1:

```python
>>> np.bitwise_and(13, 17)
1
```

```python
>>> np.bitwise_and(14, 13)
12
```

```python
>>> np.binary_repr(12)
'1100'
```

```python
>>> np.bitwise_and([14,3], 13)
array([12, 1])
```

```python
>>> np.bitwise_and([11,7], [4,25])
array([0, 1])
```

```python
>>> np.bitwise_and(np.array([2,5,255]), np.array([3,14,16]))
array([ 2,  4, 16])
```

```python
>>> np.bitwise_and([True, True], [False, True])
array([False, True], dtype=bool)
```

numpy.bitwise_or(x1, x2[, out]) = <ufunc ‘bitwise_or’>

Compute the bit-wise OR of two arrays element-wise.

Computes the bit-wise OR of the underlying binary representation of the integers in the input arrays. This ufunc implements the C/Python operator |.

Parameters

x1, x2 : array_like

Only integer and boolean types are handled.

out : ndarray, optional

Array into which the output is placed. Its type is preserved and it must be of the right shape to hold the output. See doc.ufuncs.

Returns

out : array_like

Result.

See also:

logical_or, bitwise_and, bitwise_xor

binary_repr

Return the binary representation of the input number as a string.
Examples

The number 13 has the binary representation `00001101`. Likewise, 16 is represented by `00010000`. The bit-wise OR of 13 and 16 is then `00011101`, or 29:

```python
>>> np.bitwise_or(13, 16)
29
>>> np.binary_repr(29)
'11101'
```

```python
>>> np.bitwise_or(32, 2)
34
```

```python
>>> np.bitwise_or([33, 4], 1)
array([33, 5])
>>> np.bitwise_or([33, 4], [1, 2])
array([33, 6])
```

```python
>>> np.bitwise_or(np.array([2, 5, 255]), np.array([4, 4, 4]))
array([ 6,  5, 255])
>>> np.array([2, 5, 255]) | np.array([4, 4, 4])
array([ 6,  5, 255])
```

```python
>>> np.bitwise_or(np.array([2, 5, 255, 2147483647L], dtype=np.int32),
... np.array([4, 4, 4, 2147483647L], dtype=np.int32))
array([ 6,  5, 255, 2147483647])
```

```python
>>> np.bitwise_or([True, True], [False, True])
array([ True,  True], dtype=bool)
```

numpy.bitwise_xor(x1, x2[, out]) = <ufunc ‘bitwise_xor’>

Compute the bit-wise XOR of two arrays element-wise.

Computes the bit-wise XOR of the underlying binary representation of the integers in the input arrays. This ufunc implements the C/Python operator `^`.

**Parameters**
- **x1, x2**: array_like
  Only integer and boolean types are handled.

**Returns**
- **out**: array_like
  Result.

**See also:**
- logical_xor, bitwise_and, bitwise_or
- binary_repr
  Return the binary representation of the input number as a string.

Examples

The number 13 is represented by `00001101`. Likewise, 17 is represented by `00010001`. The bit-wise XOR of 13 and 17 is therefore `00011100`, or 28:

```python
>>> np.bitwise_xor(13, 17)
28
>>> np.binary_repr(28)
'11100'
```

```python
>>> np.bitwise_xor(31, 5)
26
```
```python
>>> np.bitwise_xor([31, 3], 5)
array([26, 6])

>>> np.bitwise_xor([31, 3], [5, 6])
array([26, 5])

>>> np.bitwise_xor([True, True], [False, True])
array([ True, False], dtype=bool)
```

numpy.invert(x[, out]) = <ufunc 'invert'>

Compute bit-wise inversion, or bit-wise NOT, element-wise.

Computes the bit-wise NOT of the underlying binary representation of the integers in the input arrays. This ufunc implements the C/Python operator ~.

For signed integer inputs, the two's complement is returned. In a two's-complement system negative numbers are represented by the two's complement of the absolute value. This is the most common method of representing signed integers on computers [R32]. A N-bit two's-complement system can represent every integer in the range \(-2^{N-1}\) to \(+2^{N-1} - 1\).

Parameters

x1 : array_like

Only integer and boolean types are handled.

Returns

out : array_like

Result.

See also:

bitwise_and, bitwise_or, bitwise_xor, logical_not

binary_repr

Return the binary representation of the input number as a string.

Notes

bitwise_not is an alias for invert:

```python
>>> np.bitwise_not is np.invert
True
```

References

[R32]

Examples

We've seen that 13 is represented by 00001101. The invert or bit-wise NOT of 13 is then:

```python
>>> np.invert(np.array([13], dtype=uint8))
array([242], dtype=uint8)

>>> np.binary_repr(x, width=8)
'00001101'

>>> np.binary_repr(242, width=8)
'11110010'
```

The result depends on the bit-width:
>>> np.invert(np.array([13], dtype=uint16))
array([65522], dtype=uint16)
>>> np.binary_repr(x, width=16)
'0000000000001101'
>>> np.binary_repr(65522, width=16)
'1111111111110010'

When using signed integer types the result is the two's complement of the result for the unsigned type:

>>> np.invert(np.array([13], dtype=int8))
array([-14], dtype=int8)
>>> np.binary_repr(-14, width=8)
'11110010'

Booleans are accepted as well:

>>> np.invert(array([True, False]))
array([False, True], dtype=bool)

numpy.left_shift(x1, x2[, out]) = <ufunc 'left_shift'>
Shift the bits of an integer to the left.

Bits are shifted to the left by appending \(x_2\) 0s at the right of \(x_1\). Since the internal representation of numbers is in binary format, this operation is equivalent to multiplying \(x_1\) by \(2^{x_2}\).

Parameters
x1 : array_like of integer type
Input values.

x2 : array_like of integer type
Number of zeros to append to \(x_1\). Has to be non-negative.

Returns
out : array of integer type
Return \(x_1\) with bits shifted \(x_2\) times to the left.

See also:

right_shift
Shift the bits of an integer to the right.

binary_repr
Return the binary representation of the input number as a string.

Examples

>>> np.binary_repr(5)
'101'
>>> np.left_shift(5, 2)
20
>>> np.binary_repr(20)
'10100'

>>> np.left_shift(5, [1,2,3])
array([10, 20, 40])

numpy.right_shift(x1, x2[, out]) = <ufunc 'right_shift'>
Shift the bits of an integer to the right.
Bits are shifted to the right \( x_2 \). Because the internal representation of numbers is in binary format, this operation is equivalent to dividing \( x_1 \) by \( 2^{x_2} \).

**Parameters**
- \( x_1 \) : array_like, int
  Input values.
- \( x_2 \) : array_like, int
  Number of bits to remove at the right of \( x_1 \).

**Returns**
- \( \text{out} \) : ndarray, int
  Return \( x_1 \) with bits shifted \( x_2 \) times to the right.

**See also:**
- `left_shift`
  Shift the bits of an integer to the left.
- `binary_repr`
  Return the binary representation of the input number as a string.

**Examples**

```python
>>> np.binary_repr(10)
'1010'
>>> np.right_shift(10, 1)
5
>>> np.binary_repr(5)
'101'

>>> np.right_shift(10, [1,2,3])
array([5, 2, 1])
```

### 3.3.2 Bit packing

<table>
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<tr>
<th>Function</th>
<th>Description</th>
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<tr>
<td><code>packbits</code></td>
<td>Packs the elements of a binary-valued array into bits in a uint8 array.</td>
</tr>
<tr>
<td><code>unpackbits</code></td>
<td>Unpacks elements of a uint8 array into a binary-valued output array.</td>
</tr>
</tbody>
</table>

**numpy.packbits**

Packs the elements of a binary-valued array into bits in a uint8 array.

The result is padded to full bytes by inserting zero bits at the end.

**Parameters**
- \( \text{myarray} \) : array_like
  An integer type array whose elements should be packed to bits.
- \( \text{axis} \) : int, optional
  The dimension over which bit-packing is done. None implies packing the flattened array.

**Returns**
- \( \text{packed} \) : ndarray
Array of type uint8 whose elements represent bits corresponding to the logical (0 or nonzero) value of the input elements. The shape of packed has the same number of dimensions as the input (unless axis is None, in which case the output is 1-D).

See also:

unpackbits
Unpacks elements of a uint8 array into a binary-valued output array.

Examples

```python
g = np.array([[1,0,1],
              [0,1,0],
              [1,1,0],
              [0,0,1]])
gg = np.packbits(g, axis=-1)
gg
array([[160], [64]], dtype=uint8)
```

Note that in binary 160 = 1010 0000, 64 = 0100 0000, 192 = 1100 0000, and 32 = 0010 0000.

numpy.unpackbits (myarray, axis=None)
Unpacks elements of a uint8 array into a binary-valued output array.

Each element of myarray represents a bit-field that should be unpacked into a binary-valued output array. The shape of the output array is either 1-D (if axis is None) or the same shape as the input array with unpacking done along the axis specified.

Parameters

- myarray : ndarray, uint8 type
  Input array.

- axis : int, optional
  Unpacks along this axis.

Returns

- unpacked : ndarray, uint8 type
  The elements are binary-valued (0 or 1).

See also:

packbits
Packs the elements of a binary-valued array into bits in a uint8 array.

Examples

```python
g = np.array([[2], [7], [23]], dtype=np.uint8)
gg = np.unpackbits(g, axis=1)
gg
array([[0, 0, 0, 0, 0, 0, 1, 0],
        [0, 0, 0, 0, 0, 1, 1, 1],
        [0, 0, 0, 1, 0, 1, 1, 1]], dtype=uint8)
```
3.3.3 Output formatting

```
**numpy.binary_repr (num, width=None)**  

Return the binary representation of the input number as a string.
```

For negative numbers, if width is not given, a minus sign is added to the front. If width is given, the two's complement of the number is returned, with respect to that width.

In a two’s-complement system negative numbers are represented by the two’s complement of the absolute value. This is the most common method of representing signed integers on computers [R16]. A N-bit two’s-complement system can represent every integer in the range $-2^{N-1}$ to $+2^{N-1} - 1$.

**Parameters**
- `num` : int
  Only an integer decimal number can be used.
- `width` : int, optional
  The length of the returned string if `num` is positive, the length of the two’s complement if `num` is negative.

**Returns**
- `bin` : str
  Binary representation of `num` or two’s complement of `num`.

See also:
- `base_repr`  
  Return a string representation of a number in the given base system.

**Notes**

`binary_repr` is equivalent to using `base_repr` with base 2, but about 25x faster.

**References**

[R16]

**Examples**

```python
>>> np.binary_repr(3)  
'11'
>>> np.binary_repr(-3)  
'-11'
>>> np.binary_repr(3, width=4)  
'0011'
```

The two’s complement is returned when the input number is negative and width is specified:

```python
>>> np.binary_repr(-3, width=4)  
'1101'
```
3.4 String operations

This module provides a set of vectorized string operations for arrays of type \texttt{numpy.string\_} or \texttt{numpy.unicode\_}. All of them are based on the string methods in the Python standard library.

3.4.1 String operations

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{add(x1, x2)}</td>
<td>Return element-wise string concatenation for two arrays of str or unicode.</td>
</tr>
<tr>
<td>\texttt{multiply(a, i)}</td>
<td>Return ((a \times i)), that is string multiple concatenation, element-wise.</td>
</tr>
<tr>
<td>\texttt{mod(a, values)}</td>
<td>Return ((a % i)), that is pre-Python 2.6 string formatting (interpolation), element-wise for a pair of arrays.</td>
</tr>
<tr>
<td>\texttt{capitalize(a)}</td>
<td>Return a copy of (a) with only the first character of each element capitalized.</td>
</tr>
<tr>
<td>\texttt{center(a, width[, fillchar])}</td>
<td>Return a copy of (a) with its elements centered in a string of length (width). Calls \texttt{str.decode} element-wise.</td>
</tr>
<tr>
<td>\texttt{decode(a[, encoding, errors])}</td>
<td>Return a string which is the concatenation of the strings in the sequence (seq). Calls \texttt{str.encode} element-wise.</td>
</tr>
<tr>
<td>\texttt{encode(a[, encoding, errors])}</td>
<td>Return an array with the elements of (a) left-justified in a string of length (width). Return an array with the elements converted to lowercase.</td>
</tr>
<tr>
<td>\texttt{join(sep, seq)}</td>
<td>For each element in (a), return a copy with the leading characters removed. Partition each element in (a) around (sep).</td>
</tr>
<tr>
<td>\texttt{ljust(a, width[, fillchar])}</td>
<td>Return an array with the elements of (a) right-justified in a string of length (width).</td>
</tr>
<tr>
<td>\texttt{lower(a)}</td>
<td>For each element in (a), return a copy of the string with all occurrences of substring (old) replaced by (new). Return an array with the elements of (a) converted to lowercase.</td>
</tr>
<tr>
<td>\texttt{replace(a, old[, new[, count]])}</td>
<td>For each element in (a), return a list of the words in the string, using (sep) as the delimiter string.</td>
</tr>
<tr>
<td>\texttt{rpartition(a, sep)}</td>
<td>For each element in (a), return a list of the words in the string, using (sep) as the delimiter string.</td>
</tr>
<tr>
<td>\texttt{rsplit(a[, sep, maxsplit])}</td>
<td>For each element in (a), return a list of the words in the string, using (sep) as the delimiter string.</td>
</tr>
<tr>
<td>\texttt{rstrip(a[, chars])}</td>
<td>For each element in (a), return a list of the lines in the element, breaking at line boundaries.</td>
</tr>
<tr>
<td>\texttt{splitlines(a[, keepends])}</td>
<td>For each element in (a), return a copy with the leading and trailing characters removed.</td>
</tr>
<tr>
<td>\texttt{strip(a[, chars])}</td>
<td>Return element-wise a copy of the string with uppercase characters converted to lowercase and vice versa.</td>
</tr>
<tr>
<td>\texttt{swapcase(a)}</td>
<td>Return element-wise title cased version of string or unicode.</td>
</tr>
<tr>
<td>\texttt{title(a)}</td>
<td>For each element in (a), return a copy of the string where all characters occurring in the optional (table) are capitalized. Return an array with the elements converted to uppercase.</td>
</tr>
<tr>
<td>\texttt{translate(a, table[, deletechars])}</td>
<td>Return the numeric string left-filled with zeros Calls \texttt{str.zfill} element-wise.</td>
</tr>
<tr>
<td>\texttt{upper(a)}</td>
<td></td>
</tr>
<tr>
<td>\texttt{zfill(a, width)}</td>
<td></td>
</tr>
</tbody>
</table>

\texttt{numpy.core.defchararray.add(x1, x2)}

Return element-wise string concatenation for two arrays of str or unicode.

Arrays \(x1\) and \(x2\) must have the same shape.

**Parameters**

- \(x1\) : array_like of str or unicode
  - Input array.
- \(x2\) : array_like of str or unicode
  - Input array.

**Returns**

- \(add\) : ndarray
  - Output array of \texttt{string\_} or \texttt{unicode\_}, depending on input types of the same shape as \(x1\) and \(x2\).

\texttt{numpy.core.defchararray.multiply(a, i)}

Return \((a \times i)\), that is string multiple concatenation, element-wise.
Values in \( i \) of less than 0 are treated as 0 (which yields an empty string).

**Parameters**
- \( a \) : array_like of str or unicode
- \( i \) : array_like of ints

**Returns**
- \( out \) : ndarray
  Output array of str or unicode, depending on input types

\[
\text{numpy.core.defchararray.mod}(a, values)
\]
Return \((a \% i)\), that is pre-Python 2.6 string formatting (interpolation), element-wise for a pair of array_likes of str or unicode.

**Parameters**
- \( a \) : array_like of str or unicode
- \( values \) : array_like of values
  These values will be element-wise interpolated into the string.

**Returns**
- \( out \) : ndarray
  Output array of str or unicode, depending on input types

See also:
- \( \text{str.__mod__} \)

\[
\text{numpy.core.defchararray.capitalize}(a)
\]
Return a copy of \( a \) with only the first character of each element capitalized.
Calls \( \text{str.capitalize} \) element-wise.
For 8-bit strings, this method is locale-dependent.

**Parameters**
- \( a \) : array_like of str or unicode
  Input array of strings to capitalize.

**Returns**
- \( out \) : ndarray
  Output array of str or unicode, depending on input types

See also:
- \( \text{str.capitalize} \)

**Examples**

```python
>>> c = np.array(['Alb2', 'lb2a', 'b2a1', '2a1b'], 'S4'); c
array(['Alb2', 'lb2a', 'b2a1', '2a1b'], dtype='|S4')

>>> np.char.capitalize(c)
array(['Alb2', 'lb2a', 'B2a1', '2a1b'], dtype='|S4')
```

\[
\text{numpy.core.defchararray.center}(a, width, fillchar='\')
\]
Return a copy of \( a \) with its elements centered in a string of length \( width \).
Calls \( \text{str.center} \) element-wise.
Parameters
   a : array_like of str or unicode
   width : int
       The length of the resulting strings
   fillchar : str or unicode, optional
       The padding character to use (default is space).

Returns
   out : ndarray
       Output array of str or unicode, depending on input types

See also:

str.center

numpy.core.defchararray.decode (a, encoding=None, errors=None)
Calls str.decode element-wise.

The set of available codecs comes from the Python standard library, and may be extended at runtime. For more information, see the codecs module.

Parameters
   a : array_like of str or unicode
   encoding : str, optional
       The name of an encoding
   errors : str, optional
       Specifies how to handle encoding errors

Returns
   out : ndarray

See also:

str.decode

Notes
The type of the result will depend on the encoding specified.

Examples
>>> c = np.array(['aAaAaA', ' aA ', 'abABba'])
>>> c
array(['aAaAaA', ' aA ', 'abABba'],
      dtype='|S7')
>>> np.char.encode(c, encoding='cp037')
array(['\x81\xc1\x81\xc1\x81\xc1', '@@\x81\xc1@@',
      '\x81\x82\xc2\x82\xc2\x82\x81'],
      dtype='|S7')

numpy.core.defchararray.encode (a, encoding=None, errors=None)
Calls strencode element-wise.

The set of available codecs comes from the Python standard library, and may be extended at runtime. For more information, see the codecs module.
Parameters
   a : array_like of str or unicode
   encoding : str, optional
       The name of an encoding
   errors : str, optional
       Specifies how to handle encoding errors

Returns
   out : ndarray

See also:
   str.encode

Notes
   The type of the result will depend on the encoding specified.

numpy.core.defchararray.join(sep, seq)
   Return a string which is the concatenation of the strings in the sequence seq.
   Calls str.join element-wise.

Parameters
   sep : array_like of str or unicode
   seq : array_like of str or unicode

Returns
   out : ndarray
       Output array of str or unicode, depending on input types

See also:
   str.join

numpy.core.defchararray.ljust(a, width, fillchar=' ')
   Return an array with the elements of a left-justified in a string of length width.
   Calls str.ljust element-wise.

Parameters
   a : array_like of str or unicode
   width : int
       The length of the resulting strings
   fillchar : str or unicode, optional
       The character to use for padding

Returns
   out : ndarray
       Output array of str or unicode, depending on input type

See also:
   str.ljust
numpy.core.defchararray.lower(a)
Return an array with the elements converted to lowercase.

Call str.lower element-wise.

For 8-bit strings, this method is locale-dependent.

Parameters
   a : array_like, {str, unicode}
      Input array.

Returns
   out : ndarray, {str, unicode}
      Output array of str or unicode, depending on input type

See also:
   str.lower

Examples
>>> c = np.array([‘Alb C’, ‘lBCA’, ‘BCAl’]); c
array([‘Alb C’, ‘lBCA’, ‘BCAl’],
      dtype=’|S5’)
>>> np.char.lower(c)
array([‘a1b c’, ‘1bca’, ‘bca1’],
      dtype=’|S5’)

numpy.core.defchararray.lstrip(a, chars=None)
For each element in a, return a copy with the leading characters removed.

Calls str.lstrip element-wise.

Parameters
   a : array-like, {str, unicode}
      Input array.
   chars : {str, unicode}, optional
      The chars argument is a string specifying the set of characters to be removed. If omitted
      or None, the chars argument defaults to removing whitespace. The chars argument is
      not a prefix; rather, all combinations of its values are stripped.

Returns
   out : ndarray, {str, unicode}
      Output array of str or unicode, depending on input type

See also:
   str.lstrip

Examples
>>> c = np.array([‘aAaAaA’, ‘ aA ’, ‘abBABba’])
>>> c
array([‘aAaAaA’, ‘ aA ’, ‘abBABba’],
      dtype=’|S7’)

The ‘a’ variable is unstripped from c[1] because whitespace leading.
>>> np.char.lstrip(c, 'a')
array(["AaAaA", ' aA ', 'bBABba'],
      dtype='|S7')

>>> np.char.lstrip(c, 'A')  # leaves c unchanged
array(["aAaAaA", ' aA ', 'abBABba'],
      dtype='|S7')

>>> (np.char.lstrip(c, '') == np.char.lstrip(c, None)).all()
... # XXX: is this a regression? this line now returns False
... # np.char.lstrip(c,'') does not modify c at all.
True

>>> (np.char.lstrip(c, '') == np.char.lstrip(c, None)).all()
True

numpy.core.defchararray.partition(a, sep)

Partition each element in a around sep.

Calls str.partition element-wise.
For each element in a, split the element as the first occurrence of sep, and return 3 strings containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, return 3 strings containing the string itself, followed by two empty strings.

Parameters

a : array_like, {str, unicode}
Input array

sep : {str, unicode}
Separator to split each string element in a.

Returns

out : ndarray, {str, unicode}
Output array of str or unicode, depending on input type. The output array will have an extra dimension with 3 elements per input element.

See also:

str.partition

numpy.core.defchararray.replace(a, old, new, count=None)

For each element in a, return a copy of the string with all occurrences of substring old replaced by new.

Calls str.replace element-wise.

Parameters

a : array-like of str or unicode

old, new : str or unicode

count : int, optional
If the optional argument count is given, only the first count occurrences are replaced.

Returns

out : ndarray
Output array of str or unicode, depending on input type

See also:

str.replace

3.4. String operations
NumPy Reference, Release 1.9.2

numpy.core.defchararray.rjust (a, width, fillchar=' ')  
Return an array with the elements of a right-justified in a string of length width.  
Calls str.rjust element-wise.

Parameters

  a : array_like of str or unicode  
  width : int  
    The length of the resulting strings  
  fillchar : str or unicode, optional  
    The character to use for padding

Returns

  out : ndarray  
    Output array of str or unicode, depending on input type

See also:

  str.rjust

numpy.core.defchararray.rpartition (a, sep)  
Partition (split) each element around the right-most separator.  
Calls str.rpartition element-wise.

For each element in a, split the element as the last occurrence of sep, and return 3 strings containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, return 3 strings containing the string itself, followed by two empty strings.

Parameters

  a : array_like of str or unicode  
  Input array  
  sep : str or unicode  
    Right-most separator to split each element in array.

Returns

  out : ndarray  
    Output array of string or unicode, depending on input type. The output array will have an extra dimension with 3 elements per input element.

See also:

  str.rpartition

numpy.core.defchararray.rsplit (a, sep=None, maxsplit=None)  
For each element in a, return a list of the words in the string, using sep as the delimiter string.  
Calls str.rsplit element-wise.

Except for splitting from the right, rsplit behaves like split.

Parameters

  a : array_like of str or unicode  
  sep : str or unicode, optional  
    If sep is not specified or None, any whitespace string is a separator.  
  maxsplit : int, optional
If `maxsplit` is given, at most `maxsplit` splits are done, the rightmost ones.

**Returns**

- `out`: ndarray
  
  Array of list objects

**See also:**

- `str.rsplit`
- `split`

`numpy.core.defchararray.rstrip(a, chars=None)`

For each element in `a`, return a copy with the trailing characters removed.

Calls `str.rstrip` element-wise.

**Parameters**

- `a`: array-like of str or unicode
- `chars`: str or unicode, optional
  
  The `chars` argument is a string specifying the set of characters to be removed. If omitted or None, the `chars` argument defaults to removing whitespace. The `chars` argument is not a suffix; rather, all combinations of its values are stripped.

**Returns**

- `out`: ndarray
  
  Output array of str or unicode, depending on input type

**See also:**

- `str.rstrip`

**Examples**

```python
>>> c = np.array(["aAaAaA", "abBABba"], dtype='S7'); c
array(['aAaAaA', 'abBABba'],
dtype='|S7')

>>> np.char.rstrip(c, 'a')
array(['aAaAaA', 'abBABb'],
dtype='|S7')

>>> np.char.rstrip(c, 'A')
array(['aAaAa', 'abBABba'],
dtype='|S7')
```

`numpy.core.defchararray.split(a, sep=None, maxsplit=None)`

For each element in `a`, return a list of the words in the string, using `sep` as the delimiter string.

Calls `str.split` element-wise.

**Parameters**

- `a`: array_like of str or unicode
- `sep`: str or unicode, optional
- `maxsplit`: int, optional
  
  If `sep` is not specified or None, any whitespace string is a separator.

**Returns**

- `out`: ndarray
  
  Array of list objects
See also:

```
str.split, rsplit
```

numpy.core.defchararray.splitlines (a, keepends=None)

For each element in `a`, return a list of the lines in the element, breaking at line boundaries.

Calls `str.splitlines` element-wise.

**Parameters**
- `a` : array_like of str or unicode
- `keepends` : bool, optional

Line breaks are not included in the resulting list unless keepends is given and true.

**Returns**
- `out` : ndarray

Array of list objects

See also:

```
str.splitlines
```

numpy.core.defchararray.strip (a, chars=None)

For each element in `a`, return a copy with the leading and trailing characters removed.

Calls `str.rstrip` element-wise.

**Parameters**
- `a` : array-like of str or unicode
- `chars` : str or unicode, optional

The `chars` argument is a string specifying the set of characters to be removed. If omitted or None, the `chars` argument defaults to removing whitespace. The `chars` argument is not a prefix or suffix; rather, all combinations of its values are stripped.

**Returns**
- `out` : ndarray

Output array of str or unicode, depending on input type

See also:

```
str.strip
```

**Examples**

```python
c = np.array(['aAaAaA', ' aA ', 'abBAbba'])
c
array(['aAaAaA', ' aA ', 'abBAbba'],
dtype='|S7')
np.char.strip(c)
array(['aAaAaA', ' aA ', 'abBAbba'],
dtype='|S7')
np.char.strip(c, 'a')
array(['AaAaA', ' aA ', 'bBAbb'],
dtype='|S7')
np.char.strip(c, 'A')
array(['aAaAaA', ' aA ', 'abBAbba'],
dtype='|S7')
```
numpy.core.defchararray.swapcase(a)
    Return element-wise a copy of the string with uppercase characters converted to lowercase and vice versa.
    Calls str.swapcase element-wise.
    For 8-bit strings, this method is locale-dependent.

    Parameters
    a : array_like, {str, unicode}
        Input array.

    Returns
    out : ndarray, {str, unicode}
        Output array of str or unicode, depending on input type

    See also:
    str.swapcase

    Examples
    >>> c=np.array(['a1B c','1b Ca','b Ca1','cA1b'],'S5'); c
    array(['a1B c', '1b Ca', 'b Ca1', 'cA1b'],
          dtype='|S5')
    >>> np.char.swapcase(c)
    array(['A1b C', '1B cA', 'B cA1', 'Ca1B'],
          dtype='|S5')

numpy.core.defchararray.title(a)
    Return element-wise title cased version of string or unicode.
    Title case words start with uppercase characters, all remaining cased characters are lowercase.
    Calls str.title element-wise.
    For 8-bit strings, this method is locale-dependent.

    Parameters
    a : array_like, {str, unicode}
        Input array.

    Returns
    out : ndarray
        Output array of str or unicode, depending on input type

    See also:
    str.title

    Examples
    >>> c=np.array(['a1b c','1b ca','b ca1','ca1b'],'S5'); c
    array(['a1b c', '1b ca', 'b ca1', 'ca1b'],
          dtype='|S5')
    >>> np.char.title(c)
    array(['A1B C', '1B Ca', 'B Ca1', 'Ca1B'],
          dtype='|S5')

numpy.core.defchararray.translate(a, table, deletechars=None)
    For each element in a, return a copy of the string where all characters occurring in the optional argument deletechars are removed, and the remaining characters have been mapped through the given translation table.

3.4. String operations
Calls `str.translate` element-wise.

**Parameters**
- `a`: array-like of str or unicode
- `table`: str of length 256
- `deletechars`: str

**Returns**
- `out`: ndarray
  Output array of str or unicode, depending on input type

See also:
- `str.translate`
- `numpy.core.defchararray.upper(a)`
  Return an array with the elements converted to uppercase.
  Calls `str.upper` element-wise.
  For 8-bit strings, this method is locale-dependent.

**Parameters**
- `a`: array_like, {str, unicode}
  Input array.

**Returns**
- `out`: ndarray, {str, unicode}
  Output array of str or unicode, depending on input type

See also:
- `str.upper`

**Examples**

```python
>>> c = np.array(['a1b c', '1bca', 'bca1']); c
array(['a1b c', '1bca', 'bca1'],
      dtype='|S5')
>>> np.char.upper(c)
array(['A1B C', '1BCA', 'BCA1'],
      dtype='|S5')
```

- `numpy.core.defchararray.zfill(a, width)`
  Return the numeric string left-filled with zeros
  Calls `str.zfill` element-wise.

**Parameters**
- `a`: array_like, {str, unicode}
  Input array.
- `width`: int
  Width of string to left-fill elements in `a`.

**Returns**
- `out`: ndarray, {str, unicode}
  Output array of str or unicode, depending on input type
See also:

str.zfill

3.4.2 Comparison

Unlike the standard numpy comparison operators, the ones in the char module strip trailing whitespace characters before performing the comparison.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>equal(x1, x2)</code></td>
<td>Return ((x1 == x2)) element-wise.</td>
</tr>
<tr>
<td><code>not_equal(x1, x2)</code></td>
<td>Return ((x1 != x2)) element-wise.</td>
</tr>
<tr>
<td><code>greater_equal(x1, x2)</code></td>
<td>Return ((x1 &gt;= x2)) element-wise.</td>
</tr>
<tr>
<td><code>less_equal(x1, x2)</code></td>
<td>Return ((x1 &lt;= x2)) element-wise.</td>
</tr>
<tr>
<td><code>greater(x1, x2)</code></td>
<td>Return ((x1 &gt; x2)) element-wise.</td>
</tr>
<tr>
<td><code>less(x1, x2)</code></td>
<td>Return ((x1 &lt; x2)) element-wise.</td>
</tr>
</tbody>
</table>

```
numpy.core.defchararray.equal(x1, x2)
Return \((x1 == x2)\) element-wise.
```

Unlike `numpy.equal`, this comparison is performed by first stripping whitespace characters from the end of the string. This behavior is provided for backward-compatibility with numarray.

**Parameters**

- `x1, x2`: array_like of str or unicode
  - Input arrays of the same shape.

**Returns**

- `out`: {ndarray, bool}
  - Output array of bools, or a single bool if `x1` and `x2` are scalars.

See also:

not_equal, greater_equal, less_equal, greater, less

```
numpy.core.defchararray.not_equal(x1, x2)
Return \((x1 != x2)\) element-wise.
```

Unlike `numpy.not_equal`, this comparison is performed by first stripping whitespace characters from the end of the string. This behavior is provided for backward-compatibility with numarray.

**Parameters**

- `x1, x2`: array_like of str or unicode
  - Input arrays of the same shape.

**Returns**

- `out`: {ndarray, bool}
  - Output array of bools, or a single bool if `x1` and `x2` are scalars.

See also:

equal, greater_equal, less_equal, greater, less

```
numpy.core.defchararray.greater_equal(x1, x2)
Return \((x1 >= x2)\) element-wise.
```

Unlike `numpy.greater_equal`, this comparison is performed by first stripping whitespace characters from the end of the string. This behavior is provided for backward-compatibility with numarray.
Parameters
   x1, x2 : array_like of str or unicode
       Input arrays of the same shape.

Returns
   out : {ndarray, bool}
       Output array of bools, or a single bool if x1 and x2 are scalars.

See also:
equal, not_equal, less_equal, greater, less
	numpy.core.defchararray.less_equal(x1, x2)
      Return (x1 <= x2) element-wise.

      Unlike numpy.less_equal, this comparison is performed by first stripping whitespace characters from the
      end of the string. This behavior is provided for backward-compatibility with numarray.

Parameters
   x1, x2 : array_like of str or unicode
       Input arrays of the same shape.

Returns
   out : {ndarray, bool}
       Output array of bools, or a single bool if x1 and x2 are scalars.

See also:
equal, not_equal, greater_equal, greater, less
	numpy.core.defchararray.greater(x1, x2)
      Return (x1 > x2) element-wise.

      Unlike numpy.greater, this comparison is performed by first stripping whitespace characters from the end
      of the string. This behavior is provided for backward-compatibility with numarray.

Parameters
   x1, x2 : array_like of str or unicode
       Input arrays of the same shape.

Returns
   out : {ndarray, bool}
       Output array of bools, or a single bool if x1 and x2 are scalars.

See also:
equal, not_equal, greater_equal, less_equal, less
	numpy.core.defchararray.less(x1, x2)
      Return (x1 < x2) element-wise.

      Unlike numpy.greater, this comparison is performed by first stripping whitespace characters from the end
      of the string. This behavior is provided for backward-compatibility with numarray.

Parameters
   x1, x2 : array_like of str or unicode
       Input arrays of the same shape.

Returns
   out : {ndarray, bool}
Output array of bools, or a single bool if x1 and x2 are scalars.

See also:

`equal`, `not_equal`, `greater_equal`, `less_equal`, `greater`

### 3.4.3 String information

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>count(a, sub[, start, end])</code></td>
<td>Returns an array with the number of non-overlapping occurrences of substring <code>sub</code> in the range <code>[start, end]</code>.</td>
</tr>
<tr>
<td><code>find(a, sub[, start, end])</code></td>
<td>For each element, return the lowest index in the string where substring <code>sub</code> is found.</td>
</tr>
<tr>
<td><code>index(a, sub[, start, end])</code></td>
<td>Like <code>find</code>, but raises <code>ValueError</code> when the substring is not found.</td>
</tr>
<tr>
<td><code>isalpha(a)</code></td>
<td>Returns true for each element if all characters in the string are alphabetic and there is at least one character.</td>
</tr>
<tr>
<td><code>isdecimal(a)</code></td>
<td>Returns true for each element if all characters in the string are digits and there is at least one character.</td>
</tr>
<tr>
<td><code>isdigit(a)</code></td>
<td>Returns true for each element if all characters in the string are digits and there is at least one character.</td>
</tr>
<tr>
<td><code>islower(a)</code></td>
<td>Returns true for each element if all cased characters in the string are lowercase and there is at least one cased character.</td>
</tr>
<tr>
<td><code>isnumeric(a)</code></td>
<td>Returns true for each element if all characters in the string are numeric and there is at least one character.</td>
</tr>
<tr>
<td><code>isspace(a)</code></td>
<td>Returns true for each element if all characters in the string are whitespace and there is at least one character.</td>
</tr>
<tr>
<td><code>istitle(a)</code></td>
<td>Returns true for each element if the string is titlecased and there is at least one character.</td>
</tr>
<tr>
<td><code>isupper(a)</code></td>
<td>Returns true for each element if all cased characters in the string are uppercase and there is at least one cased character.</td>
</tr>
<tr>
<td><code>rfind(a, sub[, start, end])</code></td>
<td>For each element in <code>a</code>, return the highest index in the string where substring <code>sub</code> is found, such that <code>sub</code> is contained within <code>[start, end]</code>.</td>
</tr>
<tr>
<td><code>rindex(a, sub[, start, end])</code></td>
<td>Like <code>rfind</code>, but raises <code>ValueError</code> when the substring <code>sub</code> is not found.</td>
</tr>
<tr>
<td><code>startswith(a, prefix[, start, end])</code></td>
<td>Returns a boolean array which is <code>True</code> where the string element in <code>a</code> starts with <code>prefix</code>, otherwise <code>False</code>.</td>
</tr>
</tbody>
</table>

**numpy.core.defchararray.**

`count(a, sub=0, end=None)`

Calls `str.count` element-wise.

**Parameters**

- `a` : array_like of str or unicode
- `sub` : str or unicode
  
The substring to search for.
- `start, end` : int, optional
  
Optional arguments `start` and `end` are interpreted as slice notation to specify the range in which to count.

**Returns**

- `out` : ndarray
  
Output array of ints.

**See also:**

`str.count`

**Examples**

```python
>>> c = np.array(['aAaAaA', ' aA ', 'abBABba'])
>>> c
array(['aAaAaA', ' aA ', 'abBABba'],
      dtype='|S7')
>>> np.char.count(c, 'A')
array([3, 1, 1])
>>> np.char.count(c, 'aA')
array([3, 1, 0])
```

### 3.4. String operations

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```python
>>> np.char.count(c, 'A', start=1, end=4)
array([2, 1, 1])
>>> np.char.count(c, 'A', start=1, end=3)
array([1, 0, 0])
```

**numpy.core.defchararray.find**

For each element, return the lowest index in the string where substring `sub` is found.

Calls `str.find` element-wise.

For each element, return the lowest index in the string where substring `sub` is found, such that `sub` is contained in the range `[start, end]`.

**Parameters**
- `a` : array_like of str or unicode
- `sub` : str or unicode
- `start`, `end` : int, optional
  Optional arguments `start` and `end` are interpreted as in slice notation.

**Returns**
- `out` : ndarray or int
  Output array of ints. Returns -1 if `sub` is not found.

**See also:**
- `str.find`

**numpy.core.defchararray.index**

Like `find`, but raises `ValueError` when the substring is not found.

Calls `str.index` element-wise.

**Parameters**
- `a` : array_like of str or unicode
- `sub` : str or unicode
- `start`, `end` : int, optional

**Returns**
- `out` : ndarray
  Output array of ints. Returns -1 if `sub` is not found.

**See also:**
- `find`, `str.find`

**numpy.core.defchararray.isalpha**

Returns true for each element if all characters in the string are alphabetic and there is at least one character, false otherwise.

Calls `str.isalpha` element-wise.

For 8-bit strings, this method is locale-dependent.

**Parameters**
- `a` : array_like of str or unicode

**Returns**
- `out` : ndarray
Output array of bools

See also:
str.isalpha

numpy.core.defchararray.isdecimal(a)
For each element, return True if there are only decimal characters in the element.

Calls unicode.isdecimal element-wise.

Decimal characters include digit characters, and all characters that that can be used to form decimal-radix numbers, e.g. U+0660, ARABIC-INDIC DIGIT ZERO.

Parameters
a : array_like, unicode
   Input array.

Returns
out : ndarray, bool
   Array of booleans identical in shape to a.

See also:
unicode.isdecimal

numpy.core.defchararray.isdigit(a)
Returns true for each element if all characters in the string are digits and there is at least one character, false otherwise.

Calls str.isdigit element-wise.

For 8-bit strings, this method is locale-dependent.

Parameters
a : array_like of str or unicode

Returns
out : ndarray
   Output array of bools

See also:
str.isdigit

numpy.core.defchararray.islower(a)
Returns true for each element if all cased characters in the string are lowercase and there is at least one cased character, false otherwise.

Calls str.islower element-wise.

For 8-bit strings, this method is locale-dependent.

Parameters
a : array_like of str or unicode

Returns
out : ndarray
   Output array of bools

See also:
str.islower
numpy.core.defchararray.isnumeric(a)
For each element, return True if there are only numeric characters in the element.
Calls unicode.isnumeric element-wise.
Numeric characters include digit characters, and all characters that have the Unicode numeric value property, e.g. U+2155, VULGAR FRACTION ONE FIFTH.

Parameters
a : array_like, unicode
Input array.

Returns
out : ndarray, bool
Array of bools of same shape as a.

See also:
unicode.isnumeric

numpy.core.defchararray.isspace(a)
Returns true for each element if there are only whitespace characters in the string and there is at least one character, false otherwise.
Calls str.isspace element-wise.
For 8-bit strings, this method is locale-dependent.

Parameters
a : array_like of str or unicode

Returns
out : ndarray
Output array of bools

See also:
str.isspace

numpy.core.defchararray.istitle(a)
Returns true for each element if the element is a titlecased string and there is at least one character, false otherwise.
Call str.istitle element-wise.
For 8-bit strings, this method is locale-dependent.

Parameters
a : array_like of str or unicode

Returns
out : ndarray
Output array of bools

See also:
str.istitle

numpy.core.defchararray.isupper(a)
Returns true for each element if all cased characters in the string are uppercase and there is at least one character, false otherwise.
Call str.isupper element-wise.
For 8-bit strings, this method is locale-dependent.

**Parameters**
- `a`: array_like of str or unicode

**Returns**
- `out`: ndarray
  - Output array of bools

**See also:**
- `str.isupper`
- `numpy.core.defchararray.rfind(a, sub, start=0, end=None)`
  - For each element in `a`, return the highest index in the string where substring `sub` is found, such that `sub` is contained within `[start, end]`.
  - Calls `str.rfind` element-wise.

**Parameters**
- `a`: array-like of str or unicode
- `sub`: str or unicode
- `start, end`: int, optional
  - Optional arguments `start` and `end` are interpreted as in slice notation.

**Returns**
- `out`: ndarray
  - Output array of ints. Return -1 on failure.

**See also:**
- `str.rfind`
- `numpy.core.defchararray.rindex(a, sub, start=0, end=None)`
  - Like `rfind`, but raises `ValueError` when the substring `sub` is not found.
  - Calls `str.rindex` element-wise.

**Parameters**
- `a`: array-like of str or unicode
- `sub`: str or unicode
- `start, end`: int, optional

**Returns**
- `out`: ndarray
  - Output array of ints.

**See also:**
- `rfind, str.rindex`
- `numpy.core.defchararray.startswith(a, prefix, start=0, end=None)`
  - Returns a boolean array which is True where the string element in `a` starts with `prefix`, otherwise False.
  - Calls `str.startswith` element-wise.

**Parameters**
- `a`: array_like of str or unicode
- `prefix`: str
start, end : int, optional

With optional start, test beginning at that position. With optional end, stop comparing at that position.

Returns

out : ndarray

Array of booleans

See also:

str.startswith

3.4.4 Convenience class

class numpy.core.defchararray.chararray

Provides a convenient view on arrays of string and unicode values.

Note: The chararray class exists for backwards compatibility with Numarray, it is not recommended for new development. Starting from numpy 1.4, if one needs arrays of strings, it is recommended to use arrays of dtype object_.string_ or unicode_, and use the free functions in the numpy.char module for fast vectorized string operations.

Versus a regular Numpy array of type str or unicode, this class adds the following functionality:

1. values automatically have whitespace removed from the end when indexed
2. comparison operators automatically remove whitespace from the end when comparing values
3. vectorized string operations are provided as methods (e.g. endswith) and infix operators (e.g. "+", "*", "%")

chararrays should be created using numpy.char.array or numpy.char.asarray, rather than this constructor directly.

This constructor creates the array, using buffer (with offset and strides) if it is not None. If buffer is None, then constructs a new array with strides in “C order”, unless both len(shape) >= 2 and order='Fortran', in which case strides is in “Fortran order”.

Parameters

shape : tuple

Shape of the array.

itemsize : int, optional

Length of each array element, in number of characters. Default is 1.

unicode : bool, optional

Are the array elements of type unicode (True) or string (False). Default is False.

buffer : int, optional

Memory address of the start of the array data. Default is None, in which case a new array is created.

offset : int, optional

...
Fixed stride displacement from the beginning of an axis? Default is 0. Needs to be \geq 0.

**strides**: array_like of ints, optional

Strides for the array (see `ndarray.strides` for full description). Default is None.

**order**: {'C', 'F'}, optional

The order in which the array data is stored in memory: ‘C’ \textarrow row major order (the default), ‘F’ \textarrow column major (Fortran) order.

### Examples

```python
def chararray:
    charar = np.chararray((3, 3))
    charar[:] = 'a'
    charar

    chararray([[‘a’, ‘a’, ‘a’],
               [‘a’, ‘a’, ‘a’],
               [‘a’, ‘a’, ‘a’]],
               dtype=‘|S1’)

    charar = np.chararray(charar.shape, itemsize=5)
    charar[:] = ‘abc’
    charar

    chararray([[‘abc’, ‘abc’, ‘abc’],
               [‘abc’, ‘abc’, ‘abc’],
               [‘abc’, ‘abc’, ‘abc’]],
               dtype=‘|S5’)
```  

### Attributes

- **T**: Same as self.transpose(), except that self is returned if self.ndim < 2.
- **base**: Base object if memory is from some other object.
- **ctypes**: An object to simplify the interaction of the array with the ctypes module.
- **data**: Python buffer object pointing to the start of the array’s data.
- **dtype**: Data-type of the array’s elements.
- **flags**: Information about the memory layout of the array.
- **flat**: A 1-D iterator over the array.
- **imag**: The imaginary part of the array.
- **itemsize**: Length of one array element in bytes.
- **nbytes**: Total bytes consumed by the elements of the array.
- **ndim**: Number of array dimensions.
- **real**: The real part of the array.
- **shape**: Tuple of array dimensions.
- **size**: Number of elements in the array.
- **strides**: Tuple of bytes to step in each dimension when traversing an array.

### chararray.T

Same as self.transpose(), except that self is returned if self.ndim < 2.

### Examples

```python
def x:
    x = np.array([[1., 2.],
                  [3., 4.]])
    x

>>> x
array([[ 1.,  2.],
       [ 3.,  4.]])
>>> x.T
```

3.4. String operations
array([[ 1.,  3.],
       [ 2.,  4.]])
>>> x = np.array([1.,2.,3.,4.])
>>> x
array([ 1.,  2.,  3.,  4.])
>>> x.T
array([ 1.,  2.,  3.,  4.])

cchararray.base

Base object if memory is from some other object.

Examples

The base of an array that owns its memory is None:

```python
>>> x = np.array([1,2,3,4])
>>> x.base is None
True
```

Slicing creates a view, whose memory is shared with x:

```python
>>> y = x[2:]
>>> y.base is x
True
```

cchararray.ctypes

An object to simplify the interaction of the array with the ctypes module.

This attribute creates an object that makes it easier to use arrays when calling shared libraries with the ctypes module. The returned object has, among others, data, shape, and strides attributes (see Notes below) which themselves return ctypes objects that can be used as arguments to a shared library.

Parameters

None

Returns

c : Python object

Possessing attributes data, shape, strides, etc.

See also:

numpy.ctypeslib

Notes

Below are the public attributes of this object which were documented in “Guide to NumPy” (we have omitted undocumented public attributes, as well as documented private attributes):

•data: A pointer to the memory area of the array as a Python integer. This memory area may contain data that is not aligned, or not in correct byte-order. The memory area may not even be writeable. The array flags and data-type of this array should be respected when passing this attribute to arbitrary C-code to avoid trouble that can include Python crashing. User Beware! The value of this attribute is exactly the same as self._array_interface_['data'][0].

•shape (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the C-integer corresponding to dtype('p') on this platform. This base-type could be c_int, c_long, or c_longlong depending on the platform. The c_intp type is defined accordingly in numpy.ctypeslib. The ctypes array contains the shape of the underlying array.

•strides (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the same as for the shape attribute. This ctypes array contains the strides information from the underlying array.
This strides information is important for showing how many bytes must be jumped to get to the next element in the array.

• **data_as(obj)**: Return the data pointer cast to a particular c-types object. For example, calling `self._as_parameter_` is equivalent to `self.data_as(ctypes.c_void_p)`. Perhaps you want to use the data as a pointer to a ctypes array of floating-point data: `self.data_as(ctypes.POINTER(ctypes.c_double))`.

• **shape_as(obj)**: Return the shape tuple as an array of some other c-types type. For example: `self.shape_as(ctypes.c_short)`.

• **strides_as(obj)**: Return the strides tuple as an array of some other c-types type. For example: `self.strides_as(ctypes.c_longlong)`.

Be careful using the ctypes attribute - especially on temporary arrays or arrays constructed on the fly. For example, calling `(a+b).ctypes.data_as(ctypes.c_void_p)` returns a pointer to memory that is invalid because the array created as `(a+b)` is deallocated before the next Python statement. You can avoid this problem using either `c=a+b` or `ct=(a+b).ctypes`. In the latter case, `ct` will hold a reference to the array until `ct` is deleted or re-assigned.

If the ctypes module is not available, then the ctypes attribute of array objects still returns something useful, but ctypes objects are not returned and errors may be raised instead. In particular, the object will still have the as parameter attribute which will return an integer equal to the data attribute.

### Examples

```python
>>> import ctypes
>>> x
array([[0, 1],
       [2, 3]])
>>> x.ctypes.data
30439712
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_long))
<ctypes.LP_c_long object at 0x01F01300>
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_long)).contents
c_long(0)
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_longlong)).contents
c_longlong(4294967296L)
>>> x.ctypes.shape
<numpy.core._internal.c_long_Array_2 object at 0x01FFD580>
>>> x.ctypes.shape_as(ctypes.c_long)
<numpy.core._internal.c_long_Array_2 object at 0x01FCE620>
>>> x.ctypes.strides
<numpy.core._internal.c_long_Array_2 object at 0x01FCE620>
>>> x.ctypes.strides_as(ctypes.c_longlong)
<numpy.core._internal.c_longlong_Array_2 object at 0x01F01300>
```

**chararray.data**
Python buffer object pointing to the start of the array’s data.

**chararray.dtype**
Data-type of the array’s elements.

**Parameters**
None

**Returns**

- **d**: numpy dtypes object

**See also:**

numpy.dtype
Examples

```python
>>> x  
array([[0, 1],
       [2, 3]])
>>> x.dtype
dtype('int32')
>>> type(x.dtype)
<type 'numpy.dtype'>
```

cchararray.flags

Information about the memory layout of the array.

Notes

The `flags` object can be accessed dictionary-like (as in `a.flags[’WRITEABLE’]`), or by using lowercase attribute names (as in `a.flags.writeable`). Short flag names are only supported in dictionary access.

Only the UPDATEIFCOPY, WRITEABLE, and ALIGNED flags can be changed by the user, via direct assignment to the attribute or dictionary entry, or by calling `ndarray.setflags`.

The array flags cannot be set arbitrarily:

- UPDATEIFCOPY can only be set `False`.
- ALIGNED can only be set `True` if the data is truly aligned.
- WRITEABLE can only be set `True` if the array owns its own memory or the ultimate owner of the memory exposes a writeable buffer interface or is a string.

Arrays can be both C-style and Fortran-style contiguous simultaneously. This is clear for 1-dimensional arrays, but can also be true for higher dimensional arrays.

Even for contiguous arrays a stride for a given dimension `arr.strides[dim]` may be arbitrary if `arr.shape[dim] == 1` or the array has no elements. It does not generally hold that `self.strides[-1] == self.itemsize` for C-style contiguous arrays or `self.strides[0] == self.itemsize` for Fortran-style contiguous arrays is true.
Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_CONTIGUOUS</td>
<td>The data is in a single, C-style contiguous segment.</td>
</tr>
<tr>
<td>F_CONTIGUOUS</td>
<td>The data is in a single, Fortran-style contiguous segment.</td>
</tr>
<tr>
<td>OWN_DATA</td>
<td>The array owns the memory it uses or borrows it from another object.</td>
</tr>
<tr>
<td>WRITEABLE</td>
<td>The data area can be written to. Setting this to False locks the data, making it read-only. A view (slice, etc.) inherits WRITEABLE from its base array at creation time, but a view of a writeable array may be subsequently locked while the base array remains writeable. (The opposite is not true, in that a view of a locked array may not be made writeable. However, currently, locking a base object does not lock any views that already reference it, so under that circumstance it is possible to alter the contents of a locked array via a previously created writeable view onto it.) Attempting to change a non-writeable array raises a RuntimeError exception. The data and all elements are aligned appropriately for the hardware. This array is a copy of some other array. When this array is deallocated, the base array will be updated with the contents of this array.</td>
</tr>
<tr>
<td>ALIGNED</td>
<td>F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FORC</td>
<td>F_CONTIGUOUS or C_CONTIGUOUS (one-segment test).</td>
</tr>
<tr>
<td>BEHAVED</td>
<td>ALIGNED and WRITEABLE.</td>
</tr>
<tr>
<td>CARRAY</td>
<td>BEHAVED and C_CONTIGUOUS.</td>
</tr>
<tr>
<td>FARRAY</td>
<td>BEHAVED and F_CONTIGUOUS and not C_CONTIGUOUS.</td>
</tr>
</tbody>
</table>

chararray.flat

A 1-D iterator over the array.

This is a numpy.flatiter instance, which acts similarly to, but is not a subclass of, Python’s built-in iterator object.

See also:

flatten

Return a copy of the array collapsed into one dimension.

Examples

```python
g = np.arange(1, 7).reshape(2, 3)
g
array([[1, 2, 3],
       [4, 5, 6]])
g.flat[3] 4
g.T
array([[1, 4],
       [2, 5],
       [3, 6]])
```
```python
>>> x.T.flat[3]
5
>>> type(x.flat)
<type 'numpy.flatiter'>
```

An assignment example:

```python
>>> x.flat = 3; x
array([[3, 3, 3],
       [3, 3, 3]])
```

```python
>>> x.flat[[1,4]] = 1; x
array([[3, 1, 3],
       [3, 1, 3]])
```

**chararray.imag**

The imaginary part of the array.

**Examples**

```python
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.imag
array([ 0. , 0.70710678])
```

```python
>>> x.imag.dtype
dtype('float64')
```

**chararray.itemsize**

Length of one array element in bytes.

**Examples**

```python
>>> x = np.array([1,2,3], dtype=np.float64)
>>> x.itemsize
8
```

```python
>>> x = np.array([1,2,3], dtype=np.complex128)
>>> x.itemsize
16
```

**chararray.nbytes**

Total bytes consumed by the elements of the array.

**Notes**

Does not include memory consumed by non-element attributes of the array object.

**Examples**

```python
>>> x = np.zeros((3,5,2), dtype=np.complex128)
>>> x.nbytes
480
```

```python
>>> np.prod(x.shape) * x.itemsize
480
```

**chararray.ndim**

Number of array dimensions.

**Examples**

```python
>>> x = np.array([1, 2, 3])
>>> x.ndim
1
```
>>> y = np.zeros((2, 3, 4))
>>> y.ndim
3

castarray.real
The real part of the array.

See also:
numpy.real
equivalent function

Examples
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.real
array([ 1. , 0.70710678])
>>> x.real.dtype
dtype('float64')

castarray.shape
Tuple of array dimensions.

Notes
May be used to “reshape” the array, as long as this would not require a change in the total number of elements

Examples
>>> x = np.array([1, 2, 3, 4])
>>> x.shape
(4,)
>>> y = np.zeros((2, 3, 4))
>>> y.shape
(2, 3, 4)
>>> y.shape = (3, 8)
>>> y
array([[ 0., 0., 0., 0., 0., 0., 0., 0.],
       [ 0., 0., 0., 0., 0., 0., 0., 0.],
       [ 0., 0., 0., 0., 0., 0., 0., 0.]])
>>> y.shape = (3, 6)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: total size of new array must be unchanged
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: total size of new array must be unchanged

castarray.size
Number of elements in the array.

Equivalent to np.prod(a.shape), i.e., the product of the array’s dimensions.

Examples
>>> x = np.zeros((3, 5, 2), dtype=np.complex128)
>>> x.size
30

3.4. String operations
>>> np.prod(x.shape)
30

cchararray.strides
Tuple of bytes to step in each dimension when traversing an array.
The byte offset of element \((i[0], i[1], \ldots, i[n])\) in an array \(a\) is:
\[
\text{offset} = \sum (\text{np.array}(i) \times a\text{.strides})
\]
A more detailed explanation of strides can be found in the “ndarray.rst” file in the NumPy reference guide.

See also:
numpy.lib.stride_tricks.as_strided

Notes
Imagine an array of 32-bit integers (each 4 bytes):
\[
x = \text{np.array([[[0, 1, 2, 3, 4],}
\quad [5, 6, 7, 8, 9]],
\quad \text{dtype=\text{np\text{.int32})}}
\]
This array is stored in memory as 40 bytes, one after the other (known as a contiguous block of memory).
The strides of an array tell us how many bytes we have to skip in memory to move to the next position along a certain axis. For example, we have to skip 4 bytes (1 value) to move to the next column, but 20 bytes (5 values) to get to the same position in the next row. As such, the strides for the array \(x\) will be \((20, 4)\).

Examples

```python
>>> y = np.reshape(np.arange(2*3*4), (2,3,4))
>>> y
array([[[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]],
       [[12, 13, 14, 15],
        [16, 17, 18, 19],
        [20, 21, 22, 23]])
>>> y.strides
(48, 16, 4)
>>> y[1,1,1]
17
>>> offset=sum(y.strides * np.array((1,1,1)))
>>> offset/y.itemsize
17
```

```python
>>> x = np.reshape(np.arange(5*6*7*8), (5,6,7,8)).transpose(2,3,1,0)
>>> x.strides
(32, 4, 224, 1344)
>>> i = np.array([3,5,2,2])
>>> offset = sum(i * x.strides)
>>> x[3,5,2,2]
813
>>> offset / x.itemsize
813
```

Methods
3.4. String operations

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>astype(dtype[, order, casting, subok, copy])</code></td>
<td>Copy of the array, cast to a specified type.</td>
</tr>
<tr>
<td><code>copy(order)</code></td>
<td>Return a copy of the array.</td>
</tr>
<tr>
<td><code>count(sub[, start, end])</code></td>
<td>Returns an array with the number of non-overlapping occurrences of substring <code>sub</code> in <code>self</code>.</td>
</tr>
<tr>
<td><code>decode([encoding, errors])</code></td>
<td>Calls <code>str.decode</code> element-wise.</td>
</tr>
<tr>
<td><code>dump(file)</code></td>
<td>Dump a pickle of the array to the specified file.</td>
</tr>
<tr>
<td><code>dumps()</code></td>
<td>Returns the pickle of the array as a string.</td>
</tr>
<tr>
<td><code>encode([encoding, errors])</code></td>
<td>Calls <code>str.encode</code> element-wise.</td>
</tr>
<tr>
<td><code>endswith(suffix[, start, end])</code></td>
<td>Returns a boolean array which is True where the string element in <code>self</code> ends with <code>suffix</code>.</td>
</tr>
<tr>
<td><code>expandtabs([tabsize])</code></td>
<td>Return a copy of each string element where all tab characters are replaced by one or more spaces.</td>
</tr>
<tr>
<td><code>fill(value)</code></td>
<td>Fill the array with a scalar value.</td>
</tr>
<tr>
<td><code>find(sub[, start, end])</code></td>
<td>For each element, return the lowest index in the string where substring <code>sub</code> is found.</td>
</tr>
<tr>
<td><code>flatten(order)</code></td>
<td>Return a copy of the array collapsed into one dimension.</td>
</tr>
<tr>
<td><code>getfield(dtype[, offset])</code></td>
<td>Returns a field of the given array as a certain type.</td>
</tr>
<tr>
<td><code>index(sub[, start, end])</code></td>
<td>Like <code>find</code>, but raises <code>ValueError</code> when the substring is not found.</td>
</tr>
<tr>
<td><code>isalnum()</code></td>
<td>Returns true for each element if all characters in the string are alphanumeric and there is at least one character.</td>
</tr>
<tr>
<td><code>isalpha()</code></td>
<td>Returns true for each element if all characters in the string are alphabetic and there is at least one character.</td>
</tr>
<tr>
<td><code>isdigit()</code></td>
<td>Returns true for each element if the string contains only decimal characters and there is at least one character.</td>
</tr>
<tr>
<td><code>islower()</code></td>
<td>Returns true for each element if the string contains only lowercase characters and there is at least one character.</td>
</tr>
<tr>
<td><code>isnumeric()</code></td>
<td>Returns true for each element if the string contains only numeric characters and there is at least one character.</td>
</tr>
<tr>
<td><code>isspace()</code></td>
<td>Returns true for each element if there are only whitespace characters in the string and there is at least one character.</td>
</tr>
<tr>
<td><code>istitle()</code></td>
<td>Returns true for each element if the string is in title case and there is at least one character.</td>
</tr>
<tr>
<td><code>isupper()</code></td>
<td>Returns true for each element if all characters in the string are uppercase and there is at least one character.</td>
</tr>
<tr>
<td><code>item(*args)</code></td>
<td>Copy an element of an array to a standard Python scalar and return it.</td>
</tr>
<tr>
<td><code>join(seq)</code></td>
<td>Return a string which is the concatenation of the strings in the sequence <code>seq</code>.</td>
</tr>
<tr>
<td><code>ljust(width[, fillchar])</code></td>
<td>Return an array with the elements of <code>self</code> left-justified in a string of length <code>width</code>.</td>
</tr>
<tr>
<td><code>lower()</code></td>
<td>Return an array with the elements of <code>self</code> converted to lowercase.</td>
</tr>
<tr>
<td><code>lstrip([chars])</code></td>
<td>For each element in <code>self</code>, return a copy with the leading characters removed.</td>
</tr>
<tr>
<td><code>nonzero()</code></td>
<td>Return the indices of the elements that are non-zero.</td>
</tr>
<tr>
<td><code>put(indices, values[, mode])</code></td>
<td>Set <code>a.flat[n] = values[n]</code> for all <code>n</code> in indices.</td>
</tr>
<tr>
<td><code>ravel(order)</code></td>
<td>Return a flattened array.</td>
</tr>
<tr>
<td><code>repeat(repeats[, axis])</code></td>
<td>Repeat elements of an array.</td>
</tr>
<tr>
<td><code>replace(old, new[, count])</code></td>
<td>For each element in <code>self</code>, return a copy of the string with all occurrences of substring <code>old</code> replaced by <code>new</code>.</td>
</tr>
<tr>
<td><code>resize(shape[, order])</code></td>
<td>Returns an array containing the same data with a new shape.</td>
</tr>
<tr>
<td><code>resize(new_shape[, refcheck])</code></td>
<td>Change shape and size of array in-place.</td>
</tr>
<tr>
<td><code>rfind(sub[, start, end])</code></td>
<td>For each element in <code>self</code>, return the highest index in the string where substring <code>sub</code> is found.</td>
</tr>
<tr>
<td><code>rindex(sub[, start, end])</code></td>
<td>Like <code>rfind</code>, but raises <code>ValueError</code> when the substring <code>sub</code> is not found.</td>
</tr>
<tr>
<td><code>rjust(width[, fillchar])</code></td>
<td>Return an array with the elements of <code>self</code> right-justified in a string of length <code>width</code>.</td>
</tr>
<tr>
<td><code>rsplit(sep[, maxsplit])</code></td>
<td>For each element in <code>self</code>, return a list of the words in the string, using <code>sep</code> as the delimiter separator.</td>
</tr>
<tr>
<td><code>rstrip([chars])</code></td>
<td>For each element in <code>self</code>, return a copy with the trailing characters removed.</td>
</tr>
<tr>
<td><code>searchsorted(v[, side, sorter])</code></td>
<td>Find indices where elements of <code>v</code> should be inserted in a to maintain order.</td>
</tr>
<tr>
<td><code>setfield(val, dtype[, offset])</code></td>
<td>Put a value into a specified place in a field defined by a data-type.</td>
</tr>
<tr>
<td><code>setflags([write, align, uic])</code></td>
<td>Set array flags WRITEABLE, ALIGNED, and UPDATEIFCOPY, respectively.</td>
</tr>
<tr>
<td><code>sort([axis, kind, order])</code></td>
<td>Sort an array, in-place.</td>
</tr>
<tr>
<td><code>split(sep[, maxsplit])</code></td>
<td>For each element in <code>self</code>, return a list of the words in the string, using <code>sep</code> as the delimiter separator.</td>
</tr>
<tr>
<td><code>splitlines([keepends])</code></td>
<td>Remove single-dimensional entries from the shape of <code>a</code>.</td>
</tr>
<tr>
<td><code>squeeze([axis])</code></td>
<td>Returns a boolean array which is True where the string element in <code>self</code> starts with <code>prefix</code>.</td>
</tr>
<tr>
<td><code>startswith(prefix[, start, end])</code></td>
<td>For each element in <code>self</code>, return a copy with the leading and trailing characters removed.</td>
</tr>
<tr>
<td><code>strip([chars])</code></td>
<td>Return a view of the array with <code>axis1</code> and <code>axis2</code> interchanged.</td>
</tr>
<tr>
<td><code>swapaxes(axis1, axis2)</code></td>
<td>For each element in <code>self</code>, return a copy of the string with uppercase characters converted to lowercase.</td>
</tr>
<tr>
<td><code>swapcase()</code></td>
<td>Return an array formed from the elements of <code>a</code> at the given indices.</td>
</tr>
</tbody>
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**chararray.astype**(dtype, order='K', casting='unsafe', subok=True, copy=True)

Copy of the array, cast to a specified type.

**Parameters**

- **dtype**: str or dtype  
  Typecode or data-type to which the array is cast.

- **order**: {'C', 'F', 'A', 'K'}, optional  
  Controls the memory layout order of the result. ‘C’ means C order, ‘F’ means Fortran order, ‘A’ means ‘F’ order if all the arrays are Fortran contiguous, ‘C’ order otherwise, and ‘K’ means as close to the order the array elements appear in memory as possible. Default is ‘K’.

- **casting**: {'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional  
  Controls what kind of data casting may occur. Defaults to ‘unsafe’ for backwards compatibility.
  - ‘no’ means the data types should not be cast at all.
  - ‘equiv’ means only byte-order changes are allowed.
  - ‘safe’ means only casts which can preserve values are allowed.
  - ‘same_kind’ means only safe casts or casts within a kind, like float64 to float32, are allowed.
  - ‘unsafe’ means any data conversions may be done.

- **subok**: bool, optional  
  If True, then sub-classes will be passed-through (default), otherwise the returned array will be forced to be a base-class array.

- **copy**: bool, optional  
  By default, astype always returns a newly allocated array. If this is set to false, and the `dtype`, `order`, and `subok` requirements are satisfied, the input array is returned instead of a copy.

**Returns**

- **arr_t**: ndarray  
  Unless `copy` is False and the other conditions for returning the input array are satisfied (see description for `copy` input parameter), `arr_t` is a new array of the same shape as the input array, with dtype, order given by `dtype, order`.

**Raises**

- `ComplexWarning`
When casting from complex to float or int. To avoid this, one should use `a.real.astype(t)`.

**Notes**

Starting in NumPy 1.9, astype method now returns an error if the string dtype to cast to is not long enough in ‘safe’ casting mode to hold the max value of integer/float array that is being casted. Previously the casting was allowed even if the result was truncated.

**Examples**

```python
>>> x = np.array([1, 2, 2.5])
>>> x
array([ 1. , 2. , 2.5])

>>> x.astype(int)
array([1, 2, 2])
```

`chararray.copy(order='C')`

Return a copy of the array.

**Parameters**

- `order`: {'C', 'F', 'A', 'K'}, optional
  - Controls the memory layout of the copy. ‘C’ means C-order, ‘F’ means F-order, ‘A’ means ‘F’ if a is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of a as closely as possible. (Note that this function and :func:numpy.copy are very similar, but have different default values for their order= arguments.)

**See also:**

numpy.copy, numpy.copyto

**Examples**

```python
>>> x = np.array([[1,2,3],[4,5,6]], order='F')

>>> y = x.copy()

>>> x.fill(0)

>>> x
array([[0, 0, 0],
       [0, 0, 0]])

>>> y
array([[1, 2, 3],
       [4, 5, 6]])

>>> y.flags['C_CONTIGUOUS']
True
```

`chararray.count(sub, start=0, end=None)`

Returns an array with the number of non-overlapping occurrences of substring `sub` in the range `start, end`.

**See also:**

char.count

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chararray.decode(encoding=None, errors=None)
    Calls str.decode element-wise.

    See also:
    char.decode

chararray.dump(file)
    Dump a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

    Parameters
    file : str
        A string naming the dump file.

chararray.dumps()
    Returns the pickle of the array as a string. pickle.loads or numpy.loads will convert the string back to an array.

    Parameters
    None

chararray.encode(encoding=None, errors=None)
    Calls str.encode element-wise.

    See also:
    char.encode

chararray.endswith(suffix, start=0, end=None)
    Returns a boolean array which is True where the string element in self ends with suffix, otherwise False.

    See also:
    char.endswith

chararray.expandtabs(tabsize=8)
    Return a copy of each string element where all tab characters are replaced by one or more spaces.

    See also:
    char.expandtabs

chararray.fill(value)
    Fill the array with a scalar value.

    Parameters
    value : scalar
        All elements of a will be assigned this value.

Examples
>>> a = np.array([1, 2])
>>> a.fill(0)
>>> a
array([0, 0])
>>> a = np.empty(2)
>>> a.fill(1)
>>> a
array([ 1., 1.])

chararray.find(sub, start=0, end=None)
    For each element, return the lowest index in the string where substring sub is found.
See also:

char.find

chararray.\texttt{flatten}(order='C')

Return a copy of the array collapsed into one dimension.

**Parameters**

order : {'C', 'F', 'A'}, optional

Whether to flatten in C (row-major), Fortran (column-major) order, or preserve the C/Fortran ordering from \texttt{a}. The default is ‘C’.

**Returns**

y : ndarray

A copy of the input array, flattened to one dimension.

See also:

\texttt{ravel}

Return a flattened array.

\texttt{flat}

A 1-D flat iterator over the array.

**Examples**

```python
>>> a = np.array([[1,2], [3,4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])
```

chararray.\texttt{getfield}(\texttt{dtype}, \texttt{offset}=0)

Returns a field of the given array as a certain type.

A field is a view of the array data with a given data-type. The values in the view are determined by the given type and the offset into the current array in bytes. The offset needs to be such that the view dtype fits in the array dtype; for example an array of dtype complex128 has 16-byte elements. If taking a view with a 32-bit integer (4 bytes), the offset needs to be between 0 and 12 bytes.

**Parameters**

dtype : str or dtype

The data type of the view. The dtype size of the view can not be larger than that of the array itself.

offset : int

Number of bytes to skip before beginning the element view.

**Examples**

```python
>>> x = np.diag([1.+1.j]*2)
>>> x[1, 1] = 2 + 4.j
>>> x
array([[ 1.+1.j, 0.+0.j],
       [ 0.+0.j, 2.+4.j]])
>>> x.getfield(np.float64)
array([[ 1., 0.],
       [ 0., 2.]])
```
By choosing an offset of 8 bytes we can select the complex part of the array for our view:

```python
>>> x.getfield(np.float64, offset=8)
array([[ 1.,  0.],
       [ 0.,  4.]])
```

`chararray.index(sub, start=0, end=None)`
Like `find`, but raises `ValueError` when the substring is not found.

**See also:**
- `char.index`

`chararray.isalnum()`
Returns true for each element if all characters in the string are alphanumeric and there is at least one character, false otherwise.

**See also:**
- `char.isalnum`

`chararray.isalpha()`
Returns true for each element if all characters in the string are alphabetic and there is at least one character, false otherwise.

**See also:**
- `char.isalpha`

`chararray.isdecimal()`
For each element in `self`, return True if there are only decimal characters in the element.

**See also:**
- `char.isdecimal`

`chararray.isdigit()`
Returns true for each element if all characters in the string are digits and there is at least one character, false otherwise.

**See also:**
- `char.isdigit`

`chararray.islower()`
Returns true for each element if all cased characters in the string are lowercase and there is at least one cased character, false otherwise.

**See also:**
- `char.islower`

`chararray.isnumeric()`
For each element in `self`, return True if there are only numeric characters in the element.

**See also:**
- `char.isnumeric`

`chararray.isspace()`
Returns true for each element if there are only whitespace characters in the string and there is at least one character, false otherwise.

**See also:**
- `char.isspace`
chararray.\texttt{istitle}()

Returns true for each element if the element is a titlecased string and there is at least one character, false otherwise.

\textbf{See also:}

char.\texttt{istitle}

chararray.\texttt{isupper}()

Returns true for each element if all cased characters in the string are uppercase and there is at least one character, false otherwise.

\textbf{See also:}

char.\texttt{isupper}

chararray.\texttt{item}(\*\texttt{args})

Copy an element of an array to a standard Python scalar and return it.

\textbf{Parameters}

\*\texttt{args} : Arguments (variable number and type)

- none: in this case, the method only works for arrays with one element ($a.\texttt{size} == 1$), which element is copied into a standard Python scalar object and returned.

- int\_type: this argument is interpreted as a flat index into the array, specifying which element to copy and return.

- tuple of int\_types: functions as does a single int\_type argument, except that the argument is interpreted as an nd-index into the array.

\textbf{Returns}

\texttt{z} : Standard Python scalar object

A copy of the specified element of the array as a suitable Python scalar

\textbf{Notes}

When the data type of $a$ is longdouble or clongdouble, \texttt{item()} returns a scalar array object because there is no available Python scalar that would not lose information. Void arrays return a buffer object for \texttt{item()}, unless fields are defined, in which case a tuple is returned.

\texttt{item} is very similar to $a[\texttt{args}]$, except, instead of an array scalar, a standard Python scalar is returned. This can be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using Python’s optimized math.

\textbf{Examples}

```python
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[3, 1, 7],
       [2, 8, 3],
       [8, 5, 3]])
>>> x.item(3)
2
>>> x.item(7)
5
>>> x.item((0, 1))
1
>>> x.item((2, 2))
3
```
chararray.join(seq)
Return a string which is the concatenation of the strings in the sequence seq.

See also:
char.join

chararray.ljust(width, fillchar=’ ’)
Return an array with the elements of self left-justified in a string of length width.

See also:
char.ljust

chararray.lower()
Return an array with the elements of self converted to lowercase.

See also:
char.lower

chararray.lstrip(chars=None)
For each element in self, return a copy with the leading characters removed.

See also:
char.lstrip

chararray.nonzero()
Return the indices of the elements that are non-zero.
Refer to numpy.nonzero for full documentation.

See also:

numpy.nonzero
equivalent function

chararray.put(indices, values, mode=’raise’)
Set a.flat[n] = values[n] for all n in indices.
Refer to numpy.put for full documentation.

See also:

numpy.put
equivalent function

chararray.ravel([order])
Return a flattened array.
Refer to numpy.ravel for full documentation.

See also:

numpy.ravel
equivalent function

ndarray.flat
a flat iterator on the array.
chararray.repeat(repeats, axis=None)
Repeat elements of an array.
Refer to numpy.repeat for full documentation.
See also:

numpy.repeat
   equivalent function

chararray.replace(old, new, count=None)
For each element in self, return a copy of the string with all occurrences of substring old replaced by new.
See also:

char.replace

chararray.reshape(shape, order='C')
Returns an array containing the same data with a new shape.
Refer to numpy.reshape for full documentation.
See also:

numpy.reshape
   equivalent function

chararray.resize(new_shape, refcheck=True)
Change shape and size of array in-place.

Parameters
   new_shape : tuple of ints, or n ints
      Shape of resized array.
   refcheck : bool, optional
      If False, reference count will not be checked. Default is True.

Returns
   None

Raises
   ValueError
      If a does not own its own data or references or views to it exist, and the data memory must be changed.

   SystemError
      If the order keyword argument is specified. This behaviour is a bug in NumPy.

See also:

resize
   Return a new array with the specified shape.

Notes
This reallocates space for the data area if necessary.
Only contiguous arrays (data elements consecutive in memory) can be resized.
The purpose of the reference count check is to make sure you do not use this array as a buffer for another Python object and then reallocate the memory. However, reference counts can increase in other ways so if you are sure that you have not shared the memory for this array with another Python object, then you may safely set refcheck to False.

Examples

Shrinking an array: array is flattened (in the order that the data are stored in memory), resized, and re-shaped:

```python
>>> a = np.array([[0, 1], [2, 3]], order='C')
>>> a.resize((2, 1))
array([[0],
       [1]])

>>> a = np.array([[0, 1], [2, 3]], order='F')
>>> a.resize((2, 1))
array([[0],
       [2]])
```

Enlarging an array: as above, but missing entries are filled with zeros:

```python
>>> b = np.array([[0, 1], [2, 3]])
>>> b.resize(2, 3) # new_shape parameter doesn’t have to be a tuple
array([[0, 1, 2],
       [3, 0, 0]])
```

Referencing an array prevents resizing...

```python
>>> c = a
>>> a.resize((1, 1))
Traceback (most recent call last):
  ... ValueError: cannot resize an array that has been referenced ...
Traceback (most recent call last):
  ... ValueError: cannot resize an array that has been referenced ...
```

Unless refcheck is False:

```python
>>> a.resize((1, 1), refcheck=False)
>>> a
array([[0]])
>>> c
array([[0]])
```

**chararray.rfind**(sub, start=0, end=None)

For each element in self, return the highest index in the string where substring sub is found, such that sub is contained within [start, end].

**See also:**

char.rfind

chararray.rindex**(sub, start=0, end=None)**

Like rfind, but raises ValueError when the substring sub is not found.

**See also:**
chararray.rindex

chararray.rjust(width, fillchar=' ')
Return an array with the elements of self right-justified in a string of length width.

See also:
char.rjust

chararray.rsplit(sep=None, maxsplit=None)
For each element in self, return a list of the words in the string, using sep as the delimiter string.

See also:
char.rsplit

chararray.rstrip(chars=None)
For each element in self, return a copy with the trailing characters removed.

See also:
char.rstrip

chararray.searchsorted(v, side='left', sorter=None)
Find indices where elements of v should be inserted in a to maintain order.
For full documentation, see numpy.searchsorted

See also:

numpy.searchsorted

equivalent function

chararray.setfield(val, dtype, offset=0)
Put a value into a specified place in a field defined by a data-type.
Place val into a’s field defined by dtype and beginning offset bytes into the field.

Parameters
val : object
Value to be placed in field.
dtype : dtype object
Data-type of the field in which to place val.
offset : int, optional
The number of bytes into the field at which to place val.

Returns
None

See also:
getfield

Examples
>>> x = np.eye(3)
>>> x.getfield(np.float64)
array([[ 1., 0., 0.],
       [ 0., 1., 0.],
       [ 0., 0., 1.]])
>>> x.setfield(3, np.int32)
```python
>>> x.getfield(np.int32)
array([[3, 3, 3],
       [3, 3, 3],
       [3, 3, 3]])
>>> x
array([[ 1.00000000e+000, 1.48219694e-323, 1.48219694e-323],
       [ 1.48219694e-323, 1.00000000e+000, 1.48219694e-323],
       [ 1.48219694e-323, 1.48219694e-323, 1.00000000e+000]])
>>> x.setfield(np.eye(3), np.int32)
>>> x
array([[ 1., 0., 0.],
       [ 0., 1., 0.],
       [ 0., 0., 1.]])
```

`chararray.setflags(write=None, align=None, uic=None)`

Set array flags WRITEABLE, ALIGNED, and UPDATEIFCOPY, respectively.

These Boolean-valued flags affect how numpy interprets the memory area used by a (see Notes below). The ALIGNED flag can only be set to True if the data is actually aligned according to the type. The UPDATEIFCOPY flag can never be set to True. The flag WRITEABLE can only be set to True if the array owns its own memory, or the ultimate owner of the memory exposes a writeable buffer interface, or is a string. (The exception for string is made so that unpickling can be done without copying memory.)

**Parameters**

- `write`: bool, optional
  Describes whether or not a can be written to.

- `align`: bool, optional
  Describes whether or not a is aligned properly for its type.

- `uic`: bool, optional
  Describes whether or not a is a copy of another “base” array.

**Notes**

Array flags provide information about how the memory area used for the array is to be interpreted. There are 6 Boolean flags in use, only three of which can be changed by the user: UPDATEIFCOPY, WRITEABLE, and ALIGNED.

WRITEABLE (W) the data area can be written to;

ALIGNED (A) the data and strides are aligned appropriately for the hardware (as determined by the compiler);

UPDATEIFCOPY (U) this array is a copy of some other array (referenced by .base). When this array is deallocated, the base array will be updated with the contents of this array.

All flags can be accessed using their first (upper case) letter as well as the full name.

**Examples**

```python
>>> y
array([[3, 1, 7],
       [2, 0, 0],
       [8, 5, 9]])
>>> y.flags
C_CONTIGUOUS : True
F_CONTIGUOUS : False
OWNDATA : True
```
chararray.sort (axis=-1, kind='quicksort', order=None)
Sort an array, in-place.

Parameters
axis : int, optional
   Axis along which to sort. Default is -1, which means sort along the last axis.
kind : {'quicksort', 'mergesort', 'heapsort'}, optional
   Sorting algorithm. Default is 'quicksort'.
order : list, optional
   When a is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

See also:

numpy.sort
   Return a sorted copy of an array.

argsort
   Indirect sort.

 lexsort
   Indirect stable sort on multiple keys.
searchsorted
   Find elements in sorted array.

Notes
See sort for notes on the different sorting algorithms.

Examples
   >>> a = np.array([[1, 4], [3, 1]])
   >>> a.sort(axis=1)
   >>> a
array([[1, 4],
       [1, 3]])

```python
>>> a.sort(axis=0)
>>> a
array([[1, 3],
       [1, 4]])
```

Use the `order` keyword to specify a field to use when sorting a structured array:

```python
>>> a = np.array([('a', 2), ('c', 1)], dtype=[('x', 'S1'), ('y', int)])
>>> a.sort(order='y')
>>> a
array([('c', 1), ('a', 2)],
      dtype=[('x', '|S1'), ('y', '<i4')])
```

**chararray.split** *(sep=None, maxsplit=None)*

For each element in `self`, return a list of the words in the string, using `sep` as the delimiter string.

*See also:*

char.split

**chararray.splitlines** *(keepends=None)*

For each element in `self`, return a list of the lines in the element, breaking at line boundaries.

*See also:*

char.splitlines

**chararray.squeeze** *(axis=None)*

Remove single-dimensional entries from the shape of `a`.

Refer to `numpy.squeeze` for full documentation.

*See also:*

numpy.squeeze equivalent function

**chararray.startswith** *(prefix, start=0, end=None)*

Returns a boolean array which is `True` where the string element in `self` starts with `prefix`, otherwise `False`.

*See also:*

char.startswith

**chararray.strip** *(chars=None)*

For each element in `self`, return a copy with the leading and trailing characters removed.

*See also:*

char.strip

**chararray.swapaxes** *(axis1, axis2)*

Return a view of the array with `axis1` and `axis2` interchanged.

Refer to `numpy.swapaxes` for full documentation.

*See also:*

numpy.swapaxes equivalent function
chararray\texttt{.swapcase}()

For each element in \texttt{self}, return a copy of the string with uppercase characters converted to lowercase and vice versa.

\textbf{See also:}

char.swapcase

carray\texttt{.take}(\texttt{indices, axis=None, out=None, mode='raise'})

Return an array formed from the elements of \texttt{a} at the given indices.

Refer to \texttt{numpy.take} for full documentation.

\textbf{See also:}

\texttt{numpy.take}

equivalent function

carray\texttt{.title}()

For each element in \texttt{self}, return a titlecased version of the string: words start with uppercase characters, all remaining cased characters are lowercase.

\textbf{See also:}

char.title

carray\texttt{.tofile}(\texttt{fid, sep='', format='%s'})

Write array to a file as text or binary (default).

Data is always written in ‘C’ order, independent of the order of \texttt{a}. The data produced by this method can be recovered using the function \texttt{fromfile()}.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{fid} : file or str
    An open file object, or a string containing a filename.
  \item \texttt{sep} : str
    Separator between array items for text output. If “” (empty), a binary file is written, equivalent to \texttt{file.write(a.tobytes())}.
  \item \texttt{format} : str
    Format string for text file output. Each entry in the array is formatted to text by first converting it to the closest Python type, and then using “format” % item.
\end{itemize}

\textbf{Notes}

This is a convenience function for quick storage of array data. Information on endianness and precision is lost, so this method is not a good choice for files intended to archive data or transport data between machines with different endianness. Some of these problems can be overcome by outputting the data as text files, at the expense of speed and file size.

carray\texttt{.tolist}()

Return the array as a (possibly nested) list.

Return a copy of the array data as a (nested) Python list. Data items are converted to the nearest compatible Python type.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{none}
\end{itemize}
Returns

y : list

The possibly nested list of array elements.

Notes

The array may be recreated, \( a = \text{np.array}(a\text{.tolist}()) \).

Examples

```python
>>> a = np.array([1, 2])
>>> a.tolist()
[1, 2]
>>> a = np.array([[1, 2], [3, 4]])
>>> list(a)
[array([1, 2]), array([3, 4])]
>>> a.tolist()
[[1, 2], [3, 4]]
```

chararray.

```
tostring(order='C')
```

Construct Python bytes containing the raw data bytes in the array.

Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object can be produced in either ‘C’ or ‘Fortran’, or ‘Any’ order (the default is ‘C’-order). ‘Any’ order means C-order unless the F_CONTIGUOUS flag in the array is set, in which case it means ‘Fortran’ order.

This function is a compatibility alias for tobytes. Despite its name it returns bytes not strings.

Parameters

order : {‘C’, ‘F’, None}, optional

Order of the data for multidimensional arrays: C, Fortran, or the same as for the original array.

Returns

s : bytes

Python bytes exhibiting a copy of \( a \)'s raw data.

Examples

```python
>>> x = np.array([[0, 1], [2, 3]])
>>> x.tobytes()
\x00\x01\x02\x03\x04\x05\x06\x07\x08\x09\x0a\x0b\x0c\x0d\x0e\x0f\x10\x11\x12\x13\x14\x15\x16\x17\x18\x19\x1a\x1b\x1c\x1d\x1e\x1f\x20\x21\x22\x23\x24\x25\x26\x27\x28\x29\x2a\x2b\x2c\x2d\x2e\x2f\x30\x31\x32\x33\x34\x35\x36\x37\x38\x39\x3a\x3b\x3c\x3d\x3e\x3f\x40\x41\x42\x43\x44\x45\x46\x47\x48\x49\x4a\x4b\x4c\x4d\x4e\x4f\x50\x51\x52\x53\x54\x55\x56\x57\x58\x59\x5a\x5b\x5c\x5d\x5e\x5f\x60\x61\x62\x63\x64\x65\x66\x67\x68\x69\x6a\x6b\x6c\x6d\x6e\x6f\x70\x71\x72\x73\x74\x75\x76\x77\x78\x79\x7a\x7b\x7c\x7d\x7e\x7f
>>> x.tobytes('C') == x.tobytes()
True
>>> x.tobytes('F')
\x00\x01\x02\x03\x04\x05\x06\x07\x08\x09\x0a\x0b\x0c\x0d\x0e\x0f\x10\x11\x12\x13\x14\x15\x16\x17\x18\x19\x1a\x1b\x1c\x1d\x1e\x1f\x20\x21\x22\x23\x24\x25\x26\x27\x28\x29\x2a\x2b\x2c\x2d\x2e\x2f\x30\x31\x32\x33\x34\x35\x36\x37\x38\x39\x3a\x3b\x3c\x3d\x3e\x3f\x40\x41\x42\x43\x44\x45\x46\x47\x48\x49\x4a\x4b\x4c\x4d\x4e\x4f\x50\x51\x52\x53\x54\x55\x56\x57\x58\x59\x5a\x5b\x5c\x5d\x5e\x5f\x60\x61\x62\x63\x64\x65\x66\x67\x68\x69\x6a\x6b\x6c\x6d\x6e\x6f\x70\x71\x72\x73\x74\x75\x76\x77\x78\x79\x7a\x7b\x7c\x7d\x7e\x7f
```

chararray.

```
translate(table, deletechars=None)
```

For each element in self, return a copy of the string where all characters occurring in the optional argument deletechars are removed, and the remaining characters have been mapped through the given translation table.

See also:

char.translate

```
transpose(*axes)
```

Returns a view of the array with axes transposed.
For a 1-D array, this has no effect. (To change between column and row vectors, first cast the 1-D array into a matrix object.) For a 2-D array, this is the usual matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided and 
\[ \text{a.shape} = (i[0], i[1], \ldots, i[n-2], i[n-1]) \], then 
\[ \text{a.transpose().shape} = (i[n-1], i[n-2], \ldots, i[1], i[0]) \].

**Parameters**

- `axes`: None, tuple of ints, or \( n \) ints
  - None or no argument: reverses the order of the axes.
  - tuple of ints: \( i \) in the \( j \)-th place in the tuple means \( a \)'s \( i \)-th axis becomes \( a.transpose() \)'s \( j \)-th axis.
  - \( n \) ints: same as an \( n \)-tuple of the same ints (this form is intended simply as a “convenience” alternative to the tuple form)

**Returns**

- `out`: ndarray

View of \( a \), with axes suitably permuted.

**See also:**

- `ndarray.T`

Array property returning the array transposed.

**Examples**

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])
```

**chararray.upper()**

Return an array with the elements of \( self \) converted to uppercase.

**See also:**

- `char.upper`

**chararray.view**( \( dtype=None \), \( type=None \))

New view of array with the same data.

**Parameters**

- `dtype`: data-type or ndarray sub-class, optional
  
  Data-type descriptor of the returned view, e.g., float32 or int16. The default, None, results in the view having the same data-type as \( a \). This argument can also be specified as an ndarray sub-class, which then specifies the type of the returned object (this is equivalent to setting the \( type \) parameter).

- `type`: Python type, optional
Type of the returned view, e.g., ndarray or matrix. Again, the default None results in type preservation.

**Notes**

`a.view()` is used two different ways:

- `a.view(some_dtype)` or `a.view(dtype=some_dtype)` constructs a view of the array’s memory with a different data-type. This can cause a reinterpretation of the bytes of memory.
- `a.view(ndarray_subclass)` or `a.view(type=ndarray_subclass)` just returns an instance of `ndarray_subclass` that looks at the same array (same shape, dtype, etc.) This does not cause a reinterpretation of the memory.

For `a.view(some_dtype)`, if `some_dtype` has a different number of bytes per entry than the previous dtype (for example, converting a regular array to a structured array), then the behavior of the view cannot be predicted just from the superficial appearance of `a` (shown by `print(a)`). It also depends on exactly how `a` is stored in memory. Therefore if `a` is C-ordered versus fortran-ordered, versus defined as a slice or transpose, etc., the view may give different results.

**Examples**

```python
>>> x = np.array([(1, 2), (3, 4)], dtype=[('a', np.int8), ('b', np.int8)])
```

Viewing array data using a different type and dtype:

```python
>>> y = x.view(dtype=np.int16, type=np.matrix)
>>> y
matrix([[513]], dtype=int16)
>>> print type(y)
<class 'numpy.matrixlib.defmatrix.matrix'>
```

Creating a view on a structured array so it can be used in calculations

```python
>>> x = np.array([(1, 2), (3, 4)], dtype=[('a', np.int8), ('b', np.int8)])
>>> xv = x.view(dtype=np.int8).reshape(-1,2)
>>> xv
array([[1, 2],
       [3, 4]], dtype=int8)
>>> xv.mean(0)
array([ 2., 3.])
```

Making changes to the view changes the underlying array

```python
>>> xv[0,1] = 20
>>> print x
[(1, 20) (3, 4)]
```

Using a view to convert an array to a record array:

```python
>>> z = x.view(np.recarray)
>>> z.a
array([1], dtype=int8)
```

Views share data:

```python
>>> x[0] = (9, 10)
>>> z[0]
(9, 10)
```
Views that change the dtype size (bytes per entry) should normally be avoided on arrays defined by slices, transposes, fortran-ordering, etc.:

```python
>>> x = np.array([[1, 2, 3], [4, 5, 6]], dtype=np.int16)
>>> y = x[:, 0:2]
>>> y
array([[1, 2],
        [4, 5]], dtype=int16)
```
```
>>> y.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: new type not compatible with array.
```
```
>>> z = y.copy()
>>> z.view(dtype=[('width', np.int16), ('length', np.int16)])
array([[(1, 2),
        (4, 5)]]), dtype=[('width', '<i2'), ('length', '<i2')])
```
```
chararray.zfill(width)

Return the numeric string left-filled with zeros in a string of length width.

See also:

char.zfill

3.5 C-Types Foreign Function Interface (numpy.ctypeslib)

`numpy.ctypeslib.as_array(obj, shape=None)`

Create a numpy array from a ctypes array or a ctypes POINTER. The numpy array shares the memory with the ctypes object.

The size parameter must be given if converting from a ctypes POINTER. The size parameter is ignored if converting from a ctypes array

`numpy.ctypeslib.as_ctypes(obj)`

Create and return a ctypes object from a numpy array. Actually anything that exposes the __array_interface__ is accepted.

`numpy.ctypeslib.ctypes_load_library(*args, **kwds)`

deprecated, use `load_library` instead!

`numpy.ctypeslib.load_library(libname, loader_path)`

`numpy.ctypeslib.ndpointer(dtype=None, ndim=None, shape=None, flags=None)`

Array-checking restype/argtypes.

An ndpointer instance is used to describe an ndarray in restypes and argtypes specifications. This approach is more flexible than using, for example, `POINTER(c_double)`, since several restrictions can be specified, which are verified upon calling the ctypes function. These include data type, number of dimensions, shape and flags. If a given array does not satisfy the specified restrictions, a `TypeError` is raised.

Parameters

- `dtype`: data-type, optional
  Array data-type.
**ndim**: int, optional
Number of array dimensions.

**shape**: tuple of ints, optional
Array shape.

**flags**: str or tuple of str
Array flags; may be one or more of:
- C_CONTIGUOUS / C / CONTIGUOUS
- F_CONTIGUOUS / F / FORTRAN
- OWNDATA / O
- WRITEABLE / W
- ALIGNED / A
- UPDATEIFCOPY / U

**Returns**

**klass**: ndpointer type object
A type object, which is an \_ndtp\_r instance containing dtype, ndim, shape and flags information.

**Raises**

**TypeError**
If a given array does not satisfy the specified restrictions.

**Examples**

```python
>>> clib.somefunc.argtypes = [np.ctypeslib.ndpointer(dtype=np.float64,
... ndim=1,
... flags='C_CONTIGUOUS')]
... >>> clib.somefunc(np.array([1, 2, 3], dtype=np.float64))
...```

### 3.6 Datetime Support Functions

#### 3.6.1 Business Day Functions

- **busdaycalendar**
  A business day calendar object that efficiently stores information defining valid days for the busday family of functions.

- **is_busday**
  Calculates which of the given dates are valid days, and which are not.

- **busday_offset**
  First adjusts the date to fall on a valid day according to the roll rule, then applies offsets to the given dates counted in valid days.

- **busday_count**
  Counts the number of valid days between begindates and enddates, not including the enddate.

**class** **numpy.busdaycalendar**
A business day calendar object that efficiently stores information defining valid days for the busday family of functions.

The default valid days are Monday through Friday (“business days”). A busdaycalendar object can be specified with any set of weekly valid days, plus an optional “holiday” dates that always will be invalid.
Once a busdaycalendar object is created, the weekmask and holidays cannot be modified.

New in version 1.7.0.

Parameters

- **weekmask**: str or array_like of bool, optional
  
  A seven-element array indicating which of Monday through Sunday are valid days. May be specified as a length-seven list or array, like [1,1,1,1,0,0,0]; a length-seven string, like ‘111100’; or a string like “Mon Tue Wed Thu Fri”, made up of 3-character abbreviations for weekdays, optionally separated by white space. Valid abbreviations are: Mon Tue Wed Thu Fri Sat Sun

- **holidays**: array_like of datetime64[D], optional
  
  An array of dates to consider as invalid dates, no matter which weekday they fall upon. Holiday dates may be specified in any order, and NaT (not-a-time) dates are ignored. This list is saved in a normalized form that is suited for fast calculations of valid days.

Returns

- **out**: busdaycalendar
  
  A business day calendar object containing the specified weekmask and holidays values.

See also:

- **is_busday**: Returns a boolean array indicating valid days.
- **busday_offset**: Applies an offset counted in valid days.
- **busday_count**: Counts how many valid days are in a half-open date range.

Examples

```python
>>> # Some important days in July
... bdd = np.busdaycalendar(
...     holidays=['2011-07-01', '2011-07-04', '2011-07-17'])
>>> # Default is Monday to Friday weekdays
... bdd.weekmask
array([ True, True, True, True, True, False, False], dtype='bool')
>>> # Any holidays already on the weekend are removed
... bdd.holidays
array(['2011-07-01', '2011-07-04'], dtype='datetime64[D]')
```

Attributes

- **weekmask**: A copy of the seven-element boolean mask indicating valid days.
- **holidays**: A copy of the holiday array indicating additional invalid days.

---

Note: once a busdaycalendar object is created, you cannot modify the weekmask or holidays. The attributes return copies of internal data.
**numpy.is_busday** (dates, weekmask='1111100', holidays=None, busdaycal=None, out=None)

Calculates which of the given dates are valid days, and which are not.

New in version 1.7.0.

**Parameters**

- **dates** : array_like of datetime64[D]
  The array of dates to process.

- **weekmask** : str or array_like of bool, optional
  A seven-element array indicating which of Monday through Sunday are valid days. May be specified as a length-seven list or array, like [1,1,1,1,0,0]; a length-seven string, like ‘1111100’; or a string like “Mon Tue Wed Thu Fri”, made up of 3-character abbreviations for weekdays, optionally separated by white space. Valid abbreviations are: Mon Tue Wed Thu Fri Sat Sun

- **holidays** : array_like of datetime64[D], optional
  An array of dates to consider as invalid dates. They may be specified in any order, and NaT (not-a-time) dates are ignored. This list is saved in a normalized form that is suited for fast calculations of valid days.

- **busdaycal** : busdaycalendar, optional
  A busdaycalendar object which specifies the valid days. If this parameter is provided, neither weekmask nor holidays may be provided.

- **out** : array of bool, optional
  If provided, this array is filled with the result.

**Returns**

- **out** : array of bool
  An array with the same shape as dates, containing True for each valid day, and False for each invalid day.

**See also:**

- **busdaycalendar**
  An object that specifies a custom set of valid days.

- **busday_offset**
  Applies an offset counted in valid days.

- **busday_count**
  Counts how many valid days are in a half-open date range.

**Examples**

```python
>>> # The weekdays are Friday, Saturday, and Monday
... np.is_busday(['2011-07-01', '2011-07-02', '2011-07-18'],
...           holidays=['2011-07-01', '2011-07-04', '2011-07-17'])
array([[False, False,  True],
        dtype='bool'])
```

**numpy.busday_offset** (dates, offsets, roll='raise', weekmask='1111100', holidays=None, busdaycal=None, out=None)

First adjusts the date to fall on a valid day according to the roll rule, then applies offsets to the given dates counted in valid days.

New in version 1.7.0.
Parameters

dates : array_like of datetime64[D]
    The array of dates to process.

offsets : array_like of int
    The array of offsets, which is broadcast with dates.

roll : {'raise', 'nat', 'forward', 'following', 'backward', 'preceding', 'modifiedfollowing', 'modifiedpreceding'}, optional
    How to treat dates that do not fall on a valid day. The default is ‘raise’.
     • ‘raise’ means to raise an exception for an invalid day.
     • ‘nat’ means to return a NaT (not-a-time) for an invalid day.
     • ‘forward’ and ‘following’ mean to take the first valid day later in time.
     • ‘backward’ and ‘preceding’ mean to take the first valid day earlier in time.
     • ‘modifiedfollowing’ means to take the first valid day later in time unless it is across a Month boundary, in which case to take the first valid day earlier in time.
     • ‘modifiedpreceding’ means to take the first valid day earlier in time unless it is across a Month boundary, in which case to take the first valid day later in time.

weekmask : str or array_like of bool, optional
    A seven-element array indicating which of Monday through Sunday are valid days. May be specified as a length-seven list or array, like [1,1,1,1,1,0,0]; a length-seven string, like ‘1111100’; or a string like “Mon Tue Wed Thu Fri”, made up of 3-character abbreviations for weekdays, optionally separated by white space. Valid abbreviations are: Mon Tue Wed Thu Fri Sat Sun

holidays : array_like of datetime64[D], optional
    An array of dates to consider as invalid dates. They may be specified in any order, and NaT (not-a-time) dates are ignored. This list is saved in a normalized form that is suited for fast calculations of valid days.

busdaycal : busdaycalendar, optional
    A busdaycalendar object which specifies the valid days. If this parameter is provided, neither weekmask nor holidays may be provided.

out : array of datetime64[D], optional
    If provided, this array is filled with the result.

Returns

out : array of datetime64[D]
    An array with a shape from broadcasting dates and offsets together, containing the dates with offsets applied.

See also:

busdaycalendar
    An object that specifies a custom set of valid days.

is_busday
    Returns a boolean array indicating valid days.
**busday_count**

Counts how many valid days are in a half-open date range.

**Examples**

```python
>>> # First business day in October 2011 (not accounting for holidays)
... np.busday_offset('2011-10', 0, roll='forward')
numpy.datetime64('2011-10-03','D')
>>> # Last business day in February 2012 (not accounting for holidays)
... np.busday_offset('2012-02', -1, roll='forward')
numpy.datetime64('2012-02-29','D')
>>> # Third Wednesday in January 2011
... np.busday_offset('2011-01', 2, roll='forward', weekmask='Wed')
numpy.datetime64('2011-01-19','D')
>>> # 2012 Mother’s Day in Canada and the U.S.
... np.busday_offset('2012-05', 1, roll='forward', weekmask='Sun')
numpy.datetime64('2012-05-13','D')
>>> # First business day on or after a date
... np.busday_offset('2011-03-20', 0, roll='forward')
numpy.datetime64('2011-03-21','D')
>>> np.busday_offset('2011-03-22', 0, roll='forward')
numpy.datetime64('2011-03-22','D')
>>> # First business day after a date
... np.busday_offset('2011-03-20', 1, roll='backward')
numpy.datetime64('2011-03-21','D')
>>> np.busday_offset('2011-03-22', 1, roll='backward')
numpy.datetime64('2011-03-23','D')
```

```python
numpy.busday_count(begindates, enddates, weekmask='1111100', holidays=[], busdaycal=None, out=None)
```

Counts the number of valid days between `begindates` and `enddates`, not including the day of `enddates`. If `enddates` specifies a date value that is earlier than the corresponding `begindates` date value, the count will be negative.

New in version 1.7.0.

**Parameters**

- **begindates**: array_like of datetime64[D]
  The array of the first dates for counting.

- **enddates**: array_like of datetime64[D]
  The array of the end dates for counting, which are excluded from the count themselves.

- **weekmask**: str or array_like of bool, optional
  A seven-element array indicating which of Monday through Sunday are valid days. May be specified as a length-seven list or array, like [1,1,1,1,0,0,0]; a length-seven string, like ‘1111100’; or a string like “Mon Tue Wed Thu Fri”, made up of 3-character abbreviations for weekdays, optionally separated by white space. Valid abbreviations are: Mon Tue Wed Thu Fri Sat Sun

- **holidays**: array_like of datetime64[D], optional
  An array of dates to consider as invalid dates. They may be specified in any order, and NaT (not-a-time) dates are ignored. This list is saved in a normalized form that is suited for fast calculations of valid days.

- **busdaycal**: busdaycalendar, optional
A `busdaycalendar` object which specifies the valid days. If this parameter is provided, neither weekmask nor holidays may be provided.

**out**: array of int, optional

If provided, this array is filled with the result.

**Returns**

**out**: array of int

An array with a shape from broadcasting `begindates` and `enddates` together, containing the number of valid days between the begin and end dates.

**See also:**

- `busdaycalendar`:
  An object that specifies a custom set of valid days.

- `is_busday`:
  Returns a boolean array indicating valid days.

- `busday_offset`:
  Applies an offset counted in valid days.

**Examples**

```python
>>> # Number of weekdays in January 2011
... np.busday_count('2011-01', '2011-02')
21
>>> # Number of weekdays in 2011
... np.busday_count('2011', '2012')
260
>>> # Number of Saturdays in 2011
... np.busday_count('2011', '2012', weekmask='Sat')
53
```

### 3.7 Data type routines

- `numpy.can_cast(from, totype, casting = )`:
  Returns True if cast between data types can occur according to the casting rule.

- `numpy.promote_types(type1, type2)`:
  Returns the data type with the smallest size and smallest scalar kind to which both `type1` and `type2` can be cast.

- `numpy.min_scalar_type(a)`:
  For scalar `a`, returns the data type with the smallest size and smallest scalar kind which can hold its value.

- `numpy.result_type(*arrays_and_dtypes)`:
  Returns the type that results from applying the NumPy type promotion rules to the arguments.

- `numpy.common_type(*arrays)`:
  Return a scalar type which is common to the input arrays.

- `numpy.obj2sctype(rep[, default])`:
  Return the scalar dtype or NumPy equivalent of Python type of an object.

```
>>> np.can_cast(8, 'int32')
True
>>> np.promote_types('int32', 'float64')
'float64'
>>> np.min_scalar_type(7.5)
'float32'
>>> np.result_type([1, 2, 3], [4, 5, 6])
'int64'
>>> np.common_type([1, 2, 3], [4, 5, 6])
'int32'
>>> np.obj2sctype([1, 2, 3])
'int8'
```

**numpy.can_cast (from, totype, casting = ‘safe’)**

Returns True if cast between data types can occur according to the casting rule. If from is a scalar or array scalar, also returns True if the scalar value can be cast without overflow or truncation to an integer.

**Parameters**

- `from`: dtype, dtype specifier, scalar, or array
  Data type, scalar, or array to cast from.

- `totype`: dtype or dtype specifier
  Data type to cast to.
casting : {'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional

Controls what kind of data casting may occur.

- ‘no’ means the data types should not be cast at all.
- ‘equiv’ means only byte-order changes are allowed.
- ‘safe’ means only casts which can preserve values are allowed.
- ‘same_kind’ means only safe casts or casts within a kind, like float64 to float32, are allowed.
- ‘unsafe’ means any data conversions may be done.

Returns

out : bool

True if cast can occur according to the casting rule.

See also:

dtype, result_type

Notes

Starting in NumPy 1.9, can_cast function now returns False in ‘safe’ casting mode for integer/float dtype and string dtype if the string dtype length is not long enough to store the max integer/float value converted to a string. Previously can_cast in ‘safe’ mode returned True for integer/float dtype and a string dtype of any length.

Examples

Basic examples

>>> np.can_cast(np.int32, np.int64)
True
>>> np.can_cast(np.float64, np.complex)
True
>>> np.can_cast(np.complex, np.float)
False

>>> np.can_cast('i8', 'f8')
True
>>> np.can_cast('i8', 'f4')
False
>>> np.can_cast('i4', 's4')
False

Casting scalars

>>> np.can_cast(100, 'i1')
True
>>> np.can_cast(150, 'i1')
False
>>> np.can_cast(150, 'u1')
True

>>> np.can_cast(3.5e100, np.float32)
False
>>> np.can_cast(1000.0, np.float32)
True

Array scalar checks the value, array does not
Using the casting rules

>>> np.can_cast('i8', 'i8', 'no')
True

>>> np.can_cast('<i8', '>i8', 'no')
False

>>> np.can_cast('<i8', '>i8', 'equiv')
True

>>> np.can_cast('<i4', '>i8', 'equiv')
False

>>> np.can_cast('<i4', '>i8', 'safe')
True

>>> np.can_cast('<i4', '>i4', 'safe')
False

>>> np.can_cast('<i8', '>i4', 'same_kind')
True

>>> np.can_cast('<i8', '>u4', 'same_kind')
False

>>> np.can_cast('<i8', '>u4', 'unsafe')
True

```python
numpy.promote_types(type1, type2)
```

Returns the data type with the smallest size and smallest scalar kind to which both `type1` and `type2` may be safely cast. The returned data type is always in native byte order.

This function is symmetric and associative.

**Parameters**

- `type1` : dtype or dtype specifier
  
  First data type.

- `type2` : dtype or dtype specifier
  
  Second data type.

**Returns**

- `out` : dtype
  
  The promoted data type.

**See also:**

- `result_type`, `dtype`, `can_cast`

**Notes**

New in version 1.6.0.

Starting in NumPy 1.9, `promote_types` function now returns a valid string length when given an integer or float dtype as one argument and a string dtype as another argument. Previously it always returned the input string dtype, even if it wasn’t long enough to store the max integer/float value converted to a string.
Examples

```python
>>> np.promote_types('f4', 'f8')
dtype('float64')
```
```
>>> np.promote_types('i8', 'f4')
dtype('float64')
```
```
>>> np.promote_types('>i8', '<c8')
dtype('complex128')
```
```
>>> np.promote_types('i4', 'S8')
dtype('S11')
```

```python
numpy.min_scalar_type(a)
```
For scalar `a`, returns the data type with the smallest size and smallest scalar kind which can hold its value. For non-scalar array `a`, returns the vector's dtype unmodified.

Floating point values are not demoted to integers, and complex values are not demoted to floats.

**Parameters**

- `a`: scalar or array_like
  
The value whose minimal data type is to be found.

**Returns**

- `out`: dtype
  
The minimal data type.

**See also:**

result_type, promote_types, dtype, can_cast

**Notes**

New in version 1.6.0.

**Examples**

```python
>>> np.min_scalar_type(10)
dtype('uint8')
```
```
>>> np.min_scalar_type(-260)
dtype('int16')
```
```
>>> np.min_scalar_type(3.1)
dtype('float16')
```
```
>>> np.min_scalar_type(1e50)
dtype('float64')
```
```
>>> np.min_scalar_type(np.arange(4,dtype='f8'))
dtype('float64')
```

```python
numpy.result_type(*arrays_and_dtypes)
```
Returns the type that results from applying the NumPy type promotion rules to the arguments.

Type promotion in NumPy works similarly to the rules in languages like C++, with some slight differences. When both scalars and arrays are used, the array’s type takes precedence and the actual value of the scalar is taken into account.
For example, calculating 3*a, where a is an array of 32-bit floats, intuitively should result in a 32-bit float output. If the 3 is a 32-bit integer, the NumPy rules indicate it can’t convert losslessly into a 32-bit float, so a 64-bit float should be the result type. By examining the value of the constant, ‘3’, we see that it fits in an 8-bit integer, which can be cast losslessly into the 32-bit float.

**Parameters**

- `arrays_and_dtypes` : list of arrays and dtypes

  The operands of some operation whose result type is needed.

**Returns**

- `out` : dtype

  The result type.

**See also:**

dtype, promote_types, min_scalar_type, can_cast

**Notes**

New in version 1.6.0.

The specific algorithm used is as follows.

Categories are determined by first checking which of boolean, integer (int/uint), or floating point (float/complex) the maximum kind of all the arrays and the scalars are.

If there are only scalars or the maximum category of the scalars is higher than the maximum category of the arrays, the data types are combined with promote_types to produce the return value.

Otherwise, min_scalar_type is called on each array, and the resulting data types are all combined with promote_types to produce the return value.

The set of int values is not a subset of the uint values for types with the same number of bits, something not reflected in min_scalar_type, but handled as a special case in result_type.

**Examples**

```python
>>> np.result_type(3, np.arange(7, dtype='i1'))
dtype('int8')

>>> np.result_type('i4', 'c8')
dtype('complex128')

>>> np.result_type(3.0, -2)
dtype('float64')
```

numpy.common_type (*arrays*)

Return a scalar type which is common to the input arrays.

The return type will always be an inexact (i.e. floating point) scalar type, even if all the arrays are integer arrays.

If one of the inputs is an integer array, the minimum precision type that is returned is a 64-bit floating point dtype.

All input arrays can be safely cast to the returned dtype without loss of information.

**Parameters**

- `array1, array2, ...` : ndarrays

  Input arrays.

**Returns**

- `out` : data type code
Data type code.

See also:
dtype, mintypecode

Examples

```python
>>> np.common_type(np.arange(2, dtype=np.float32))
<type 'numpy.float32'>
>>> np.common_type(np.arange(2, dtype=np.float32), np.arange(2))
<type 'numpy.float64'>
>>> np.common_type(np.arange(4), np.array([45, 6.j]), np.array([45.0]))
<type 'numpy.complex128'>
```

numpy.obj2sctype (rep, default=None)

Return the scalar dtype or NumPy equivalent of Python type of an object.

Parameters

- **rep**: any
  - The object of which the type is returned.
- **default**: any, optional
  - If given, this is returned for objects whose types can not be determined. If not given, None is returned for those objects.

Returns

- **dtype**: dtype or Python type
  - The data type of `rep`.

See also:
sctype2char, issctype, issubsctype, issubdtype, maximum_sctype

Examples

```python
>>> np.obj2sctype(np.int32)
<type 'numpy.int32'>
>>> np.obj2sctype(np.array([1., 2.]))
<type 'numpy.float64'>
>>> np.obj2sctype(np.array([1.j]))
<type 'numpy.complex128'>
```

## 3.7.1 Creating data types

<table>
<thead>
<tr>
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<th>Description</th>
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<tr>
<td>dtype</td>
<td>Create a data type object.</td>
</tr>
<tr>
<td>format_parser</td>
<td>Class to convert formats, names, titles description to a dtype.</td>
</tr>
</tbody>
</table>
class numpy.dtype

Create a data type object.

A numpy array is homogeneous, and contains elements described by a dtype object. A dtype object can be constructed from different combinations of fundamental numeric types.

**Parameters**

obj

Object to be converted to a data type object.

align : bool, optional

Add padding to the fields to match what a C compiler would output for a similar C-struct. Can be True only if obj is a dictionary or a comma-separated string. If a struct dtype is being created, this also sets a sticky alignment flag isalignedstruct.

copy : bool, optional

Make a new copy of the data-type object. If False, the result may just be a reference to a built-in data-type object.

See also:

result_type

**Examples**

Using array-scalar type:

```python
>>> np.dtype(np.int16)
dtype('int16')
```

Record, one field name ‘f1’, containing int16:

```python
>>> np.dtype([('f1', np.int16)])
dtype([('f1', '<i2')])
```

Record, one field named ‘f1’, in itself containing a record with one field:

```python
>>> np.dtype([('f1', [('f1', np.int16)])])
dtype([('f1', [('f1', '<i2')])])
```

Record, two fields: the first field contains an unsigned int, the second an int32:

```python
>>> np.dtype([('f1', np.uint), ('f2', np.int32)])
dtype([('f1', '<u4'), ('f2', '<i4')])
```

Using array-protocol type strings:

```python
>>> np.dtype([('a', 'f8'),('b','S10')])
dtype([('a', '<f8'), ('b', '|S10')])
```

Using comma-separated field formats. The shape is (2,3):

```python
>>> np.dtype("i4, (2,3)f8")
dtype([('f0', '<i4'), ('f1', '<f8', (2, 3))])
```

Using tuples. int is a fixed type, 3 the field’s shape. void is a flexible type, here of size 10:

```python
>>> np.dtype([('hello', (np.int, 3)),('world',np.void,10)])
dtype([('hello', '<i4', 3), ('world', '|V10')])
```
Subdivide \texttt{int16} into 2 \texttt{int8}'s, called \texttt{x} and \texttt{y}. 0 and 1 are the offsets in bytes:

```python
>>> np.dtype((np.int16, {'x':(np.int8,0), 'y':(np.int8,1)}))
dtype('<i2', [('x', '|i1'), ('y', '|i1')])
```

Using dictionaries. Two fields named ‘gender’ and ‘age’:

```python
>>> np.dtype(({'names':['gender','age'], 'formats':['S1',np.uint8]})
dtype([('gender', '|S1'), ('age', '|u1')])
```

Offsets in bytes, here 0 and 25:

```python
>>> np.dtype(({'surname':('S25',0),'age':(np.uint8,25)})
dtype([('surname', '|S25'), ('age', '|u1')])
```

### Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \texttt{dtype.base} )</td>
<td>Array-interface compliant full description of the data-type.</td>
</tr>
<tr>
<td>( \texttt{dtype.descr} )</td>
<td>Dictionary of named fields defined for this data type, or None.</td>
</tr>
<tr>
<td>( \texttt{dtype.fields} )</td>
<td>Boolean indicating whether this dtype contains any reference-counted objects in any fields or sub-dtypes.</td>
</tr>
<tr>
<td>( \texttt{dtype.isalignedstruct} )</td>
<td>Boolean indicating whether the dtype is a struct which maintains field alignment.</td>
</tr>
<tr>
<td>( \texttt{dtype.isbuiltin} )</td>
<td>Integer indicating how this dtype relates to the built-in dtypes.</td>
</tr>
<tr>
<td>( \texttt{dtype.isnative} )</td>
<td>Boolean indicating whether the byte order of this dtype is native to the platform.</td>
</tr>
<tr>
<td>( \texttt{dtype.metadata} )</td>
<td>A bit-width name for this data-type.</td>
</tr>
<tr>
<td>( \texttt{dtype.names} )</td>
<td>Ordered list of field names, or None if there are no fields.</td>
</tr>
<tr>
<td>( \texttt{dtype.shape} )</td>
<td>Shape tuple of the sub-array if this data type describes a sub-array, and () otherwise.</td>
</tr>
<tr>
<td>( \texttt{dtype.str} )</td>
<td>The array-protocol typestring of this data-type object.</td>
</tr>
<tr>
<td>( \texttt{dtype.subdtype} )</td>
<td>Tuple ((\texttt{item_dtype}, \texttt{shape})) if this ( \texttt{dtype} ) describes a sub-array, and None otherwise.</td>
</tr>
</tbody>
</table>

\( \texttt{dtype\_base} \)

\( \texttt{dtext.descr} \)

Array-interface compliant full description of the data-type.

The format is that required by the ‘descr’ key in the \_\_array\_interface\_\_ attribute.

\( \texttt{dtytype\_fields} \)

Dictionary of named fields defined for this data type, or None.

The dictionary is indexed by keys that are the names of the fields. Each entry in the dictionary is a tuple fully describing the field:

\[(\texttt{dtype}, \texttt{offset}[[, \texttt{title}]]\]

If present, the optional title can be any object (if it is a string or unicode then it will also be a key in the fields dictionary, otherwise it’s meta-data). Notice also that the first two elements of the tuple can be passed directly as arguments to the \texttt{ndarray.getfield} and \texttt{ndarray.setfield} methods.

**See also:**

\texttt{ndarray.getfield}, \texttt{ndarray.setfield}

### Examples
```python
dt = np.dtype([('name', np.str_, 16), ('grades', np.float64, (2,))])

print dt.fields
{'grades': (dtype(('float64', (2,))), 16), 'name': (dtype('|S16'), 0)}
```

dtype.**hasobject**

Boolean indicating whether this dtype contains any reference-counted objects in any fields or sub-dtypes.

Recall that what is actually in the ndarray memory representing the Python object is the memory address of that object (a pointer). Special handling may be required, and this attribute is useful for distinguishing data types that may contain arbitrary Python objects and data-types that won’t.

dtype.**isalignedstruct**

Boolean indicating whether the dtype is a struct which maintains field alignment. This flag is sticky, so when combining multiple structs together, it is preserved and produces new dtypes which are also aligned.

dtype.**isbuiltin**

Integer indicating how this dtype relates to the built-in dtypes.

Read-only.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>if this is a structured array type, with fields</td>
</tr>
<tr>
<td>1</td>
<td>if this is a dtype compiled into numpy (such as ints, floats etc)</td>
</tr>
<tr>
<td>2</td>
<td>if the dtype is for a user-defined numpy type A user-defined type uses the numpy C-API machinery to extend numpy to handle a new array type. See <code>user.user-defined-data-types</code> in the Numpy manual.</td>
</tr>
</tbody>
</table>

**Examples**

```python
>>> dt = np.dtype('i2')
>>> dt.isbuiltin
1
>>> dt = np.dtype('f8')
>>> dt.isbuiltin
1
>>> dt = np.dtype([('field1', 'f8')])
>>> dt.isbuiltin
0
```

dtype.**isnative**

Boolean indicating whether the byte order of this dtype is native to the platform.

dtype.**metadata**

dtype.**name**

A bit-width name for this data-type.

Un-sized flexible data-type objects do not have this attribute.

dtype.**names**

Ordered list of field names, or None if there are no fields.

The names are ordered according to increasing byte offset. This can be used, for example, to walk through all of the named fields in offset order.

**Examples**

```python
>>> dt = np.dtype([('name', np.str_, 16), ('grades', np.float64, (2,))])
>>> dt.names
('name', 'grades')
```
**dtype**.shape
Shape tuple of the sub-array if this data type describes a sub-array, and () otherwise.

**dtype**.str
The array-protocol typestring of this data-type object.

**dtype**.subdtype
Tuple (item_dtype, shape) if this dtype describes a sub-array, and None otherwise.

The shape is the fixed shape of the sub-array described by this data type, and item_dtype the data type of the array.

If a field whose dtype object has this attribute is retrieved, then the extra dimensions implied by shape are tacked on to the end of the retrieved array.

**Methods**

 newbyteorder([new_order])  
Return a new dtype with a different byte order.

**dtype**.newbyteorder(new_order='S')
Return a new dtype with a different byte order.

Changes are also made in all fields and sub-arrays of the data type.

**Parameters**

 new_order : string, optional
Byte order to force; a value from the byte order specifications below. The default value ('S') results in swapping the current byte order. new_order codes can be any of:

* 'S' - swap dtype from current to opposite endian
* {'<', 'L'} - little endian
* {'>', 'B'} - big endian
* {'=', 'N'} - native order
* {'|', 'I'} - ignore (no change to byte order)

The code does a case-insensitive check on the first letter of new_order for these alternatives. For example, any of '>' or 'B' or 'b' or 'brian' are valid to specify big-endian.

**Returns**

 new_dtype : dtype
New dtype object with the given change to the byte order.

**Notes**
Changes are also made in all fields and sub-arrays of the data type.

**Examples**

```python
>>> import sys
>>> sys_is_le = sys.byteorder == 'little'
>>> native_code = sys_is_le and '<' or '>
>>> swapped_code = sys_is_le and '>' or '<
>>> native_dt = np.dtype(native_code+'i2')
>>> swapped_dt = np.dtype(swapped_code+'i2')
>>> native_dt.newbyteorder('S') == swapped_dt
True
>>> native_dt.newbyteorder() == swapped_dt
True
```
class numpy.format_parser(formats, names, titles, aligned=False, byteorder=None)

Class to convert formats, names, titles description to a dtype.

After constructing the format_parser object, the dtype attribute is the converted data-type: dtype = format_parser(formats, names, titles).dtype

Parameters

- formats : str or list of str
  
  The format description, either specified as a string with comma-separated format descriptions in the form 'f8, i4, a5', or a list of format description strings in the form ['f8', 'i4', 'a5'].

- names : str or list/tuple of str
  
  The field names, either specified as a comma-separated string in the form 'col1, col2, col3', or as a list or tuple of strings in the form ['col1', 'col2', 'col3']. An empty list can be used, in that case default field names ('f0', 'f1', ...) are used.

- titles : sequence
  
  Sequence of title strings. An empty list can be used to leave titles out.

- aligned : bool, optional
  
  If True, align the fields by padding as the C-compiler would. Default is False.

- byteorder : str, optional
  
  If specified, all the fields will be changed to the provided byte-order. Otherwise, the default byte-order is used. For all available string specifiers, see dtype.newbyteorder.

See also:

dtype, typename, sctype2char

Examples

>>> np.format_parser([['f8', 'i4', 'a5'], ['col1', 'col2', 'col3'], ...
                     ['T1', 'T2', 'T3']].dtype
dtype([('T1', 'col1'), '<f8'), ('T2', 'col2'), '<i4')],
       ('T3', 'col3'), '|S5')])

names and/or titles can be empty lists. If titles is an empty list, titles will simply not appear. If names is empty, default field names will be used.

```python
>>> np.format_parser(['f8', 'i4', 'a5'], ['col1', 'col2', 'col3'],
                   []).dtype
dtype([('col1', '<f8'), ('col2', '<i4'), ('col3', '|S5')])
```  

```python
>>> np.format_parser(['f8', 'i4', 'a5'], [], []).dtype
dtype([('f0', '<f8'), ('f1', '<i4'), ('f2', '|S5')])
```  

### Attributes

| dtype | (dtype) The converted data-type. |

#### 3.7.2 Data type information

<table>
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<th>Machine limits for floating point types.</th>
</tr>
</thead>
<tbody>
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<td>iinfo(type)</td>
<td>Machine limits for integer types.</td>
</tr>
<tr>
<td>MachAr(float_conv, int_conv, ...)</td>
<td>Diagnosing machine parameters.</td>
</tr>
</tbody>
</table>

**class numpy.finfo**

Machine limits for floating point types.

**Parameters**

- dtype : float, dtype, or instance

  Kind of floating point data-type about which to get information.

**See also:**

- MachAr

  The implementation of the tests that produce this information.

- iinfo

  The equivalent for integer data types.

**Notes**

For developers of NumPy: do not instantiate this at the module level. The initial calculation of these parameters is expensive and negatively impacts import times. These objects are cached, so calling finfo() repeatedly inside your functions is not a problem.
Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>eps</td>
<td>(float) The smallest representable positive number such that 1.0 + eps != 1.0. Type of eps is an appropriate floating point type.</td>
</tr>
<tr>
<td>epsneg</td>
<td>(float) The smallest representable positive number such that 1.0 - epsneg != 1.0.</td>
</tr>
<tr>
<td>iexp</td>
<td>(int) The number of bits in the exponent portion of the floating point representation.</td>
</tr>
<tr>
<td>machar</td>
<td>(MachAr) The object which calculated these parameters and holds more detailed information.</td>
</tr>
<tr>
<td>machep</td>
<td>(float) The largest representable number.</td>
</tr>
<tr>
<td>max</td>
<td>(float) The smallest positive power of the base (2) that causes overflow.</td>
</tr>
<tr>
<td>maxexp</td>
<td>(int) The exponent that yields max.</td>
</tr>
<tr>
<td>min</td>
<td>(float) The smallest representable number, typically -max.</td>
</tr>
<tr>
<td>minexp</td>
<td>(int) The most negative power of the base (2) consistent with there being no leading 0's in the mantissa.</td>
</tr>
<tr>
<td>negep</td>
<td>(int) The exponent that yields epsneg.</td>
</tr>
<tr>
<td>nexp</td>
<td>(int) The number of bits in the exponent including its sign and bias.</td>
</tr>
<tr>
<td>nmant</td>
<td>(int) The number of bits in the mantissa.</td>
</tr>
<tr>
<td>precision</td>
<td>(int) The approximate number of decimal digits to which this kind of float is precise.</td>
</tr>
<tr>
<td>resolution</td>
<td>(float) The approximate decimal resolution of this type, i.e., 10**(-precision).</td>
</tr>
<tr>
<td>tiny</td>
<td>(float) The smallest positive usable number. Type of tiny is an appropriate floating point type.</td>
</tr>
</tbody>
</table>

class numpy.iinfo (type)

Machine limits for integer types.

Parameters

- type : integer type, dtype, or instance
  The kind of integer data type to get information about.

See also:

finfo

The equivalent for floating point data types.

Examples

With types:

```python
generate examples
```

With instances:

```python
generate examples
```
>>> ii32.max
2147483647

**Attributes**

- `min`: Minimum value of given dtype.
- `max`: Maximum value of given dtype.

```
>>> iinfo.min
Minimum value of given dtype.
>>> iinfo.max
Maximum value of given dtype.
```

**class** `numpy.MachAr`

```python
(float_conv=<type 'float'>, int_conv=<type 'int'>, float_to_float=<type 'float'>,
 float_to_str=<function <lambda> at 0x4156c6bc>, title='Python floating point number')
```

Diagnosing machine parameters.

**Parameters**

- `float_conv`: function, optional
  Function that converts an integer or integer array to a float or float array. Default is `float`.
- `int_conv`: function, optional
  Function that converts a float or float array to an integer or integer array. Default is `int`.
- `float_to_float`: function, optional
  Function that converts a float array to float. Default is `float`. Note that this does not seem to do anything useful in the current implementation.
- `float_to_str`: function, optional
  Function that converts a single float to a string. Default is `lambda v:'%24.16e' %v`.
- `title`: str, optional
  Title that is printed in the string representation of `MachAr`.

**See also:**

- `finfo`
  Machine limits for floating point types.
- `iinfo`
  Machine limits for integer types.

**References**

[R1]
### Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ibeta</td>
<td>(int) Radix in which numbers are represented.</td>
</tr>
<tr>
<td>it</td>
<td>(int) Number of base-ibeta digits in the floating point mantissa M.</td>
</tr>
<tr>
<td>machep</td>
<td>(int) Exponent of the smallest (most negative) power of ibeta that, added to 1.0, gives something different from 1.0.</td>
</tr>
<tr>
<td>eps</td>
<td>(float) Floating-point number $\beta^*\text{machep}$ (floating point precision).</td>
</tr>
<tr>
<td>negep</td>
<td>(int) Exponent of the smallest power of ibeta that, substracted from 1.0, gives something different from 1.0.</td>
</tr>
<tr>
<td>epsneg</td>
<td>(float) Floating-point number $\beta^*\text{negep}$.</td>
</tr>
<tr>
<td>iexp</td>
<td>(int) Number of bits in the exponent (including its sign and bias).</td>
</tr>
<tr>
<td>minexp</td>
<td>(int) Smallest (most negative) power of ibeta consistent with there being no leading zeros in the mantissa.</td>
</tr>
<tr>
<td>xmin</td>
<td>(float) Floating point number $\beta^*\text{minexp}$ (the smallest [in magnitude] usable floating value).</td>
</tr>
<tr>
<td>maxexp</td>
<td>(int) Smallest (positive) power of ibeta that causes overflow.</td>
</tr>
<tr>
<td>xmax</td>
<td>(float) $(1-\text{epsneg}) * \beta^*\text{maxexp}$ (the largest [in magnitude] usable floating value).</td>
</tr>
<tr>
<td>irnd</td>
<td>(int) In range(6), information on what kind of rounding is done in addition, and on how underflow is handled.</td>
</tr>
<tr>
<td>ngrd</td>
<td>(int) Number of ‘guard digits’ used when truncating the product of two mantissas to fit the representation.</td>
</tr>
<tr>
<td>epsilon</td>
<td>(float) Same as eps.</td>
</tr>
<tr>
<td>tiny</td>
<td>(float) Same as xmin.</td>
</tr>
<tr>
<td>huge</td>
<td>(float) Same as xmax.</td>
</tr>
<tr>
<td>precision</td>
<td>(float) $-\int(-\log10(\text{eps}))$</td>
</tr>
<tr>
<td>resolution</td>
<td>(float) $10^{\text{precision}}$</td>
</tr>
</tbody>
</table>

### 3.7.3 Data type testing

- **issctype**(<rep>)
  - Determines whether the given object represents a scalar data-type.

- **issubdtype**(<arg1>, <arg2>)
  - Returns True if first argument is a typecode lower/equal in type hierarchy.

- **issubsctype**(<arg1>, <arg2>)
  - Determine if the first argument is a subclass of the second argument.

- **issubclass_**(<arg1>, <arg2>)
  - Determine if a class is a subclass of a second class.

- **find_common_type**(<array_types>, <scalar_types>)
  - Determine common type following standard coercion rules.

```python
numpy.issctype(<rep>)
```

Determine whether the given object represents a scalar data-type.

**Parameters**

- **rep**: any

  If `rep` is an instance of a scalar dtype, True is returned. If not, False is returned.

**Returns**

- **out**: bool

  Boolean result of check whether `rep` is a scalar dtype.

**See also:**

- issubsctype, issubdtype, obj2sctype, sctype2char
Examples
>>> np.issctype(np.int32)
True
>>> np.issctype(list)
False
>>> np.issctype(1.1)
False

Strings are also a scalar type:
>>> np.issctype(np.dtype('str'))
True

numpy.issubdtype(arg1, arg2)
Returns True if first argument is a typecode lower/equal in type hierarchy.

Parameters
arg1, arg2 : dtype_like
dtype or string representing a typecode.

Returns
out : bool

See also:
issubsctype, issubclass_

numpy.core.numerictypes
Overview of numpy type hierarchy.

Examples
>>> np.issubdtype('S1', str)
True
>>> np.issubdtype(np.float64, np.float32)
False

numpy.issubsctype(arg1, arg2)
Determine if the first argument is a subclass of the second argument.

Parameters
arg1, arg2 : dtype or dtype specifier
Data-types.

Returns
out : bool
The result.

See also:
issctype, issubdtype, obj2sctype

Examples
>>> np.issubsctype('S8', str)
True
>>> np.issubsctype(np.array([1]), np.int)
True
>>> np.issubsctype(np.array([1]), np.float)
False
NumPy Reference, Release 1.9.2

numpy.issubclass_(arg1, arg2)

Determine if a class is a subclass of a second class.

issubclass_ is equivalent to the Python built-in issubclass, except that it returns False instead of raising a TypeError if one of the arguments is not a class.

Parameters
arg1 : class
    Input class. True is returned if arg1 is a subclass of arg2.
arg2 : class or tuple of classes.
    Input class. If a tuple of classes, True is returned if arg1 is a subclass of any of the tuple elements.

Returns
out : bool
    Whether arg1 is a subclass of arg2 or not.

See also:
issubdtype, issubdtype, issctype

Examples
>>> np.issubclass_(np.int32, np.int)
True
>>> np.issubclass_(np.int32, np.float)
False

numpy.find_common_type(array_types, scalar_types)

Determine common type following standard coercion rules.

Parameters
array_types : sequence
    A list of dtypes or dtype convertible objects representing arrays.
scalar_types : sequence
    A list of dtypes or dtype convertible objects representing scalars.

Returns
datatype : dtype
    The common data type, which is the maximum of array_types ignoring scalar_types, unless the maximum of scalar_types is of a different kind (dtype.kind). If the kind is not understood, then None is returned.

See also:
dtype, common_type, can_cast, mintypecode

Examples
>>> np.find_common_type([], [np.int64, np.float32, np.complex])
dtype('complex128')
>>> np.find_common_type([np.int64, np.float32], [])
dtype('float64')

The standard casting rules ensure that a scalar cannot up-cast an array unless the scalar is of a fundamentally different kind of data (i.e. under a different hierarchy in the data type hierarchy) then the array:
NumPy Reference, Release 1.9.2

>>> np.find_common_type([np.float32], [np.int64, np.float64])
dtype('float32')

Complex is of a different type, so it up-casts the float in the *array_types* argument:

>>> np.find_common_type([np.float32], [np.complex])
dtype('complex128')

Type specifier strings are convertible to dtypes and can therefore be used instead of dtypes:

>>> np.find_common_type(['f4', 'f4', 'i4'], ['c8'])
dtype('complex128')

3.7.4 Miscellaneous

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>typename(char)</code></td>
<td>Return a description for the given data type code.</td>
</tr>
<tr>
<td><code>sctype2char(sctype)</code></td>
<td>Return the string representation of a scalar dtype.</td>
</tr>
<tr>
<td><code>mintypecode</code></td>
<td>Return the character for the minimum-size type to which given types can be safely cast.</td>
</tr>
</tbody>
</table>

numpy.*typename*(*char*)

Return a description for the given data type code.

**Parameters**

- **char**: str
  
  Data type code.

**Returns**

- **out**: str
  
  Description of the input data type code.

**See also:**

dtype, typecodes

**Examples**

```python
>>> typechars = ['S1', '?', 'B', 'D', 'G', 'F', 'I', 'H', 'L', 'O', 'Q', ...    's', 'u', 'v', 'b', 'd', 'g', 'f', 'i', 'h', 'l', 'q']
>>> for typechar in typechars:
...     print(typechar, ': ', np.typename(typechar))
...S1 : character
? : bool
B : unsigned char
D : complex double precision
G : complex long double precision
F : complex single precision
I : unsigned integer
H : unsigned short
L : unsigned long integer
O : object
Q : unsigned long long integer
S : string
U : unicode
V : void
```
b : signed char
d : double precision
g : long precision
f : single precision
i : integer
h : short
l : long integer
q : long long integer

numpy.sctype2char(sctype)
Return the string representation of a scalar dtype.

Parameters
- sctype : scalar dtype or object
  If a scalar dtype, the corresponding string character is returned. If an object,
  sctype2char tries to infer its scalar type and then return the corresponding string
  character.

Returns
typechar : str
The string character corresponding to the scalar type.

Raises
ValueError
If sctype is an object for which the type cannot be inferred.

See also:
obj2sctype, issctype, issubsctype, mintypecode

Examples
>>> for sctype in [np.int32, np.float, np.complex, np.string_, np.ndarray]:
...    print np.sctype2char(sctype)
  l
d
D
S
O

>>> x = np.array([1., 2-1.j])
>>> np.sctype2char(x)
'D'
>>> np.sctype2char(list)
'O'

numpy.mintypecode(typechars, typeset='GDFgdf', default='d')
Return the character for the minimum-size type to which given types can be safely cast.

The returned type character must represent the smallest size dtype such that an array of the returned type can
handle the data from an array of all types in typechars (or if typechars is an array, then its dtype.char).

Parameters
- typechars : list of str or array_like
  If a list of strings, each string should represent a dtype. If array_like, the character
  representation of the array dtype is used.

- typeset : str or list of str, optional
The set of characters that the returned character is chosen from. The default set is ‘GDFgdf’.

**default** : str, optional

The default character, this is returned if none of the characters in *typechars* matches a character in *typeset*.

**Returns**

**typechar** : str

The character representing the minimum-size type that was found.

**See also:**

dtype, sctype2char, maximum_sctype

**Examples**

```python
>>> np.mintypecode(['d', 'f', 'S'])
'd'
>>> x = np.array([1.1, 2-3.j])
>>> np.mintypecode(x)
'D'
>>> np.mintypecode('abceh', default='G')
'G'
```

### 3.8 Optionally Scipy-accelerated routines (`numpy.dual`)

Aliases for functions which may be accelerated by Scipy.

Scipy can be built to use accelerated or otherwise improved libraries for FFTs, linear algebra, and special functions. This module allows developers to transparently support these accelerated functions when scipy is available but still support users who have only installed Numpy.

#### 3.8.1 Linear algebra

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>cholesky(a)</code></td>
<td>Cholesky decomposition.</td>
</tr>
<tr>
<td><code>det(a)</code></td>
<td>Compute the determinant of an array.</td>
</tr>
<tr>
<td><code>eig(a)</code></td>
<td>Compute the eigenvalues and right eigenvectors of a square array.</td>
</tr>
<tr>
<td><code>eigh(a[, UPLO])</code></td>
<td>Return the eigenvalues and eigenvectors of a Hermitian or symmetric matrix.</td>
</tr>
<tr>
<td><code>eigvals(a)</code></td>
<td>Compute the eigenvalues of a general matrix.</td>
</tr>
<tr>
<td><code>eigvalsh(a[, UPLO])</code></td>
<td>Compute the eigenvalues of a Hermitian or real symmetric matrix.</td>
</tr>
<tr>
<td><code>inv(a)</code></td>
<td>Compute the (multiplicative) inverse of a matrix.</td>
</tr>
<tr>
<td><code>lstsq(a, b[, rcond])</code></td>
<td>Return the least-squares solution to a linear matrix equation.</td>
</tr>
<tr>
<td><code>norm(x[, ord, axis])</code></td>
<td>Matrix or vector norm.</td>
</tr>
<tr>
<td><code>pinv(a[, rcond])</code></td>
<td>Compute the (Moore-Penrose) pseudo-inverse of a matrix.</td>
</tr>
<tr>
<td><code>solve(a, b)</code></td>
<td>Solve a linear matrix equation, or system of linear scalar equations.</td>
</tr>
<tr>
<td><code>svd(a[, full_matrices, compute_uv])</code></td>
<td>Singular Value Decomposition.</td>
</tr>
</tbody>
</table>

#### 3.8.2 FFT
fft(a[, n, axis]) Compute the one-dimensional discrete Fourier Transform.
fft2(a[, s, axes]) Compute the 2-dimensional discrete Fourier Transform. This function computes the n-dimensional discrete Fourier Transform.
fftn(a[, s, axes]) Compute the N-dimensional discrete Fourier Transform.
ifft(a[, n, axis]) Compute the one-dimensional inverse discrete Fourier Transform.
ifft2(a[, s, axes]) Compute the 2-dimensional inverse discrete Fourier Transform.
ifftn(a[, s, axes]) Compute the N-dimensional inverse discrete Fourier Transform.

3.8.3 Other

10(x) Modified Bessel function of the first kind, order 0.

3.9 Mathematical functions with automatic domain (numpy.emath)

Note: numpy.emath is a preferred alias for numpy.lib.scimath, available after numpy is imported.

Wrapper functions to more user-friendly calling of certain math functions whose output data-type is different than the input data-type in certain domains of the input.

For example, for functions like log with branch cuts, the versions in this module provide the mathematically valid answers in the complex plane:

```python
>>> import math
>>> from numpy.lib import scimath
>>> scimath.log(-math.exp(1)) == (1+1j*math.pi)
True
```

Similarly, sqrt, other base logarithms, power and trig functions are correctly handled. See their respective docstrings for specific examples.

3.10 Floating point error handling

3.10.1 Setting and getting error handling

```python
seterr([all, divide, over, under, invalid]) Set how floating-point errors are handled.
geterr() Get the current way of handling floating-point errors.
seterrcall(func) Set the floating-point error callback function or log object.
geterrcall() Return the current callback function used on floating-point errors.
errstate(**kwargs) Context manager for floating-point error handling.
```

```python
numpy.seterr (all=None, divide=None, over=None, under=None, invalid=None)
Set how floating-point errors are handled.
```

Note that operations on integer scalar types (such as int16) are handled like floating point, and are affected by these settings.

**Parameters**

- **all**: {'ignore', 'warn', 'raise', 'call', 'print', 'log'}, optional
  - Set treatment for all types of floating-point errors at once:
• ignore: Take no action when the exception occurs.
• warn: Print a RuntimeWarning (via the Python warnings module).
• raise: Raise a FloatingPointError.
• call: Call a function specified using the seterrcall function.
• print: Print a warning directly to stdout.
• log: Record error in a Log object specified by seterrcall.

The default is not to change the current behavior.

   Treatment for division by zero.
   Treatment for floating-point overflow.
   Treatment for floating-point underflow.
   Treatment for invalid floating-point operation.

Returns
old_settings : dict
   Dictionary containing the old settings.

See also:

seterrcall
   Set a callback function for the ‘call’ mode.

geterr, geterrcall, errstate

Notes

The floating-point exceptions are defined in the IEEE 754 standard [1]:
• Division by zero: infinite result obtained from finite numbers.
• Overflow: result too large to be expressed.
• Underflow: result so close to zero that some precision was lost.
• Invalid operation: result is not an expressible number, typically indicates that a NaN was produced.

Examples

>>> old_settings = np.seterr(all='ignore')  # seterr to known value
>>> np.seterr(over='raise')
‘under’: ‘ignore’}
>>> np.seterr(**old_settings)  # reset to default
```python
>>> np.int16(32000) * np.int16(3)
30464

>>> old_settings = np.seterr(all='warn', over='raise')
>>> np.int16(32000) * np.int16(3)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
FloatingPointError: overflow encountered in short_scalars

>>> old_settings = np.seterr(all='print')
>>> np.int16(32000) * np.int16(3)
Warning: overflow encountered in short_scalars
30464
```

**numpy.geterr()**

Get the current way of handling floating-point errors.

**Returns**

res : dict

A dictionary with keys “divide”, “over”, “under”, and “invalid”, whose values are from the strings “ignore”, “print”, “log”, “warn”, “raise”, and “call”. The keys represent possible floating-point exceptions, and the values define how these exceptions are handled.

**See also:**

geterrcall, seterr, seterrcall

**Notes**

For complete documentation of the types of floating-point exceptions and treatment options, see `seterr`.

**Examples**

```python
>>> np.geterr()
{'over': 'warn', 'divide': 'warn', 'invalid': 'warn', 'under': 'ignore'}

>>> np.arange(3.) / np.arange(3.)
array([ NaN,  1.,  1.])

>>> oldsettings = np.seterr(all='warn', over='raise')
>>> np.geterr()
{'over': 'raise', 'divide': 'warn', 'invalid': 'warn', 'under': 'warn'}

>>> np.arange(3.) / np.arange(3.)
__main__:1: RuntimeWarning: invalid value encountered in divide
array([ NaN,  1.,  1.])
```

**numpy.seterrcall(func)**

Set the floating-point error callback function or log object.

There are two ways to capture floating-point error messages. The first is to set the error-handler to ‘call’, using `seterr`. Then, set the function to call using this function.

The second is to set the error-handler to ‘log’, using `seterr`. Floating-point errors then trigger a call to the ‘write’ method of the provided object.
**Parameters**

- **func**: callable f(err, flag) or object with write method

  Function to call upon floating-point errors (‘call’-mode) or object whose ‘write’ method is used to log such message (‘log’-mode).

  The call function takes two arguments. The first is the type of error (one of “divide”, “over”, “under”, or “invalid”), and the second is the status flag. The flag is a byte, whose least-significant bits indicate the status:

  \[0 \ 0 \ 0 \ 0 \text{invalid} \ \text{over} \ \text{under} \ \text{invalid}\]

  In other words, \( \text{flags} = \text{divide} + 2 \times \text{over} + 4 \times \text{under} + 8 \times \text{invalid} \).

- **Returns**

  - **h**: callable, log instance or None

    The old error handler.

**See also:**

- `seterr`
- `geterr`
- `geterrcall`

**Examples**

**Callback upon error:**

```python
def err_handler(type, flag):
    print "Floating point error \(\$(s)\), with flag \$$s\" \% (type, flag)

np.array([1, 2, 3]) / 0.0
\tilde{\text{Floating point error (divide by zero), with flag 1}}
array([\text{Inf}, \text{Inf}, \text{Inf}])
```

**Log error message:**

```python
class Log(object):
    def write(self, msg):
        print "LOG: \$s" \% msg

log = Log()
np.array([1, 2, 3]) / 0.0
\tilde{\text{LOG: Warning: divide by zero encountered in divide}}
array([\text{Inf}, \text{Inf}, \text{Inf}])
```
np.seterrcall(saved_handler)
<_main__Log object at 0x...>
np.seterr(**save_err)
{'over': 'log', 'divide': 'log', 'invalid': 'log', 'under': 'log'}

numpy.geterrcall()
Return the current callback function used on floating-point errors.

When the error handling for a floating-point error (one of “divide”, “over”, “under”, or “invalid”) is set to ‘call’ or ‘log’, the function that is called or the log instance that is written to is returned by geterrcall. This function or log instance has been set with seterrcall.

Returns

errobj : callable, log instance or None

The current error handler. If no handler was set through seterrcall, None is returned.

See also:

seterrcall, seterr, geterr

Notes

For complete documentation of the types of floating-point exceptions and treatment options, see seterr.

Examples

>>> np.geterrcall()  # we did not yet set a handler, returns None

>>> oldsettings = np.seterr(all='call')
>>> def err_handler(type, flag):
...     print "Floating point error ($s), with flag $s" % (type, flag)
>>> oldhandler = np.seterrcall(err_handler)
>>> np.array([1, 2, 3]) / 0.0
Floating point error (divide by zero), with flag 1
array([Inf, Inf, Inf])

>>> cur_handler = np.geterrcall()
>>> cur_handler is err_handler
True

class numpy.errstate(**kwargs)

Context manager for floating-point error handling.

Using an instance of errstate as a context manager allows statements in that context to execute with a known error handling behavior. Upon entering the context the error handling is set with seterr and seterrcall, and upon exiting it is reset to what it was before.

Parameters

kwargs : {divide, over, under, invalid}

Keyword arguments. The valid keywords are the possible floating-point exceptions. Each keyword should have a string value that defines the treatment for the particular error. Possible values are {‘ignore’, ‘warn’, ‘raise’, ‘call’, ‘print’, ‘log’}.

See also:

seterr, geterr, seterrcall, geterrcall

3.10. Floating point error handling 625
### Notes

The `with` statement was introduced in Python 2.5, and can only be used there by importing it: `from __future__ import with_statement`. In earlier Python versions the `with` statement is not available.

For complete documentation of the types of floating-point exceptions and treatment options, see `seterr`.

### Examples

```python
>>> from __future__ import with_statement  # use 'with' in Python 2.5
>>> olderr = np.seterr(all='ignore')  # Set error handling to known state.

>>> np.arange(3) / 0.
array([ NaN, Inf, Inf])

>>> with np.errstate(divide='warn'):
...    np.arange(3) / 0.
...__main__:2: RuntimeWarning: divide by zero encountered in divide
array([ NaN, Inf, Inf])

>>> np.sqrt(-1)
nan

>>> with np.errstate(invalid='raise'):
...    np.sqrt(-1)
...Traceback (most recent call last):
  File "<stdin>"", line 2, in <module>
FloatingPointError: invalid value encountered in sqrt

Outside the context the error handling behavior has not changed:

```python
>>> np.geterr()
{'over': 'warn', 'divide': 'warn', 'invalid': 'warn', 'under': 'ignore'}
```

### 3.10.2 Internal functions

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>seterrobj</code></td>
<td>Set the object that defines floating-point error handling.</td>
</tr>
<tr>
<td><code>geterrobj</code></td>
<td>Return the current object that defines floating-point error handling.</td>
</tr>
</tbody>
</table>

```python
numpy.seterrobj(errobj)
```

Set the object that defines floating-point error handling.

The error object contains all information that defines the error handling behavior in Numpy. `seterrobj` is used internally by the other functions that set error handling behavior (`seterr`, `seterrcall`).

**Parameters**

- `errobj` : list
  - The error object, a list containing three elements: [internal numpy buffer size, error mask, error callback function].
  - The error mask is a single integer that holds the treatment information on all four floating-point errors. The information for each error type is contained in three bits of the
integer. If we print it in base 8, we can see what treatment is set for “invalid”, “under”, “over”, and “divide” (in that order). The printed string can be interpreted with

- 0 : ‘ignore’
- 1 : ‘warn’
- 2 : ‘raise’
- 3 : ‘call’
- 4 : ‘print’
- 5 : ‘log’

See also:
geterrobj, seterr, geterr, seterrcall, geterrcall, getbufsize, setbufsize

Notes
For complete documentation of the types of floating-point exceptions and treatment options, see seterr.

Examples

```python
g >>> old_errobj = np.geterrobj()  # first get the defaults
g >>> old_errobj
[10000, 0, None]

g >>> def err_handler(type, flag):
...     print "Floating point error ($s), with flag $s" % (type, flag)
... 
g >>> new_errobj = [20000, 12, err_handler]

g >>> np.seterrobj(new_errobj)

g >>> np.base_repr(12, 8)  # int for divide=4 ('print') and over=1 ('warn')
'14'

g >>> np.geterr()
{'over': 'warn', 'divide': 'print', 'invalid': 'ignore', 'under': 'ignore'}

g >>> np.geterrcall() is err_handler
True
```

g geterrobj()

Return the current object that defines floating-point error handling.

The error object contains all information that defines the error handling behavior in Numpy. geterrobj is used internally by the other functions that get and set error handling behavior (geterr, seterr, geterrcall, seterrcall).

Returns

- errobj : list

The error object, a list containing three elements: [internal numpy buffer size, error mask, error callback function].

The error mask is a single integer that holds the treatment information on all four floating point errors. The information for each error type is contained in three bits of the integer. If we print it in base 8, we can see what treatment is set for “invalid”, “under”, “over”, and “divide” (in that order). The printed string can be interpreted with

- 0 : ‘ignore’
- 1 : ‘warn’
- 2 : ‘raise’
NumPy Reference, Release 1.9.2

3.11 Discrete Fourier Transform (numpy.fft)

3.11.1 Standard FFTs

**fft(a[, n, axis])**  
Compute the one-dimensional discrete Fourier Transform.

**ifft(a[, n, axis])**  
Compute the one-dimensional inverse discrete Fourier Transform.

**fft2(a[, s, axes])**  
Compute the 2-dimensional discrete Fourier Transform This function computes the n-dimensional discrete Four

**ifft2(a[, s, axes])**  
Compute the 2-dimensional inverse discrete Fourier Transform.

**fftn(a[, s, axes])**  
Compute the N-dimensional discrete Fourier Transform.

**ifftn(a[, s, axes])**  
Compute the N-dimensional inverse discrete Fourier Transform.

**numpy.fft.fft(a, n=None, axis=-1)**  
Compute the one-dimensional discrete Fourier Transform.

This function computes the one-dimensional n-point discrete Fourier Transform (DFT) with the efficient Fast Fourier Transform (FFT) algorithm [CT].

**Parameters**

- **a**: array_like
Input array, can be complex.

\[ n : \text{int, optional} \]

Length of the transformed axis of the output. If \( n \) is smaller than the length of the input, the input is cropped. If it is larger, the input is padded with zeros. If \( n \) is not given, the length of the input along the axis specified by \( axis \) is used.

\[ axis : \text{int, optional} \]

Axis over which to compute the FFT. If not given, the last axis is used.

**Returns**

\[ \text{out} : \text{complex ndarray} \]

The truncated or zero-padded input, transformed along the axis indicated by \( axis \), or the last one if \( axis \) is not specified.

**Raises**

\[ \text{IndexError} \]

if \( axes \) is larger than the last axis of \( a \).

See also:

- `numpy.fft`
  for definition of the DFT and conventions used.
- `ifft`
  The inverse of `fft`.
- `fft2`
  The two-dimensional FFT.
- `fftn`
  The \( n \)-dimensional FFT.
- `rfftn`
  The \( n \)-dimensional FFT of real input.
- `fftfreq`
  Frequency bins for given FFT parameters.

**Notes**

FFT (Fast Fourier Transform) refers to a way the discrete Fourier Transform (DFT) can be calculated efficiently, by using symmetries in the calculated terms. The symmetry is highest when \( n \) is a power of 2, and the transform is therefore most efficient for these sizes.

The DFT is defined, with the conventions used in this implementation, in the documentation for the `numpy.fft` module.

**References**

[CT]

**Examples**

```python
>>> np.fft.fft(np.exp(2j * np.pi * np.arange(8) / 8))
array([[-3.44505240e-16+1.14383329e-17j,
        8.00000000e+00-5.71092652e-15j,
       +1.22460635e-16j,
       3.11. Discrete Fourier Transform (numpy.fft) 629
```
NumPy Reference, Release 1.9.2

9.95839695e-17 +2.33482938e-16j,
0.00000000e+00 +1.66837030e-15j,
1.14383329e-17 +1.22460635e-16j,
-1.64863782e-15 +1.77635684e-15j]

>>> import matplotlib.pyplot as plt
>>> t = np.arange(256)
>>> sp = np.fft.fft(np.sin(t))
>>> freq = np.fft.fftfreq(t.shape[-1])
>>> plt.plot(freq, sp.real, freq, sp.imag)
[<matplotlib.lines.Line2D object at 0x...>, <matplotlib.lines.Line2D object at 0x...>]
>>> plt.show()

In this example, real input has an FFT which is Hermitian, i.e., symmetric in the real part and anti-symmetric in
the imaginary part, as described in the \texttt{numpy.fft} documentation.

\texttt{numpy.fft.ifft}(a, n=None, axis=-1)

Compute the one-dimensional inverse discrete Fourier Transform.

This function computes the inverse of the one-dimensional \( n \)-point discrete Fourier transform computed by
\texttt{fft}. In other words, \texttt{ifft(fft(a)) \equiv a} to within numerical accuracy. For a general description of the
algorithm and definitions, see \texttt{numpy.fft}.

The input should be ordered in the same way as is returned by \texttt{fft}, i.e., \( a[0] \) should contain the zero fre-
quency term, \( a[1:n/2+1] \) should contain the positive-frequency terms, and \( a[n/2+1:] \) should contain the
negative-frequency terms, in order of decreasingly negative frequency. See \texttt{numpy.fft} for details.

\textbf{Parameters}

\texttt{a} : array_like

Input array, can be complex.

\texttt{n} : int, optional

Length of the transformed axis of the output. If \( n \) is smaller than the length of the input,
the input is cropped. If it is larger, the input is padded with zeros. If \( n \) is not given,
the length of the input along the axis specified by \texttt{axis} is used. See notes about padding
issues.

\texttt{axis} : int, optional

Axis over which to compute the inverse DFT. If not given, the last axis is used.

\textbf{Returns}

\texttt{out} : complex \texttt{ndarray}

The truncated or zero-padded input, transformed along the axis indicated by \texttt{axis}, or the
last one if \texttt{axis} is not specified.

\textbf{Raises}

\texttt{IndexError}

If \texttt{axes} is larger than the last axis of \texttt{a}.

\textbf{See also:}

\texttt{numpy.fft}

An introduction, with definitions and general explanations.

\texttt{fft}

The one-dimensional (forward) FFT, of which \texttt{ifft} is the inverse
ifft2
The two-dimensional inverse FFT.

ifftn
The n-dimensional inverse FFT.

Notes
If the input parameter \( n \) is larger than the size of the input, the input is padded by appending zeros at the end. Even though this is the common approach, it might lead to surprising results. If a different padding is desired, it must be performed before calling ifft.

Examples
```python
>>> np.fft.ifft([0, 4, 0, 0])
array([ 1.+0.j, 0.+1.j, -1.+0.j, 0.-1.j])
```
Create and plot a band-limited signal with random phases:
```python
>>> import matplotlib.pyplot as plt

>>> t = np.arange(400)

>>> n = np.zeros((400,), dtype=complex)

>>> n[40:60] = np.exp(1j*np.random.uniform(0, 2*np.pi, (20,)))

>>> s = np.fft.ifft(n)

>>> plt.plot(t, s.real, 'b-', t, s.imag, 'r--')
[<matplotlib.lines.Line2D object at 0x...>, <matplotlib.lines.Line2D object at 0x...>]

>>> plt.legend(('real', 'imaginary'))
<matplotlib.legend.Legend object at 0x...>

>>> plt.show()
```

```
numpy.fft.fft2(a, s=None, axes=(-2, -1))
Compute the 2-dimensional discrete Fourier Transform

This function computes the \( n \)-dimensional discrete Fourier Transform over any axes in an \( M \)-dimensional array by means of the Fast Fourier Transform (FFT). By default, the transform is computed over the last two axes of the input array, i.e., a 2-dimensional FFT.

Parameters
a : array_like
```
Input array, can be complex

`s` : sequence of ints, optional

Shape (length of each transformed axis) of the output (`s[0]` refers to axis 0, `s[1]` to axis 1, etc.). This corresponds to `n` for `fft(x, n)`. Along each axis, if the given shape is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros. If `s` is not given, the shape of the input along the axes specified by `axes` is used.

`axes` : sequence of ints, optional

Axes over which to compute the FFT. If not given, the last two axes are used. A repeated index in `axes` means the transform over that axis is performed multiple times. A one-element sequence means that a one-dimensional FFT is performed.

Returns

`out` : complex ndarray

The truncated or zero-padded input, transformed along the axes indicated by `axes`, or the last two axes if `axes` is not given.

Raises

`ValueError`

If `s` and `axes` have different length, or `axes` not given and `len(s)` != 2.

`IndexError`

If an element of `axes` is larger than the number of axes of `a`.

See also:

`numpy.fft`

Overall view of discrete Fourier transforms, with definitions and conventions used.

`ifft2`

The inverse two-dimensional FFT.

`fft`

The one-dimensional FFT.

`fftn`

The n-dimensional FFT.

`fftshift`

Shifts zero-frequency terms to the center of the array. For two-dimensional input, swaps first and third quadrants, and second and fourth quadrants.

Notes

`fft2` is just `fftn` with a different default for `axes`.

The output, analogously to `fft`, contains the term for zero frequency in the low-order corner of the transformed axes, the positive frequency terms in the first half of these axes, the term for the Nyquist frequency in the middle of the axes and the negative frequency terms in the second half of the axes, in order of decreasingly negative frequency.

See `fftn` for details and a plotting example, and `numpy.fft` for definitions and conventions used.

Examples
```python
>>> a = np.mgrid[:5, :5][0]
>>> np.fft.fft2(a)
array([[ 50.0 +0.j , 0.0 +0.j , 0.0 +0.j ,
        0.0 +0.j , 0.0 +0.j ],
       [-12.5+17.20477401j, 0.0 +0.j , 0.0 +0.j ,
         0.0 +0.j , 0.0 +0.j ],
       [-12.5 +4.0614962j , 0.0 +0.j , 0.0 +0.j ,
        0.0 +0.j , 0.0 +0.j ],
       [-12.5 -4.0614962j , 0.0 +0.j , 0.0 +0.j ,
        0.0 +0.j , 0.0 +0.j ],
       [-12.5-17.20477401j, 0.0 +0.j , 0.0 +0.j ,
        0.0 +0.j , 0.0 +0.j ]])
```

`numpy.fft.ifft2(a, s=None, axes=(-2, -1))`

Compute the 2-dimensional inverse discrete Fourier Transform.

This function computes the inverse of the 2-dimensional discrete Fourier Transform over any number of axes in an M-dimensional array by means of the Fast Fourier Transform (FFT). In other words, `ifft2(fft2(a)) == a` to within numerical accuracy. By default, the inverse transform is computed over the last two axes of the input array.

The input, analogously to `ifft`, should be ordered in the same way as is returned by `fft2`, i.e. it should have the term for zero frequency in the low-order corner of the two axes, the positive frequency terms in the first half of these axes, the term for the Nyquist frequency in the middle of the axes and the negative frequency terms in the second half of both axes, in order of decreasingly negative frequency.

**Parameters**

- **a**: array_like
  Input array, can be complex.

- **s**: sequence of ints, optional
  Shape (length of each axis) of the output (`s[0]` refers to axis 0, `s[1]` to axis 1, etc.). This corresponds to `n` for `ifft(x, n)`. Along each axis, if the given shape is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros. If `s` is not given, the shape of the input along the axes specified by `axes` is used. See notes for issue on `ifft` zero padding.

- **axes**: sequence of ints, optional
  Axes over which to compute the FFT. If not given, the last two axes are used. A repeated index in `axes` means the transform over that axis is performed multiple times. A one-element sequence means that a one-dimensional FFT is performed.

**Returns**

- **out**: complex ndarray
  The truncated or zero-padded input, transformed along the axes indicated by `axes`, or the last two axes if `axes` is not given.

**Raises**

- **ValueError**
  If `s` and `axes` have different length, or `axes` not given and `len(s) != 2`.

- **IndexError**
  If an element of `axes` is larger than than the number of axes of `a`.

See also:
numpy.fft

Overall view of discrete Fourier transforms, with definitions and conventions used.

fft2

The forward 2-dimensional FFT, of which ifft2 is the inverse.

ifftn

The inverse of the n-dimensional FFT.

fft

The one-dimensional FFT.

ifft

The one-dimensional inverse FFT.

Notes

ifft2 is just ifftn with a different default for axes.

See ifftn for details and a plotting example, and numpy.fft for definition and conventions used.

Zero-padding, analogously with ifft, is performed by appending zeros to the input along the specified dimension. Although this is the common approach, it might lead to surprising results. If another form of zero padding is desired, it must be performed before ifft2 is called.

Examples

```python
>>> a = 4 * np.eye(4)
>>> np.fft.ifft2(a)
array([[ 1.+0.j,  0.+0.j,  0.+0.j,  0.+0.j],
       [ 0.+0.j,  0.+0.j,  0.+0.j,  1.+0.j],
       [ 0.+0.j,  0.+0.j,  1.+0.j,  0.+0.j],
       [ 0.+0.j,  1.+0.j,  0.+0.j,  0.+0.j]])
```

numpy.fft.fftn(a, s=None, axes=None)

Compute the N-dimensional discrete Fourier Transform.

This function computes the N-dimensional discrete Fourier Transform over any number of axes in an M-dimensional array by means of the Fast Fourier Transform (FFT).

Parameters

- a : array_like
  Input array, can be complex.

- s : sequence of ints, optional
  Shape (length of each transformed axis) of the output (s[0] refers to axis 0, s[1] to axis 1, etc.). This corresponds to n for fft(x, n). Along any axis, if the given shape is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros. If s is not given, the shape of the input along the axes specified by axes is used.

- axes : sequence of ints, optional
  Axes over which to compute the FFT. If not given, the last len(s) axes are used, or all axes if s is also not specified. Repeated indices in axes means that the transform over that axis is performed multiple times.

Returns

- out : complex ndarray
  The truncated or zero-padded input, transformed along the axes indicated by axes, or by a combination of s and a, as explained in the parameters section above.
Raises

ValueError

If \( s \) and \( \text{axes} \) have different length.

IndexError

If an element of \( \text{axes} \) is larger than than the number of axes of \( a \).

See also:

numpy.fft

Overall view of discrete Fourier transforms, with definitions and conventions used.

ifftn

The inverse of fftn, the inverse \( n \)-dimensional FFT.

fft

The one-dimensional FFT, with definitions and conventions used.

rfft

The \( n \)-dimensional FFT of real input.

fft2

The two-dimensional FFT.

fftshift

Shifts zero-frequency terms to centre of array

Notes

The output, analogously to fft, contains the term for zero frequency in the low-order corner of all axes, the positive frequency terms in the first half of all axes, the term for the Nyquist frequency in the middle of all axes and the negative frequency terms in the second half of all axes, in order of decreasingly negative frequency.

See numpy.fft for details, definitions and conventions used.

Examples

```python
>>> a = np.mgrid[:3, :3, :3][0]
>>> np.fft.fftn(a, axes=(1, 2))
array((([[ 0.+0.j, 0.+0.j, 0.+0.j],
        [ 0.+0.j, 0.+0.j, 0.+0.j],
        [ 0.+0.j, 0.+0.j, 0.+0.j]],
       [[ 9.+0.j, 0.+0.j, 0.+0.j],
        [ 0.+0.j, 0.+0.j, 0.+0.j],
        [ 0.+0.j, 0.+0.j, 0.+0.j]],
       [[18.+0.j, 0.+0.j, 0.+0.j],
        [ 0.+0.j, 0.+0.j, 0.+0.j],
        [ 0.+0.j, 0.+0.j, 0.+0.j]]),

>>> np.fft.fftn(a, (2, 2), axes=(0, 1))
array((([[ 2.+0.j, 2.+0.j, 2.+0.j],
        [ 0.+0.j, 0.+0.j, 0.+0.j]],
       [[-2.+0.j, -2.+0.j, -2.+0.j],
        [ 0.+0.j, 0.+0.j, 0.+0.j]]),

>>> import matplotlib.pyplot as plt
>>> [X, Y] = np.meshgrid(2 * np.pi * np.arange(200) / 12,
...                       2 * np.pi * np.arange(200) / 34)
>>> S = np.sin(X) + np.cos(Y) + np.random.uniform(0, 1, X.shape)
>>> FS = np.fft.fftn(S)
```
```python
>>> plt.imshow(np.log(np.abs(np.fft.fftshift(FS))**2))
<matplotlib.image.AxesImage object at 0x...>
>>> plt.show()
```

```
0 50 100 150 200
0
50
100
150
200
```

```
numpy.fft.ifftn(a, s=None, axes=None)

Compute the N-dimensional inverse discrete Fourier Transform.

This function computes the inverse of the N-dimensional discrete Fourier Transform over any number of axes in an M-dimensional array by means of the Fast Fourier Transform (FFT). In other words, `ifftn(fftn(a)) == a` to within numerical accuracy. For a description of the definitions and conventions used, see `numpy.fft`.

The input, analogously to `ifft`, should be ordered in the same way as is returned by `fftn`, i.e. it should have the term for zero frequency in all axes in the low-order corner, the positive frequency terms in the first half of all axes, the term for the Nyquist frequency in the middle of all axes and the negative frequency terms in the second half of all axes, in order of decreasingly negative frequency.

**Parameters**

- `a`: array_like
  Input array, can be complex.

- `s`: sequence of ints, optional
  Shape (length of each transformed axis) of the output (`s[0]` refers to axis 0, `s[1]` to axis 1, etc.). This corresponds to `n` for `ifft(x, n)`. Along any axis, if the given shape is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros. if `s` is not given, the shape of the input along the axes specified by `axes` is used. See notes for issue on `ifft` zero padding.

- `axes`: sequence of ints, optional
  Axes over which to compute the IFFT. If not given, the last `len(s)` axes are used, or all axes if `s` is also not specified. Repeated indices in `axes` means that the inverse transform over that axis is performed multiple times.

**Returns**

- `out`: complex ndarray
  The truncated or zero-padded input, transformed along the axes indicated by `axes`, or by a combination of `s` or `a`, as explained in the parameters section above.
```
Raises

**ValueError**

If `s` and `axes` have different length.

**IndexError**

If an element of `axes` is larger than than the number of axes of `a`.

See also:

* `numpy.fft`
  Overall view of discrete Fourier transforms, with definitions and conventions used.

* `fftn`
  The forward `n`-dimensional FFT, of which `ifftn` is the inverse.

* `ifft`
  The one-dimensional inverse FFT.

* `ifft2`
  The two-dimensional inverse FFT.

* `ifftshift`
  Undoes `fftshift`, shifts zero-frequency terms to beginning of array.

Notes

See `numpy.fft` for definitions and conventions used.

Zero-padding, analogously with `ifft`, is performed by appending zeros to the input along the specified dimension. Although this is the common approach, it might lead to surprising results. If another form of zero padding is desired, it must be performed before `ifftn` is called.

Examples

```python
c = np.eye(4)
c = np.fft.ifftn(np.fft.fftn(c, axes=(0,)), axes=(1,))
array([[ 1.+0.j,  0.+0.j,  0.+0.j,  0.+0.j],
       [ 0.+0.j,  1.+0.j,  0.+0.j,  0.+0.j],
       [ 0.+0.j,  0.+0.j,  1.+0.j,  0.+0.j],
       [ 0.+0.j,  0.+0.j,  0.+0.j,  1.+0.j]])
```

Create and plot an image with band-limited frequency content:

```python
import matplotlib.pyplot as plt
n = np.zeros((200,200), dtype=complex)
n[60:80, 20:40] = np.exp(1j*np.random.uniform(0, 2*np.pi, (20, 20)))
im = np.fft.ifftn(n).real
plt.imshow(im)
plt.show()
```
3.11.2 Real FFTs

```python
numpy.fft.rfft(a[, n, axis])
```

Compute the one-dimensional discrete Fourier Transform for real input.

This function computes the one-dimensional \( n \)-point discrete Fourier Transform (DFT) of a real-valued array by means of an efficient algorithm called the Fast Fourier Transform (FFT).

**Parameters**

- \( a \) : array_like
  
  Input array

- \( n \) : int, optional

  Number of points along transformation axis in the input to use. If \( n \) is smaller than the length of the input, the input is cropped. If it is larger, the input is padded with zeros. If \( n \) is not given, the length of the input along the axis specified by \( axis \) is used.

- \( axis \) : int, optional

  Axis over which to compute the FFT. If not given, the last axis is used.

**Returns**

- \( out \) : complex ndarray

  The truncated or zero-padded input, transformed along the axis indicated by \( axis \), or the last one if \( axis \) is not specified. If \( n \) is even, the length of the transformed axis is \((n/2)+1\). If \( n \) is odd, the length is \((n+1)/2\).
Raises

IndexError

If `axis` is larger than the last axis of `a`.

See also:

```
numpy.fft
```

For definition of the DFT and conventions used.

```
irfft
```

The inverse of `rfft`.

```
fft
```

The one-dimensional FFT of general (complex) input.

```
fftn
```

The `n`-dimensional FFT.

```
rfftn
```

The `n`-dimensional FFT of real input.

Notes

When the DFT is computed for purely real input, the output is Hermitian-symmetric, i.e. the negative frequency terms are just the complex conjugates of the corresponding positive-frequency terms, and the negative-frequency terms are therefore redundant. This function does not compute the negative frequency terms, and the length of the transformed axis of the output is therefore `n//2 + 1`.

When `A = rfft(a)` and `fs` is the sampling frequency, `A[0]` contains the zero-frequency term `0*fs`, which is real due to Hermitian symmetry.

If `n` is even, `A[-1]` contains the term representing both positive and negative Nyquist frequency (`+fs/2` and `-fs/2`), and must also be purely real. If `n` is odd, there is no term at `fs/2`; `A[-1]` contains the largest positive frequency (`fs/2*(n-1)/n`), and is complex in the general case.

If the input `a` contains an imaginary part, it is silently discarded.

Examples

```python
>>> np.fft.fft([0, 1, 0, 0])
array([ 1.+0.j, 0.-1.j, -1.+0.j, 0.+1.j])
```

```python
>>> np.fft.rfft([0, 1, 0, 0])
array([ 1.+0.j, 0.-1.j, -1.+0.j])
```

Notice how the final element of the `fft` output is the complex conjugate of the second element, for real input.

For `rfft`, this symmetry is exploited to compute only the non-negative frequency terms.

```
numpy.fft.irfft (a, n=None, axis=-1)
```

Compute the inverse of the `n`-point DFT for real input.

This function computes the inverse of the one-dimensional `n`-point discrete Fourier Transform of real input computed by `rfft`. In other words, `irfft(rfft(a), len(a)) == a` to within numerical accuracy. (See Notes below for why `len(a)` is necessary here.)

The input is expected to be in the form returned by `rfft`, i.e. the real zero-frequency term followed by the complex positive frequency terms in order of increasing frequency. Since the discrete Fourier Transform of real input is Hermitian-symmetric, the negative frequency terms are taken to be the complex conjugates of the corresponding positive frequency terms.

Parameters

```
a : array_like
```

3.11. Discrete Fourier Transform (``numpy.fft``)
The input array.

\( n : \text{int, optional} \)

Length of the transformed axis of the output. For \( n \) output points, \( n//2+1 \) input points are necessary. If the input is longer than this, it is cropped. If it is shorter than this, it is padded with zeros. If \( n \) is not given, it is determined from the length of the input along the axis specified by \( axis \).

\( axis : \text{int, optional} \)

Axis over which to compute the inverse FFT. If not given, the last axis is used.

**Returns**

\( \text{out} : \text{ndarray} \)

The truncated or zero-padded input, transformed along the axis indicated by \( axis \), or the last one if \( axis \) is not specified. The length of the transformed axis is \( n \), or, if \( n \) is not given, \( 2 \times (m-1) \) where \( m \) is the length of the transformed axis of the input. To get an odd number of output points, \( n \) must be specified.

**Raises**

* * *

IndexError

If \( axis \) is larger than the last axis of \( a \).

**See also:**

- **numpy.fft**
  For definition of the DFT and conventions used.
- **rfft**
  The one-dimensional FFT of real input, of which **irfft** is inverse.
- **fft**
  The one-dimensional FFT.
- **irfft2**
  The inverse of the two-dimensional FFT of real input.
- **irfftn**
  The inverse of the \( n \)-dimensional FFT of real input.

**Notes**

Returns the real valued \( n \)-point inverse discrete Fourier transform of \( a \), where \( a \) contains the non-negative frequency terms of a Hermitian-symmetric sequence. \( n \) is the length of the result, not the input.

If you specify an \( n \) such that \( a \) must be zero-padded or truncated, the extra/removed values will be added/removed at high frequencies. One can thus resample a series to \( m \) points via Fourier interpolation by:

\[
\text{a\_resamp} = \text{irfft(\text{rfft(a)}, m)}.
\]

**Examples**

```python
>>> np.fft.ifft([1, -1j, -1, 1j])
array([ 0.+0.j, 1.+0.j, 0.+0.j, 0.+0.j])
>>> np.fft.irfft([1, -1j, -1])
array([ 0., 1., 0., 0.])
```

Notice how the last term in the input to the ordinary **ifft** is the complex conjugate of the second term, and the output has zero imaginary part everywhere. When calling **irfft**, the negative frequencies are not specified, and the output array is purely real.
Compute the 2-dimensional FFT of a real array.

**Parameters**
- `a`: array
  - Input array, taken to be real.
- `s`: sequence of ints, optional
  - Shape of the FFT.
- `axes`: sequence of ints, optional
  - Axes over which to compute the FFT.

**Returns**
- `out`: ndarray
  - The result of the real 2-D FFT.

See also:
- [rfftn](#)
  - Compute the N-dimensional discrete Fourier Transform for real input.

**Notes**
This is really just `rfftn` with different default behavior. For more details see `rfftn`.

Compute the 2-dimensional inverse FFT of a real array.

**Parameters**
- `a`: array_like
  - The input array
- `s`: sequence of ints, optional
  - Shape of the inverse FFT.
- `axes`: sequence of ints, optional
  - The axes over which to compute the inverse fft. Default is the last two axes.

**Returns**
- `out`: ndarray
  - The result of the inverse real 2-D FFT.

See also:
- [irfftn](#)
  - Compute the inverse of the N-dimensional FFT of real input.

**Notes**
This is really `irfftn` with different defaults. For more details see `irfftn`.

Compute the N-dimensional discrete Fourier Transform for real input.
This function computes the N-dimensional discrete Fourier Transform over any number of axes in an M-
dimensional real array by means of the Fast Fourier Transform (FFT). By default, all axes are transformed,
with the real transform performed over the last axis, while the remaining transforms are complex.

**Parameters**

- `a` : array_like
  Input array, taken to be real.

- `s` : sequence of ints, optional
  Shape (length along each transformed axis) to use from the input. (`s[0]` refers to axis 0, `s[1]` to axis 1, etc.). The final element of `s` corresponds to `n` for `rfft(x, n)`, while for the remaining axes, it corresponds to `n` for `fft(x, n)`. Along any axis, if the given shape is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros. If `s` is not given, the shape of the input along the axes specified by `axes` is used.

- `axes` : sequence of ints, optional
  Axes over which to compute the FFT. If not given, the last `len(s)` axes are used, or all axes if `s` is also not specified.

**Returns**

- `out` : complex ndarray
  The truncated or zero-padded input, transformed along the axes indicated by `axes`, or by a combination of `s` and `a`, as explained in the parameters section above. The length of the last axis transformed will be `s[-1]//2+1`, while the remaining transformed axes will have lengths according to `s`, or unchanged from the input.

**Raises**

- `ValueError`
  If `s` and `axes` have different length.

- `IndexError`
  If an element of `axes` is larger than the number of axes of `a`.

**See also:**

- `irfftn`
  The inverse of `rfftn`, i.e. the inverse of the n-dimensional FFT of real input.

- `fft`
  The one-dimensional FFT, with definitions and conventions used.

- `rfft`
  The one-dimensional FFT of real input.

- `fftn`
  The n-dimensional FFT.

- `rfft2`
  The two-dimensional FFT of real input.

**Notes**

The transform for real input is performed over the last transformation axis, as by `rfft`, then the transform over the remaining axes is performed as by `fftn`. The order of the output is as for `rfft` for the final transformation axis, and as for `fftn` for the remaining transformation axes.
See `fft` for details, definitions and conventions used.

### Examples

```python
>>> a = np.ones((2, 2, 2))
>>> np.fft.rfftn(a)
array([[[ 8.+0.j,  0.+0.j],
        [ 0.+0.j,  0.+0.j]],
       [[ 0.+0.j,  0.+0.j],
        [ 0.+0.j,  0.+0.j]]])
```

```python
>>> np.fft.rfftn(a, axes=(2, 0))
array([[[ 4.+0.j,  0.+0.j],
        [ 0.+0.j,  0.+0.j]],
       [[ 0.+0.j,  0.+0.j],
        [ 0.+0.j,  0.+0.j]]])
```

`numpy.fft.irfftn(a, s=None, axes=None)`

Compute the inverse of the N-dimensional FFT of real input.

This function computes the inverse of the N-dimensional discrete Fourier Transform for real input over any number of axes in an M-dimensional array by means of the Fast Fourier Transform (FFT). In other words, `irfftn(rfftn(a), a.shape) == a` to within numerical accuracy. (The `a.shape` is necessary like `len(a)` is for `irfft`, and for the same reason.)

The input should be ordered in the same way as is returned by `rfftn`, i.e. as for `irfft` for the final transformation axis, and as for `ifftn` along all the other axes.

**Parameters**

- `a` : array_like
  Input array.

- `s` : sequence of ints, optional
  Shape (length of each transformed axis) of the output (`s[0]` refers to axis 0, `s[1]` to axis 1, etc.). `s` is also the number of input points used along this axis, except for the last axis, where `s[-1]//2+1` points of the input are used. Along any axis, if the shape indicated by `s` is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros. If `s` is not given, the shape of the input along the axes specified by `axes` is used.

- `axes` : sequence of ints, optional
  Axes over which to compute the inverse FFT. If not given, the last `len(s)` axes are used, or all axes if `s` is also not specified. Repeated indices in `axes` means that the inverse transform over that axis is performed multiple times.

**Returns**

- `out` : ndarray
  The truncated or zero-padded input, transformed along the axes indicated by `axes`, or by a combination of `s` or `a`, as explained in the parameters section above. The length of each transformed axis is as given by the corresponding element of `s`, or the length of the input in every axis except for the last one if `s` is not given. In the final transformed axis the length of the output when `s` is not given is `2* (m-1)` where `m` is the length of the final transformed axis of the input. To get an odd number of output points in the final axis, `s` must be specified.

**Raises**

- `ValueError`
If $s$ and $axes$ have different length.

**IndexError**

If an element of $axes$ is larger than than the number of axes of $a$.

See also:

- **rfftn**
  The forward n-dimensional FFT of real input, of which **ifftn** is the inverse.

- **fft**
  The one-dimensional FFT, with definitions and conventions used.

- **irfft**
  The inverse of the one-dimensional FFT of real input.

- **irfft2**
  The inverse of the two-dimensional FFT of real input.

**Notes**

See **fft** for definitions and conventions used.

See **rfft** for definitions and conventions used for real input.

**Examples**

```python
>>> a = np.zeros((3, 2, 2))
>>> a[0, 0, 0] = 3 * 2 * 2
>>> np.fft.irfftn(a)
array([[[ 1., 1.],
    [ 1., 1.]],
   [[ 1., 1.],
    [ 1., 1.]],
   [[ 1., 1.],
    [ 1., 1.]]])
```

### 3.11.3 Hermitian FFTs

<table>
<thead>
<tr>
<th>hfft(a[, n, axis])</th>
<th>Compute the FFT of a signal which has Hermitian symmetry (real spectrum).</th>
</tr>
</thead>
<tbody>
<tr>
<td>ihfft(a[, n, axis])</td>
<td>Compute the inverse FFT of a signal which has Hermitian symmetry.</td>
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</table>

**numpy.fft.hfft** $(a, n=None, axis=-1)$

Compute the FFT of a signal which has Hermitian symmetry (real spectrum).

**Parameters**

- **a** : array_like
  
The input array.

- **n** : int, optional
  
  Length of the transformed axis of the output. For $n$ output points, $n//2+1$ input points are necessary. If the input is longer than this, it is cropped. If it is shorter than this, it is padded with zeros. If $n$ is not given, it is determined from the length of the input along the axis specified by `axis`.

- **axis** : int, optional

---

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Axis over which to compute the FFT. If not given, the last axis is used.

Returns

out : ndarray

The truncated or zero-padded input, transformed along the axis indicated by axis, or the last one if axis is not specified. The length of the transformed axis is n, or, if n is not given, 2*(m−1) where m is the length of the transformed axis of the input. To get an odd number of output points, n must be specified.

Raises

IndexError

If axis is larger than the last axis of a.

See also:

* rfft
  Compute the one-dimensional FFT for real input.
* ihfft
  The inverse of hfft.

Notes

hfft/ihfft are a pair analogous to rfft/irfft, but for the opposite case: here the signal has Hermitian symmetry in the time domain and is real in the frequency domain. So here it’s hfft for which you must supply the length of the result if it is to be odd: ihfft(hfft(a), len(a)) == a, within numerical accuracy.

Examples

```python
>>> signal = np.array([1, 2, 3, 4, 3, 2])
>>> np.fft.fft(signal)
array([ 15.+0.j, -4.+0.j, 0.+0.j, -1.-0.j, 0.+0.j, -4.+0.j])

>>> np.fft.fft(signal[:4]) # Input first half of signal
array([ 15., -4., 0., -1., 0., -4.])

>>> np.fft.fft(signal, 6) # Input entire signal and truncate
array([ 15., -4., 0., -1., 0., -4.])

>>> signal = np.array([[1, 1.j], [-1.j, 2]])
>>> np.conj(signal.T) - signal # check Hermitian symmetry
array([[ 0.-0.j, 0.+0.j],
       [ 0.+0.j, 0.-0.j]])

>>> freq_spectrum = np.fft.fft(signal)
>>> freq_spectrum
array([[ 1.,  1.],
       [ 2., -2.]])
```

**numpy.fft.ihfft** (a, n=None, axis=-1)

Compute the inverse FFT of a signal which has Hermitian symmetry.

Parameters

- **a**: array_like
  Input array.
- **n**: int, optional
  Length of the inverse FFT. Number of points along transformation axis in the input to use. If n is smaller than the length of the input, the input is cropped. If it is larger,
the input is padded with zeros. If \( n \) is not given, the length of the input along the axis specified by \( \text{axis} \) is used.

\[ \text{axis} : \text{int, optional} \]
Axis over which to compute the inverse FFT. If not given, the last axis is used.

Returns

\[ \text{out} : \text{complex ndarray} \]
The truncated or zero-padded input, transformed along the axis indicated by \( \text{axis} \), or the last one if \( \text{axis} \) is not specified. If \( n \) is even, the length of the transformed axis is \((n/2)+1\). If \( n \) is odd, the length is \((n+1)/2\).

See also:

\[ \text{hfft}, \text{irfft} \]

Notes

\[ \text{hfft}/\text{ihfft} \] are a pair analogous to \[ \text{rfft}/\text{irfft} \], but for the opposite case: here the signal has Hermitian symmetry in the time domain and is real in the frequency domain. So here it’s \[ \text{hfft} \] for which you must supply the length of the result if it is to be odd: \[ \text{ihfft}(\text{hfft}(a), \text{len}(a)) == a \], within numerical accuracy.

Examples

\[
>>> \text{spectrum} = \text{np.array([15, -4, 0, -1, 0, -4])}
>>> \text{np.fft.ifft(spectrum)}
\text{array([1.+0.j, 2.-0.j, 3.+0.j, 4.+0.j, 3.+0.j, 2.-0.j])}
>>> \text{np.fft.ihfft(spectrum)}
\text{array([1.-0.j, 2.-0.j, 3.-0.j, 4.-0.j])}
\]

3.11.4 Helper routines

\[ \text{numpy.fft.fftfreq}(n[, d]) \]
Return the Discrete Fourier Transform sample frequencies.

\[ \text{f} = [0, 1, \ldots, n/2-1, -n/2, \ldots, -1] / (d*n) \text{ if } n \text{ is even} \]
\[ f = [0, 1, \ldots, (n-1)/2, -(n-1)/2, \ldots, -1] / (d*n) \text{ if } n \text{ is odd} \]

\[ \text{Parameters} \]
\[ n : \text{int} \]
Window length.
\[ d : \text{scalar, optional} \]
Sample spacing (inverse of the sampling rate). Defaults to 1.
Returns

f : ndarray

Array of length \( n \) containing the sample frequencies.

Examples

```python
>>> signal = np.array([-2, 8, 6, 4, 1, 0, 3, 5], dtype=float)
>>> fourier = np.fft.fft(signal)
>>> n = signal.size
>>> timestep = 0.1
>>> freq = np.fft.fftfreq(n, d=timestep)
>>> freq
array([ 0. , 1.25, 2.5 , 3.75, -5. , -3.75, -2.5 , -1.25])
```

```python
numpy.fft.rfftfreq(n, d=1.0)

Return the Discrete Fourier Transform sample frequencies (for usage with rfft, irfft).

The returned float array \( f \) contains the frequency bin centers in cycles per unit of the sample spacing (with zero at the start). For instance, if the sample spacing is in seconds, then the frequency unit is cycles/second.

Given a window length \( n \) and a sample spacing \( d \):

\[
f = [0, 1, ..., n/2-1, n/2] / (d*n) \quad \text{if } n \text{ is even}
\]

\[
f = [0, 1, ..., (n-1)/2-1, (n-1)/2] / (d*n) \quad \text{if } n \text{ is odd}
\]

Unlike `fftfreq` (but like `scipy.fftpack.rfftfreq`) the Nyquist frequency component is considered to be positive.

Parameters

- \( n \) : int
  - Window length.

- \( d \) : scalar, optional
  - Sample spacing (inverse of the sampling rate). Defaults to 1.

Returns

f : ndarray

Array of length \( n//2 + 1 \) containing the sample frequencies.

Examples

```python
>>> signal = np.array([-2, 8, 6, 4, 1, 0, 3, 5, -3, 4], dtype=float)
>>> fourier = np.fft.rfft(signal)
>>> n = signal.size
>>> sample_rate = 100
>>> freq = np.fft.fftfreq(n, d=1./sample_rate)
>>> freq
array([ 0., 10., 20., 30., 40., -50., -40., -30., -20., -10.])
>>> freq = np.fft.rfftfreq(n, d=1./sample_rate)
>>> freq
array([ 0., 10., 20., 30., 40., 50.])
```

```python
numpy.fft.fftshift(x, axes=None)

Shift the zero-frequency component to the center of the spectrum.

This function swaps half-spaces for all axes listed (defaults to all). Note that \( y[0] \) is the Nyquist component only if \( \text{len}(x) \) is even.

Parameters

- x : array_like

3.11. Discrete Fourier Transform (numpy.fft)
Input array.

axes : int or shape tuple, optional

Axes over which to shift. Default is None, which shifts all axes.

Returns

y : ndarray

The shifted array.

See also:

ifftshift

The inverse of fftshift.

Examples

>>> freqs = np.fft.fftfreq(10, 0.1)
>>> freqs
array([ 0.,  1.,  2.,  3.,  4., -5., -4., -3., -2., -1.])
>>> np.fft.fftshift(freqs)
array([-5., -4., -3., -2., -1.,  0.,  1.,  2.,  3.,  4.])

Shift the zero-frequency component only along the second axis:

>>> freqs = np.fft.fftfreq(9, d=1./9).reshape(3, 3)
>>> freqs
array([[ 0.,  1.,  2.],
       [ 3.,  4., -4.],
       [-3., -2., -1.]]
>>> np.fft.fftshift(freqs, axes=(1,))
array([[ 2.,  0.,  1.],
       [-4.,  3.,  4.],
       [-1., -3., -2.]]

numpy.fft.ifftshift(x, axes=None)

The inverse of fftshift. Although identical for even-length x, the functions differ by one sample for odd-length x.

Parameters

x : array_like

Input array.

axes : int or shape tuple, optional

Axes over which to calculate. Defaults to None, which shifts all axes.

Returns

y : ndarray

The shifted array.

See also:

fftshift

Shift zero-frequency component to the center of the spectrum.
Examples

```python
>>> freqs = np.fft.fftfreq(9, d=1./9).reshape(3, 3)
>>> freqs
array([[ 0.,  1.,  2.],
       [ 3.,  4., -4.],
       [-3., -2., -1.]])
>>> np.fft.ifftshift(np.fft.fftshift(freqs))
array([[ 0.,  1.,  2.],
       [ 3.,  4., -4.],
       [-3., -2., -1.]])
```

3.11.5 Background information

Fourier analysis is fundamentally a method for expressing a function as a sum of periodic components, and for recovering the function from those components. When both the function and its Fourier transform are replaced with discretized counterparts, it is called the discrete Fourier transform (DFT). The DFT has become a mainstay of numerical computing in part because of a very fast algorithm for computing it, called the Fast Fourier Transform (FFT), which was known to Gauss (1805) and was brought to light in its current form by Cooley and Tukey [CT]. Press et al. [NR] provide an accessible introduction to Fourier analysis and its applications.

Because the discrete Fourier transform separates its input into components that contribute at discrete frequencies, it has a great number of applications in digital signal processing, e.g., for filtering, and in this context the discretized input to the transform is customarily referred to as a signal, which exists in the time domain. The output is called a spectrum or transform and exists in the frequency domain.

3.11.6 Implementation details

There are many ways to define the DFT, varying in the sign of the exponent, normalization, etc. In this implementation, the DFT is defined as

\[
A_k = \sum_{m=0}^{n-1} a_m \exp\left\{ -2\pi i \frac{mk}{n} \right\} \quad k = 0, \ldots, n - 1.
\]

The DFT is in general defined for complex inputs and outputs, and a single-frequency component at linear frequency \( f \) is represented by a complex exponential \( a_m = \exp\{2\pi i fm\Delta t\} \), where \( \Delta t \) is the sampling interval.

The values in the result follow so-called “standard” order: If \( A = \text{fft}(a, n) \), then \( A[0] \) contains the zero-frequency term (the mean of the signal), which is always purely real for real inputs. Then \( A[1:n/2] \) contains the positive-frequency terms, and \( A[n/2+1:] \) contains the negative-frequency terms, in order of decreasingly negative frequency. For an even number of input points, \( A[n/2] \) represents both positive and negative Nyquist frequency, and is also purely real for real input. For an odd number of input points, \( A[(n-1)/2] \) contains the largest positive frequency, while \( A[(n+1)/2] \) contains the largest negative frequency. The routine `np.fft.fftfreq(n)` returns an array giving the frequencies of corresponding elements in the output. The routine `np.fft.fftshift(A)` shifts transforms and their frequencies to put the zero-frequency components in the middle, and `np.fft.ifftshift(A)` undoes that shift.

When the input \( a \) is a time-domain signal and \( A = \text{fft}(a) \), `np.abs(A)` is its amplitude spectrum and `np.abs(A)**2` is its power spectrum. The phase spectrum is obtained by `np.angle(A)`.

The inverse DFT is defined as

\[
a_m = \frac{1}{n} \sum_{k=0}^{n-1} A_k \exp\left\{ 2\pi i \frac{mk}{n} \right\} \quad m = 0, \ldots, n - 1.
\]

It differs from the forward transform by the sign of the exponential argument and the normalization by \( 1/n \).
3.11.7 Real and Hermitian transforms

When the input is purely real, its transform is Hermitian, i.e., the component at frequency \( f_k \) is the complex conjugate of the component at frequency \(-f_k\), which means that for real inputs there is no information in the negative frequency components that is not already available from the positive frequency components. The family of \( rfft \) functions is designed to operate on real inputs, and exploits this symmetry by computing only the positive frequency components, up to and including the Nyquist frequency. Thus, \( n \) input points produce \( n/2+1 \) complex output points. The inverses of this family assumes the same symmetry of its input, and for an output of \( n \) points uses \( n/2+1 \) input points.

Correspondingly, when the spectrum is purely real, the signal is Hermitian. The \( hfft \) family of functions exploits this symmetry by using \( n/2+1 \) complex points in the input (time) domain for \( n \) real points in the frequency domain.

In higher dimensions, FFTs are used, e.g., for image analysis and filtering. The computational efficiency of the FFT means that it can also be a faster way to compute large convolutions, using the property that a convolution in the time domain is equivalent to a point-by-point multiplication in the frequency domain.

3.11.8 Higher dimensions

In two dimensions, the DFT is defined as

\[
A_{kl} = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} a_{mn} \exp \left\{ -2\pi i \left( m \frac{k}{M} + n \frac{l}{N} \right) \right\} \quad k = 0, \ldots, M - 1; \quad l = 0, \ldots, N - 1,
\]

which extends in the obvious way to higher dimensions, and the inverses in higher dimensions also extend in the same way.

3.11.9 References

3.11.10 Examples

For examples, see the various functions.

3.12 Financial functions

3.12.1 Simple financial functions

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<td>( \text{pmt} )</td>
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\text{numpy} \ . \ \text{fv} \ (\text{rate, nper, pmt, pv[, when='end']})

Compute the future value.
Given:

- a present value, \( \text{pv} \)
- an interest rate compounded once per period, of which there are
- \( \text{nper} \) total
- a (fixed) payment, \( \text{pmt} \), paid either
- at the beginning (\( \text{when} = \{\text{‘begin’, 1}\} \)) or the end (\( \text{when} = \{\text{‘end’, 0}\} \)) of each period

Return:

the value at the end of the \( \text{nper} \) periods

Parameters

- \( \text{rate} \) : scalar or array_like of shape(M, )
  Rate of interest as decimal (not per cent) per period
- \( \text{nper} \) : scalar or array_like of shape(M, )
  Number of compounding periods
- \( \text{pmt} \) : scalar or array_like of shape(M, )
  Payment
- \( \text{pv} \) : scalar or array_like of shape(M, )
  Present value
- \( \text{when} \) : \{\{‘begin’, 1\}, \{‘end’, 0\}\}, \{\text{string}, \text{int}\}, \text{optional}
  When payments are due (‘begin’ (1) or ‘end’ (0)). Defaults to {‘end’, 0}.

Returns

- \( \text{out} \) : ndarray
  Future values. If all input is scalar, returns a scalar float. If any input is array_like, returns future values for each input element. If multiple inputs are array_like, they all must have the same shape.

Notes

The future value is computed by solving the equation:

\[
fv + pv*(1+rate)**nper + pmt*(1 + rate*\text{when})/rate*{(1 + rate)**nper - 1} == 0
\]

or, when \( \text{rate} == 0 \):

\[
fv + pv + pmt * nper == 0
\]

References

[WRW]
Examples

What is the future value after 10 years of saving $100 now, with an additional monthly savings of $100. Assume the interest rate is 5% (annually) compounded monthly?

```python
>>> np.fv(0.05/12, 10*12, -100, -100)
15692.928894335748
```

By convention, the negative sign represents cash flow out (i.e. money not available today). Thus, saving $100 a month at 5% annual interest leads to $15,692.93 available to spend in 10 years.

If any input is array_like, returns an array of equal shape. Let’s compare different interest rates from the example above.

```python
>>> a = np.array((0.05, 0.06, 0.07))/12
>>> np.fv(a, 10*12, -100, -100)
array([ 15692.92889434, 16569.87435405, 17509.44688102])
```

**numpy.pv** (rate, nper, pmt, fv=0.0, when='end')

Compute the present value.

Given:

- a future value, `fv`
- an interest rate compounded once per period, of which there are `nper` total
- a (fixed) payment, `pmt`, paid either
- at the beginning (`when = {'begin', 1}`) or the end (`when = {'end', 0}`) of each period

Return:

the value now

**Parameters**

- `rate` : array_like
  Rate of interest (per period)
- `nper` : array_like
  Number of compounding periods
- `pmt` : array_like
  Payment
- `fv` : array_like, optional
  Future value
- `when` : {{‘begin’, 1}, {‘end’, 0}}, {string, int}, optional
  When payments are due (‘begin’ (1) or ‘end’ (0))

**Returns**

- `out` : ndarray, float
  Present value of a series of payments or investments.
Notes

The present value is computed by solving the equation:

\[
fv + pv \times (1 + rate)^{nper} +
pmt \times (1 + rate \times when) / rate \times ((1 + rate)^{nper} - 1) = 0
\]

or, when rate = 0:

\[
fv + pv + pmt \times nper = 0
\]

for pv, which is then returned.

References

[WRW]

Examples

What is the present value (e.g., the initial investment) of an investment that needs to total $15692.93 after 10 years of saving $100 every month? Assume the interest rate is 5% (annually) compounded monthly.

```python
>>> np.pv(0.05/12, 10*12, -100, 15692.93)
-100.00067131625819
```

By convention, the negative sign represents cash flow out (i.e., money not available today). Thus, to end up with $15,692.93 in 10 years saving $100 a month at 5% annual interest, one's initial deposit should also be $100.

If any input is array_like, `pv` returns an array of equal shape. Let's compare different interest rates in the example above:

```python
>>> a = np.array((0.05, 0.04, 0.03))/12
>>> np.pv(a, 10*12, -100, 15692.93)
array([-100.00067132, -649.26771385, -1273.78633713])
```

So, to end up with the same $15692.93 under the same $100 per month “savings plan,” for annual interest rates of 4% and 3%, one would need initial investments of $649.27 and $1273.79, respectively.

`numpy.pv`:

Returns the NPV (Net Present Value) of a cash flow series.

**Parameters**

- `rate`: scalar
  
  The discount rate.

- `values`: array_like, shape(M,)
  
  The values of the time series of cash flows. The (fixed) time interval between cash flow “events” must be the same as that for which `rate` is given (i.e., if `rate` is per year, then precisely a year is understood to elapse between each cash flow event). By convention, investments or “deposits” are negative, income or “withdrawals” are positive; `values` must begin with the initial investment, thus `values[0]` will typically be negative.

**Returns**

- `out`: float
  
  The NPV of the input cash flow series `values` at the discount `rate`.  

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Notes
Returns the result of: [G53]
\[ \sum_{t=0}^{M-1} \frac{values_t}{(1 + rate)^t} \]

References
[G53]

Examples
```python
>>> np.npv(0.281, [-100, 39, 59, 55, 20])
-0.0084785916384548798
```
(Compare with the Example given for numpy.lib.financial.irr)

```python
numpy.pmt(rate, nper, pv, fv=0, when='end')
```
Compute the payment against loan principal plus interest.

Given:
- a present value, `pv` (e.g., an amount borrowed)
- a future value, `fv` (e.g., 0)
- an interest `rate` compounded once per period, of which there are
- `nper` total
- and (optional) specification of whether payment is made at the beginning (`when` = {'begin', 1}) or the end (`when` = {'end', 0}) of each period

Return:
the (fixed) periodic payment.

Parameters
- `rate`: array_like
  Rate of interest (per period)
- `nper`: array_like
  Number of compounding periods
- `pv`: array_like
  Present value
- `fv`: array_like (optional)
  Future value (default = 0)
- `when`: {'begin', 1}, {'end', 0}, {string, int}
  When payments are due ('begin' (1) or 'end' (0))

Returns
- `out`: ndarray
  Payment against loan plus interest. If all input is scalar, returns a scalar float. If any input is array_like, returns payment for each input element. If multiple inputs are array_like, they all must have the same shape.
Notes

The payment is computed by solving the equation:

\[ \text{fv} + \text{pv} \times (1 + \text{rate})^{\text{nper}} + \text{pmt} \times \frac{(1 + \text{rate} \times \text{when})}{\text{rate}} \times \left( (1 + \text{rate})^{\text{nper}} - 1 \right) = 0 \]

or, when rate == 0:

\[ \text{fv} + \text{pv} + \text{pmt} \times \text{nper} = 0 \]

for pmt.

Note that computing a monthly mortgage payment is only one use for this function. For example, pmt returns the periodic deposit one must make to achieve a specified future balance given an initial deposit, a fixed, periodically compounded interest rate, and the total number of periods.

References

[WRW]

Examples

What is the monthly payment needed to pay off a $200,000 loan in 15 years at an annual interest rate of 7.5%?

```python
>>> np.pmt(0.075/12, 12*15, 200000)
-1854.0247200054619
```

In order to pay-off (i.e., have a future-value of 0) the $200,000 obtained today, a monthly payment of $1,854.02 would be required. Note that this example illustrates usage of fv having a default value of 0.

numpy.ppmt(rate, per, nper, pv, fv=0.0, when='end')

Compute the payment against loan principal.

Parameters

- **rate**: array_like
  Rate of interest (per period)

- **per**: array_like, int
  Amount paid against the loan changes. The per is the period of interest.

- **nper**: array_like
  Number of compounding periods

- **pv**: array_like
  Present value

- **fv**: array_like, optional
  Future value

- **when**: {'begin', 1}, {'end', 0}, {string, int}
  When payments are due ('begin' (1) or 'end' (0))

See also:

- pmt, pv, ipmt

numpy.ipmt(rate, per, nper, pv, fv=0.0, when='end')

Compute the interest portion of a payment.
Parameters

rate : scalar or array_like of shape(M, )

Rate of interest as decimal (not per cent) per period

per : scalar or array_like of shape(M, )

Interest paid against the loan changes during the life or the loan. The per is the payment period to calculate the interest amount.

nper : scalar or array_like of shape(M, )

Number of compounding periods

pv : scalar or array_like of shape(M, )

Present value

fv : scalar or array_like of shape(M, ), optional

Future value

when : {{'begin', 1}, {'end', 0}}, {string, int}, optional

When payments are due (‘begin’ (1) or ‘end’ (0)). Defaults to {‘end’, 0}.

Returns

out : ndarray

Interest portion of payment. If all input is scalar, returns a scalar float. If any input is array_like, returns interest payment for each input element. If multiple inputs are array_like, they all must have the same shape.

See also:

ppmt, pmt, pv

Notes

The total payment is made up of payment against principal plus interest.

pmt = ppmt + ipmt

Examples

What is the amortization schedule for a 1 year loan of $2500 at 8.24% interest per year compounded monthly?

```python
>>> principal = 2500.00

The ‘per’ variable represents the periods of the loan. Remember that financial equations start the period count at 1!

```python
>>> per = np.arange(1*12) + 1
>>> ipmt = np.ipmt(0.0824/12, per, 1*12, principal)
>>> ppmt = np.ppmt(0.0824/12, per, 1*12, principal)

Each element of the sum of the ‘ipmt’ and ‘ppmt’ arrays should equal ‘pmt’.

```python
>>> pmt = np.pmt(0.0824/12, 1*12, principal)
>>> np.allclose(ipmt + ppmt, pmt)
```

```python
True

>>> fmt = ’{0:2d} {1:8.2f} {2:8.2f} {3:8.2f}’
>>> for payment in per:
...    index = payment - 1
```
... principal = principal + ppmt[index]
>>> print fmt.format(payment, ppmt[index], ipmt[index], principal)
1 -200.58 -17.17 2299.42
2 -201.96 -15.79 2097.46
3 -203.35 -14.40 1894.11
4 -204.74 -13.01 1689.37
5 -206.15 -11.60 1483.22
6 -207.56 -10.18 1275.66
7 -208.99 -8.76 1066.67
8 -210.42 -7.32 856.25
9 -211.87 -5.88 644.38
10 -213.32 -4.42 431.05
11 -214.79 -2.96 216.26
12 -216.26 -1.49 -0.00

>>> interestpd = np.sum(ipmt)
>>> np.round(interestpd, 2)
-112.98

`numpy.irr(values)`

Return the Internal Rate of Return (IRR).

This is the “average” periodically compounded rate of return that gives a net present value of 0.0; for a more complete explanation, see Notes below.

**Parameters**

values : array_like, shape(N,)

Input cash flows per time period. By convention, net “deposits” are negative and net “withdrawals” are positive. Thus, for example, at least the first element of values, which represents the initial investment, will typically be negative.

**Returns**

out : float

Internal Rate of Return for periodic input values.

**Notes**

The IRR is perhaps best understood through an example (illustrated using np.irr in the Examples section below). Suppose one invests 100 units and then makes the following withdrawals at regular (fixed) intervals: 39, 59, 55, 20. Assuming the ending value is 0, one’s 100 unit investment yields 173 units; however, due to the combination of compounding and the periodic withdrawals, the “average” rate of return is neither simply 0.73/4 nor \((1.73)^{0.25}-1\). Rather, it is the solution (for \(r\)) of the equation:

\[-100 + \frac{39}{1+r} + \frac{59}{(1+r)^2} + \frac{55}{(1+r)^3} + \frac{20}{(1+r)^4} = 0\]

In general, for values = \([v_0, v_1, \ldots v_M]\), irr is the solution of the equation: [G32]

\[\sum_{t=0}^{M} \frac{v_t}{(1+irr)^t} = 0\]

**References**

[G32]
Examples

```python
>>> round(irr([-100, 39, 59, 55, 20]), 5)
0.28095
>>> round(irr([-100, 0, 0, 74]), 5)
-0.0955
>>> round(irr([-100, 100, 0, -7]), 5)
-0.0833
>>> round(irr([-100, 100, 0, 7]), 5)
0.06206
>>> round(irr([-5, 10.5, 1, -8, 1]), 5)
0.0886
```

(Compare with the Example given for numpy.lib.financial.npv)

```python
numpy.mirr(values, finance_rate, reinvest_rate)
```

Modified internal rate of return.

Parameters

- **values**: array_like
  Cash flows (must contain at least one positive and one negative value) or nan is returned. The first value is considered a sunk cost at time zero.

- **finance_rate**: scalar
  Interest rate paid on the cash flows

- **reinvest_rate**: scalar
  Interest rate received on the cash flows upon reinvestment

Returns

- **out**: float
  Modified internal rate of return

```python
numpy.nper(rate, pmt, pv, fv=0, when='end')
```

Compute the number of periodic payments.

Parameters

- **rate**: array_like
  Rate of interest (per period)

- **pmt**: array_like
  Payment

- **pv**: array_like
  Present value

- **fv**: array_like, optional
  Future value

- **when**: {{‘begin’, 1}, {‘end’, 0}}, {string, int}, optional
  When payments are due (‘begin’ (1) or ‘end’ (0))

Notes

The number of periods nper is computed by solving the equation:
$fv + pv \times (1+rate)^{nper} + pmt \times (1+rate \times \text{when})/rate \times ((1+rate)^{nper}-1) = 0$

but if $rate = 0$ then:

$fv + pv + pmt \times nper = 0$

**Examples**

If you only had $150/month to pay towards the loan, how long would it take to pay-off a loan of $8,000 at 7% annual interest?

```python
>>> print round(np.nper(0.07/12, -150, 8000), 5)
64.07335
```

So, over 64 months would be required to pay off the loan.

The same analysis could be done with several different interest rates and/or payments and/or total amounts to produce an entire table.

```python
>>> np.nper(*(np.ogrid[0.07/12: 0.08/12: 0.01/12, ... -150 : -99 : 50 , ... 8000 : 9001 : 1000]))
```

```python
array([[ 64.07334877, 74.06368256],
       [108.07548412, 127.99022654],
       [166.12443902, 186.87897353],
       [246.70165583, 287.90124779]])
```

**numpy.rate**  
Compute the rate of interest per period.

**Parameters**

- `nper`: array_like  
Number of compounding periods

- `pmt`: array_like  
Payment

- `pv`: array_like  
Present value

- `fv`: array_like  
Future value

- `when`: {{‘begin’, 1}, {‘end’, 0}}, {string, int}, optional  
When payments are due (‘begin’ (1) or ‘end’ (0))

- `guess`: float, optional  
Starting guess for solving the rate of interest

- `tol`: float, optional  
Required tolerance for the solution

- `maxiter`: int, optional  
Maximum iterations in finding the solution
Notes
The rate of interest is computed by iteratively solving the (non-linear) equation:
\[ fv + pv \times (1+\text{rate})^{nper} + \text{pmt} \times (1+\text{rate}\times\text{when})/\text{rate} \times ((1+\text{rate})^{nper} - 1) = 0 \]
for rate.

References

3.13 Functional programming

| apply_along_axis(func1d, axis, arr, *args, ...) | Apply a function to 1-D slices along the given axis. |
| apply_over_axes(func, a, axes) | Apply a function repeatedly over multiple axes. |
| vectorize(pyfunc[, otypes, doc, excluded, cache]) | Generalized function class. |
| frompyfunc(func, nin, nout) | Takes an arbitrary Python function and returns a Numpy ufunc. |
| piecewise(x, condlist, funclist, *args, **kw) | Evaluate a piecewise-defined function. |

```
numpy.apply_along_axis(func1d, axis, arr, *args, **kwargs)
```
Apply a function to 1-D slices along the given axis.

Execute `func1d(a, *args)` where `func1d` operates on 1-D arrays and `a` is a 1-D slice of `arr` along `axis`.

Parameters

- **func1d** : function
  This function should accept 1-D arrays. It is applied to 1-D slices of `arr` along the specified axis.

- **axis** : integer
  Axis along which `arr` is sliced.

- **arr** : ndarray
  Input array.

- **args** : any
  Additional arguments to `func1d`.

- **kwargs** : any
  Additional named arguments to `func1d`.

New in version 1.9.0.

Returns

- **apply_along_axis** : ndarray
  The output array. The shape of `outarr` is identical to the shape of `arr`, except along the `axis` dimension, where the length of `outarr` is equal to the size of the return value of `func1d`. If `func1d` returns a scalar `outarr` will have one fewer dimensions than `arr`. 

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See also:

**apply_over_axes**
Apply a function repeatedly over multiple axes.

**Examples**
```python
def my_func(a):
    """Average first and last element of a 1-D array""
    return (a[0] + a[-1]) * 0.5
>> b = np.array([[1,2,3], [4,5,6], [7,8,9]])
>>> np.apply_along_axis(my_func, 0, b)
array([ 4., 5., 6.])
```
```python
>>> np.apply_along_axis(my_func, 1, b)
array([ 2., 5., 8.])
```
For a function that doesn’t return a scalar, the number of dimensions in *outarr* is the same as *arr*.
```python
>>> b = np.array([[8,1,7], [4,3,9], [5,2,6]])
>>> np.apply_along_axis(sorted, 1, b)
array([[1, 7, 8],
       [3, 4, 9],
       [2, 5, 6]])
```

```python
numpy.apply_over_axes(func, a, axes)
```
Apply a function repeatedly over multiple axes.
`func` is called as `res = func(a, axis)`, where `axis` is the first element of `axes`. The result `res` of the function call must have either the same dimensions as `a` or one less dimension. If `res` has one less dimension than `a`, a dimension is inserted before `axis`. The call to `func` is then repeated for each axis in `axes`, with `res` as the first argument.

**Parameters**
- `func` : function
  This function must take two arguments, `func(a, axis)`.
- `a` : array_like
  Input array.
- `axes` : array_like
  Axes over which `func` is applied; the elements must be integers.

**Returns**
- `apply_over_axis` : ndarray
  The output array. The number of dimensions is the same as `a`, but the shape can be different. This depends on whether `func` changes the shape of its output with respect to its input.

**See also:**

**apply_along_axis**
Apply a function to 1-D slices of an array along the given axis.

**Notes**
This function is equivalent to tuple axis arguments to reorderable ufuncs with keepdims=True. Tuple axis arguments to ufuncs have been available since version 1.7.0.
Examples

```python
>>> a = np.arange(24).reshape(2,3,4)
>>> a
array([[[ 0, 1, 2, 3],
        [ 4, 5, 6, 7],
        [ 8, 9, 10, 11]],
       [[12, 13, 14, 15],
        [16, 17, 18, 19],
        [20, 21, 22, 23]]])
```

Sum over axes 0 and 2. The result has same number of dimensions as the original array:

```python
>>> np.apply_over_axes(np.sum, a, [0,2])
array([[[ 60],
        [ 92],
        [124]]])
```

Tuple axis arguments to ufuncs are equivalent:

```python
>>> np.sum(a, axis=(0,2), keepdims=True)
array([[[ 60],
        [ 92],
        [124]]])
```

class `numpy.vectorize`(pyfunc, otypes='', doc=None, excluded=None, cache=False)

Generalized function class.

Define a vectorized function which takes a nested sequence of objects or numpy arrays as inputs and returns a numpy array as output. The vectorized function evaluates `pyfunc` over successive tuples of the input arrays like the python map function, except it uses the broadcasting rules of numpy.

The data type of the output of `vectorized` is determined by calling the function with the first element of the input. This can be avoided by specifying the `otypes` argument.

**Parameters**

- **pyfunc**: callable
  A python function or method.

- **otypes**: str or list of dtypes, optional
  The output data type. It must be specified as either a string of keycode characters or a list of data type specifiers. There should be one data type specifier for each output.

- **doc**: str, optional
  The docstring for the function. If None, the docstring will be the `pyfunc.__doc__`.

- **excluded**: set, optional
  Set of strings or integers representing the positional or keyword arguments for which the function will not be vectorized. These will be passed directly to `pyfunc` unmodified.

  New in version 1.7.0.

- **cache**: bool, optional
  If True, then cache the first function call that determines the number of outputs if `otypes` is not provided.

  New in version 1.7.0.

**Returns**

- **vectorized**: callable
Vectorized function.

Notes

The `vectorize` function is provided primarily for convenience, not for performance. The implementation is essentially a for loop.

If `otypes` is not specified, then a call to the function with the first argument will be used to determine the number of outputs. The results of this call will be cached if `cache` is True to prevent calling the function twice. However, to implement the cache, the original function must be wrapped which will slow down subsequent calls, so only do this if your function is expensive.

The new keyword argument interface and excluded argument support further degrades performance.

Examples

```python
>>> def myfunc(a, b):
...     "Return a\-b if a>b, otherwise return a\+b"
...     if a > b:
...         return a - b
...     else:
...         return a + b

>>> vfunc = np.vectorize(myfunc)
>>> vfunc([1, 2, 3, 4], 2)
a
array([3, 4, 1, 2])

The docstring is taken from the input function to `vectorize` unless it is specified

```python
>>> vfunc.__doc__
"Return a\-b if a>b, otherwise return a\+b"
```  

```python
>>> vfunc = np.vectorize(myfunc, doc='Vectorized 'myfunc')
>>> vfunc.__doc__
'Vectorized 'myfunc'
```

The output type is determined by evaluating the first element of the input, unless it is specified

```python
>>> out = vfunc([1, 2, 3, 4], 2)
>>> type(out[0])
<type 'numpy.int32'>
```  

```python
>>> vfunc = np.vectorize(myfunc, otypes=[np.float])
>>> out = vfunc([1, 2, 3, 4], 2)
>>> type(out[0])
<type 'numpy.float64'>
```

The excluded argument can be used to prevent vectorizing over certain arguments. This can be useful for array-like arguments of a fixed length such as the coefficients for a polynomial as in `polyval`:

```python
>>> def mypolyval(p, x):
...     _p = list(p)
...     res = _p.pop(0)
...     while _p:
...         res = res*x + _p.pop(0)
...     return res

>>> vpolyval = np.vectorize(mypolyval, excluded=['p'])
>>> vpolyval(p=[1, 2, 3], x=[0, 1])
a
array([3, 6])
```

Positional arguments may also be excluded by specifying their position:
NumPy Reference, Release 1.9.2

>>> vpolyval.excluded.add(0)
>>> vpolyval([1, 2, 3], x=[0, 1])
array([3, 6])

Methods

__call__(*args, **kwargs)
Return arrays with the results of pyfunc broadcast (vectorized) over args and kwargs not in excluded.

vectorize.__call__(*args, **kwargs)
Return arrays with the results of pyfunc broadcast (vectorized) over args and kwargs not in excluded.

numpy.frompyfunc(func, nin, nout)
Takes an arbitrary Python function and returns a Numpy ufunc.

Can be used, for example, to add broadcasting to a built-in Python function (see Examples section).

Parameters

func : Python function object
An arbitrary Python function.

nin : int
The number of input arguments.

nout : int
The number of objects returned by func.

Returns

out : ufunc
Returns a Numpy universal function (ufunc) object.

Notes

The returned ufunc always returns PyObject arrays.

Examples

Use frompyfunc to add broadcasting to the Python function oct:

>>> oct_array = np.frompyfunc(oct, 1, 1)
>>> oct_array(np.array((10, 30, 100)))
array(['012', '036', '0144'], dtype='|S4')

numpy.piecewise(x, condlist, funclist, *args, **kw)
Evaluate a piecewise-defined function.

Given a set of conditions and corresponding functions, evaluate each function on the input data wherever its condition is true.

Parameters

x : ndarray
The input domain.

condlist : list of bool arrays

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Each boolean array corresponds to a function in `funclist`. Wherever `condlist[i]` is True, `funclist[i](x)` is used as the output value.

Each boolean array in `condlist` selects a piece of `x`, and should therefore be of the same shape as `x`.

The length of `condlist` must correspond to that of `funclist`. If one extra function is given, i.e. if `len(funclist) - len(condlist) == 1`, then that extra function is the default value, used wherever all conditions are false.

- **funclist**: list of callables, `f(x,*args,**kw)`, or scalars
  
  Each function is evaluated over `x` wherever its corresponding condition is True. It should take an array as input and give an array or a scalar value as output. If, instead of a callable, a scalar is provided then a constant function (`lambda x: scalar`) is assumed.

- **args**: tuple, optional
  
  Any further arguments given to `piecewise` are passed to the functions upon execution, i.e., if called `piecewise(..., ..., 1, 'a')`, then each function is called as `f(x, 1, 'a')`.

- **kw**: dict, optional
  
  Keyword arguments used in calling `piecewise` are passed to the functions upon execution, i.e., if called `piecewise(..., ..., lambda=1)`, then each function is called as `f(x, lambda=1)`.

**Returns**

- **out**: ndarray
  
  The output is the same shape and type as `x` and is found by calling the functions in `funclist` on the appropriate portions of `x`, as defined by the boolean arrays in `condlist`. Portions not covered by any condition have a default value of 0.

**See also:**

- `choose`, `select`, `where`

**Notes**

This is similar to `choose` or `select`, except that functions are evaluated on elements of `x` that satisfy the corresponding condition from `condlist`.

The result is:

```python
|--
|funclist[0](x[condlist[0]])
|funclist[1](x[condlist[1]])
|...
|funclist[n2](x[condlist[n2]])
|--
```

**Examples**

Define the sigma function, which is `-1` for `x < 0` and `+1` for `x >= 0`.

```python
>>> x = np.linspace(-2.5, 2.5, 6)
>>> np.piecewise(x, [x < 0, x >= 0], [-1, 1])
array([-1., -1., -1., 1., 1., 1.])
```

Define the absolute value, which is `-x` for `x < 0` and `x` for `x >= 0`.

```python
>>> x = np.linspace(-2.5, 2.5, 6)
>>> np.piecewise(x, [x < 0, x >= 0], [np.abs(x), x])
array([-2.5, -2.5, -2.5,  2.5,  2.5,  2.5])
```
>>> np.piecewise(x, [x < 0, x >= 0], [lambda x: -x, lambda x: x])
array([ 2.5,  1.5,  0.5,  0.5,  1.5,  2.5])

3.14 Numpy-specific help functions

3.14.1 Finding help

```
lookfor(what[, module, import_modules, ...])  # Do a keyword search on docstrings.
```

```
numpy.lookfor(what, module=None, import_modules=True, regenerate=False, output=None)

  Do a keyword search on docstrings.

  A list of of objects that matched the search is displayed, sorted by relevance. All given keywords need to be
  found in the docstring for it to be returned as a result, but the order does not matter.

  Parameters

    what : str
      String containing words to look for.

    module : str or list, optional
      Name of module(s) whose docstrings to go through.

    import_modules : bool, optional
      Whether to import sub-modules in packages. Default is True.

    regenerate : bool, optional
      Whether to re-generate the docstring cache. Default is False.

    output : file-like, optional
      File-like object to write the output to. If omitted, use a pager.

  See also:

    source, info

  Notes

  Relevance is determined only roughly, by checking if the keywords occur in the function name, at the start of a
docstring, etc.

  Examples

  >>> np.lookfor('binary representation')
  Search results for 'binary representation'
  ------------------------------------------
  numpy.binary_repr
    Return the binary representation of the input number as a string.
  numpy.core.setup_common.long_double_representation
    Given a binary dump as given by GNU od -b, look for long double
  numpy.base_repr
    Return a string representation of a number in the given base system.
  ...
```
3.14.2 Reading help

```
info((object, maxwidth, output, toplevel))  Get help information for a function, class, or module.
source((object, output))                  Print or write to a file the source code for a Numpy object.
```

```
numpy.info(object=None, maxwidth=76, output=<open file 'stdout', mode 'w' at 0x402ab078>, toplevel='numpy')
```

Get help information for a function, class, or module.

**Parameters**

- **object**: object or str, optional
  
  Input object or name to get information about. If `object` is a numpy object, its doc-string is given. If it is a string, available modules are searched for matching objects. If None, information about `info` itself is returned.

- **maxwidth**: int, optional
  
  Printing width.

- **output**: file like object, optional
  
  File like object that the output is written to, default is `stdout`. The object has to be opened in 'w' or 'a' mode.

- **toplevel**: str, optional
  
  Start search at this level.

**See also:**

`source`, `lookfor`

**Notes**

When used interactively with an object, `np.info(obj)` is equivalent to `help(obj)` on the Python prompt or `obj?` on the IPython prompt.

**Examples**

```
>>> np.info(np.polyval)
polyval(p, x)
   Evaluate the polynomial p at x.
   ...
```

When using a string for `object` it is possible to get multiple results.

```
>>> np.info('fft')
   *** Found in numpy ***
Core FFT routines
   ...
   *** Found in numpy.fft ***
   fft(a, n=None, axis=-1)
   ...
   *** Repeat reference found in numpy.fft.fftpack ***
   *** Total of 3 references found. ***
```

```
numpy.source((object, output=<open file 'stdout', mode 'w' at 0x402ab078>))
```

Print or write to a file the source code for a Numpy object.

The source code is only returned for objects written in Python. Many functions and classes are defined in C and will therefore not return useful information.
Parameters

object : numpy object

Input object. This can be any object (function, class, module, ...).

output : file object, optional

If output not supplied then source code is printed to screen (sys.stdout). File object must be created with either write ‘w’ or append ‘a’ modes.

See also:

lookfor, info

Examples

```python
>>> np.source(np.interp)
In file: /usr/lib/python2.6/dist-packages/numpy/lib/function_base.py
def interp(x, xp, fp, left=None, right=None):
   """... (full docstring printed)""
   if isinstance(x, (float, int, number)):
      return compiled_interp([x], xp, fp, left, right).item()
   else:
      return compiled_interp(x, xp, fp, left, right)
```

The source code is only returned for objects written in Python.

```python
>>> np.source(np.array)
Not available for this object.
```

3.15 Indexing routines

See also:

Indexing

3.15.1 Generating index arrays

<table>
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<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td><code>c_</code></td>
<td>Translates slice objects to concatenation along the second axis.</td>
</tr>
<tr>
<td><code>r_</code></td>
<td>Translates slice objects to concatenation along the first axis.</td>
</tr>
<tr>
<td><code>s_</code></td>
<td>A nicer way to build up index tuples for arrays.</td>
</tr>
<tr>
<td><code>nonzero(a)</code></td>
<td>Return the indices of the elements that are non-zero.</td>
</tr>
<tr>
<td><code>where(condition, [x, y])</code></td>
<td>Return elements, either from ( x ) or ( y ), depending on ( condition ).</td>
</tr>
<tr>
<td><code>indices(dimensions[, dtype])</code></td>
<td>Return an array representing the indices of a grid.</td>
</tr>
<tr>
<td><code>ix_(*args)</code></td>
<td>Construct an open mesh from multiple sequences.</td>
</tr>
<tr>
<td><code>ogrid</code></td>
<td>Converts a tuple of index arrays into an array of flat indices, applying boundary conditions.</td>
</tr>
<tr>
<td><code>ravel_multi_index</code>(multi_index, dims[, mode, ...])</td>
<td>Converts a tuple of index arrays into a tuple of coordinate arrays.</td>
</tr>
<tr>
<td><code>unravel_index</code>(indices, dims[, order])</td>
<td>Return the indices to access the main diagonal of an array.</td>
</tr>
<tr>
<td><code>diag_indices</code>(n[, ndim])</td>
<td>Return the indices to access the main diagonal of an n-dimensional array.</td>
</tr>
<tr>
<td><code>diag_indices_from</code>(arr)</td>
<td>Return the indices to access the main diagonal of ( arr ).</td>
</tr>
<tr>
<td><code>mask_indices</code>(n, mask_func[, k])</td>
<td>Return the indices to access ( (n, n) ) arrays, given a masking function.</td>
</tr>
<tr>
<td><code>tril_indices</code>(n[, k, m])</td>
<td>Return the indices for the lower-triangle of ( (n, m) ) array.</td>
</tr>
<tr>
<td><code>tril_indices_from</code>(arr[, k])</td>
<td>Return the indices for the lower-triangle of ( arr ).</td>
</tr>
<tr>
<td><code>triu_indices</code>(n[, k, m])</td>
<td>Return the indices for the upper-triangle of ( (n, m) ) array.</td>
</tr>
</tbody>
</table>
Table 3.53 – continued from previous page

**triu_indices_from**

(arr[, k])

Return the indices for the upper-triangle of arr.

```python
numpy.c_ = <numpy.lib.index_tricks.CClass object at 0x41607e6c>

Translates slice objects to concatenation along the second axis.

This is short-hand for np.r_['-1,2,0', index expression], which is useful because of its common occurrence. In particular, arrays will be stacked along their last axis after being upgraded to at least 2-D with 1’s post-pended to the shape (column vectors made out of 1-D arrays).

For detailed documentation, see r_.

**Examples**

```python
>>> np.c_[np.array([[1,2,3]]), 0, 0, np.array([[4,5,6]]))
array([[1, 2, 3, 0, 0, 4, 5, 6]])
```

```python
numpy.r_ = <numpy.lib.index_tricks.RClass object at 0x41607dcc>

Translates slice objects to concatenation along the first axis.

This is a simple way to build up arrays quickly. There are two use cases.

1. If the index expression contains comma separated arrays, then stack them along their first axis.

2. If the index expression contains slice notation or scalars then create a 1-D array with a range indicated by the slice notation.

If slice notation is used, the syntax start:stop:step is equivalent to np.arange(start, stop, step) inside of the brackets. However, if step is an imaginary number (i.e. 100j) then its integer portion is interpreted as a number-of-points desired and the start and stop are inclusive. In other words start:stop:stepj is interpreted as np.linspace(start, stop, step, endpoint=1) inside of the brackets. After expansion of slice notation, all comma separated sequences are concatenated together.

Optional character strings placed as the first element of the index expression can be used to change the output. The strings ‘r’ or ‘c’ result in matrix output. If the result is 1-D and ‘r’ is specified a 1 x N (row) matrix is produced. If the result is 1-D and ‘c’ is specified, then a N x 1 (column) matrix is produced. If the result is 2-D then both provide the same matrix result.

A string integer specifies which axis to stack multiple comma separated arrays along. A string of two comma-separated integers allows indication of the minimum number of dimensions to force each entry into as the second integer (the axis to concatenate along is still the first integer).

A string with three comma-separated integers allows specification of the axis to concatenate along, the minimum number of dimensions to force the entries to, and which axis should contain the start of the arrays which are less than the specified number of dimensions. In other words the third integer allows you to specify where the 1’s should be placed in the shape of the arrays that have their shapes upgraded. By default, they are placed in the front of the shape tuple. The third argument allows you to specify where the start of the array should be instead. Thus, a third argument of ‘0’ would place the 1’s at the end of the array shape. Negative integers specify where in the new shape tuple the last dimension of upgraded arrays should be placed, so the default is ‘-1’.

**Parameters**

Not a function, so takes no parameters

**Returns**

A concatenated ndarray or matrix.

**See also:**

- **concatenate**

Join a sequence of arrays together.
c_

Translates slice objects to concatenation along the second axis.

**Examples**

```python
>>> np.r_[np.array([1,2,3]), 0, 0, np.array([4,5,6])]
aarray([1, 2, 3, 0, 0, 4, 5, 6])
```

```python
>>> np.r_[-1:1:6j, [0]*3, 5, 6]
aarray([-1., -0.6, -0.2, 0.2, 0.6, 1., 0., 0., 0., 5., 6.])
```

String integers specify the axis to concatenate along or the minimum number of dimensions to force entries into.

```python
>>> a = np.array([[0, 1, 2], [3, 4, 5]])
```

```python
>>> np.r_['-1', a, a]  # concatenate along last axis
aarray([[0, 1, 2, 0, 1, 2],
        [3, 4, 5, 3, 4, 5]])
```

```python
>>> np.r_['0,2', [1,2,3], [4,5,6]]  # concatenate along first axis, dim>=2
aarray([[1, 2, 3],
        [4, 5, 6]])
```

```python
>>> np.r_['0,2,0', [1,2,3], [4,5,6]]
aarray([[1],
        [2],
        [3],
        [4],
        [5],
        [6]])
```

```python
>>> np.r_['1,2,0', [1,2,3], [4,5,6]]
aarray([[1, 4],
        [2, 5],
        [3, 6]])
```

Using 'r' or 'c' as a first string argument creates a matrix.

```python
>>> np.r_['r',[1,2,3], [4,5,6]]
matrix([[1, 2, 3, 4, 5, 6]])
```

**Note:** Use one of the two predefined instances `index_exp` or `s_` rather than directly using `IndexExpression`.

For any index combination, including slicing and axis insertion, `a[indices]` is the same as `a[np.index_exp[indices]]` for any array `a`. However, `np.index_exp[indices]` can be used anywhere in Python code and returns a tuple of slice objects that can be used in the construction of complex index expressions.

**Parameters**

- `maketuple` : bool
  If True, always returns a tuple.

**See also:**

- `index_exp`
  Predefined instance that always returns a tuple: `index_exp = IndexExpression(maketuple=True)`.

- `s_`
  Predefined instance without tuple conversion: `s_ = IndexExpression(maketuple=False)`. 
Notes

You can do all this with `slice()` plus a few special objects, but there’s a lot to remember and this version is simpler because it uses the standard array indexing syntax.

Examples

```python
>>> np.s_[2::2]
slice(2, None, 2)
>>> np.index_exp[2::2]
(slice(2, None, 2),)

>>> np.array([0, 1, 2, 3, 4])[np.s_[2::2]]
array([2, 4])
```

**numpy.nonzero(a)**

Return the indices of the elements that are non-zero.

Returns a tuple of arrays, one for each dimension of `a`, containing the indices of the non-zero elements in that dimension. The corresponding non-zero values can be obtained with:

```python
a[nonzero(a)]
```

To group the indices by element, rather than dimension, use:

```python
transpose(nonzero(a))
```

The result of this is always a 2-D array, with a row for each non-zero element.

**Parameters**

- `a`: array_like
  Input array.

**Returns**

- `tuple_of_arrays`: tuple
  Indices of elements that are non-zero.

**See also:**

- `flatnonzero`
  Return indices that are non-zero in the flattened version of the input array.

- `ndarray.nonzero`
  Equivalent ndarray method.

- `count_nonzero`
  Counts the number of non-zero elements in the input array.

**Examples**

```python
>>> x = np.eye(3)
```

```python
array([(0, 1, 2, 3, 4)][np.s_[2::2]])
```

```python
numpy.nonzero(a)
```

Return the indices of the elements that are non-zero.

Returns a tuple of arrays, one for each dimension of `a`, containing the indices of the non-zero elements in that dimension. The corresponding non-zero values can be obtained with:

```python
a[nonzero(a)]
```

To group the indices by element, rather than dimension, use:

```python
transpose(nonzero(a))
```

The result of this is always a 2-D array, with a row for each non-zero element.

**Parameters**

- `a`: array_like
  Input array.

**Returns**

- `tuple_of_arrays`: tuple
  Indices of elements that are non-zero.

**See also:**

- `flatnonzero`
  Return indices that are non-zero in the flattened version of the input array.

- `ndarray.nonzero`
  Equivalent ndarray method.

- `count_nonzero`
  Counts the number of non-zero elements in the input array.

**Examples**

```python
>>> x = np.eye(3)
```

```python
array([(0, 1, 2, 3, 4)][np.s_[2::2]])
```
A common use for `nonzero` is to find the indices of an array, where a condition is True. Given an array `a`, the condition `a > 3` is a boolean array and since False is interpreted as 0, `np.nonzero(a > 3)` yields the indices of the `a` where the condition is true.

```python
>>> a = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])
>>> a > 3
array([[False, False, False],
       [ True,  True,  True],
       [ True,  True,  True]], dtype=bool)
>>> np.nonzero(a > 3)
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

The `nonzero` method of the boolean array can also be called.

```python
>>> (a > 3).nonzero()
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

`numpy.where(condition[, x, y])`

Return elements, either from `x` or `y`, depending on `condition`.

If only `condition` is given, return `condition.nonzero()`.

Parameters

- `condition`: array_like, bool
  When True, yield `x`, otherwise yield `y`.
- `x, y`: array_like, optional
  Values from which to choose. `x` and `y` need to have the same shape as `condition`.

Returns

- `out`: ndarray or tuple of ndarrays
  If both `x` and `y` are specified, the output array contains elements of `x` where `condition` is True, and elements from `y` elsewhere.
  If only `condition` is given, return the tuple `condition.nonzero()`, the indices where `condition` is True.

See also:

- `nonzero`, `choose`

Notes

If `x` and `y` are given and input arrays are 1-D, `where` is equivalent to:

```python
[xv if c else yv for (c,xv,yv) in zip(condition,x,y)]
```

Examples

```python
>>> np.where([[True, False], [True, True]],
           [[1, 2], [3, 4]],
           [[9, 8], [7, 6]])
```
array([[1, 8],
       [3, 4]])

>>> np.where([[0, 1], [1, 0]])
(array([0, 1]), array([1, 0]))

>>> x = np.arange(9.).reshape(3, 3)
>>> np.where(x > 5)
(array([2, 2, 2]), array([0, 1, 2]))

>>> x[np.where(x > 3.0)]  # Note: result is 1D.
array([4., 5., 6., 7., 8.])

>>> np.where(x < 5, x, -1)  # Note: broadcasting.
array([[  0.,   1.,   2.],
       [  3.,   4., -1.],
       [-1., -1., -1.]])

Find the indices of elements of x that are in goodvalues.

>>> goodvalues = [3, 4, 7]
>>> ix = np.in1d(x.ravel(), goodvalues).reshape(x.shape)
>>> ix
array([[False, False, False],
       [ True,  True, False],
       [False, True, False]], dtype=bool)

numpy.indices(dimensions, dtype=<type 'int'>)
Return an array representing the indices of a grid.

Compute an array where the subarrays contain index values 0,1,... varying only along the corresponding axis.

Parameters

- dimensions : sequence of ints
  The shape of the grid.
- dtype : dtype, optional
  Data type of the result.

Returns

- grid : ndarray
  The array of grid indices, grid.shape = (len(dimensions),) + tuple(dimensions).

See also:

mgrid, meshgrid

Notes

The output shape is obtained by prepending the number of dimensions in front of the tuple of dimensions, i.e. if dimensions is a tuple (r0, ..., rN-1) of length N, the output shape is (N, r0, ..., rN-1).

The subarrays grid[k] contains the N-D array of indices along the k-th axis. Explicitly:
grid[k, i0, i1, ..., iN-1] = ik
Examples

```python
>>> grid = np.indices((2, 3))
>>> grid.shape
(2, 2, 3)
>>> grid[0]  # row indices
array([[0, 0, 0],
       [1, 1, 1]])
>>> grid[1]  # column indices
array([[0, 1, 2],
       [0, 1, 2]])
```

The indices can be used as an index into an array.

```python
>>> x = np.arange(20).reshape(5, 4)
>>> row, col = np.indices((2, 3))
>>> x[row, col]
array([[0, 1, 2],
       [4, 5, 6]])
```

Note that it would be more straightforward in the above example to extract the required elements directly with `x[:, :3].`

```
numpy.ix_(*args)
Construct an open mesh from multiple sequences.

This function takes N 1-D sequences and returns N outputs with N dimensions each, such that the shape is 1 in all but one dimension and the dimension with the non-unit shape value cycles through all N dimensions.

Using `ix_` one can quickly construct index arrays that will index the cross product. `a[np.ix_([1,3],[2,5])]` returns the array `[[a[1,2] a[1,5]], [a[3,2] a[3,5]]].`

Parameters

- `args`: 1-D sequences

Returns

- `out`: tuple of ndarrays

  N arrays with N dimensions each, with N the number of input sequences. Together these arrays form an open mesh.

See also:

`ogrid, mgrid, meshgrid`

Examples

```python
>>> a = np.arange(10).reshape(2, 5)
>>> a
array([[0, 1, 2, 3, 4],
       [5, 6, 7, 8, 9]])
>>> ixgrid = np.ix_([0,1], [2,4])
>>> ixgrid
(array([[0],
        [1]]), array([[2, 4]]))
>>> ixgrid[0].shape, ixgrid[1].shape
((2, 1), (1, 2))
>>> a[ixgrid]
array([[2, 4],
       [7, 9]])
```
NumPy Reference, Release 1.9.2

numpy.ogrid = <numpy.lib.index_tricks.nd_grid object at 0x41607d4c>

nd_grid instance which returns an open multi-dimensional “meshgrid”.

An instance of numpy.lib.index_tricks.nd_grid which returns an open (i.e. not fleshed out) meshgrid when indexed, so that only one dimension of each returned array is greater than 1. The dimension and number of the output arrays are equal to the number of indexing dimensions. If the step length is not a complex number, then the stop is not inclusive.

However, if the step length is a complex number (e.g. 5j), then the integer part of its magnitude is interpreted as specifying the number of points to create between the start and stop values, where the stop value is inclusive.

Returns
mesh-grid ndarrays with only one dimension ≠ 1

See also:

np.lib.index_tricks.nd_grid
class of ogrid and mgrid objects

mgrid
like ogrid but returns dense (or fleshed out) mesh grids

r_
array concatenator

Examples

>>> from numpy import ogrid
>>> ogrid[-1:1:5j]
array([-1. , -0.5,  0. ,  0.5,  1. ])

Examples

>>> ogrid[0:5,0:5]
[array([[0, 1, 2, 3, 4],
       [1, 2, 3, 4, 5],
       [2, 3, 4, 5, 0],
       [3, 4, 5, 0, 1],
       [4, 0, 1, 2, 3]])]

ndarrays

numpy.ravel_multi_index (multi_index, dims, mode='raise', order='C')

Converts a tuple of index arrays into an array of flat indices, applying boundary modes to the multi-index.

Parameters
multi_index : tuple of array_like
    A tuple of integer arrays, one array for each dimension.
dims : tuple of ints
    The shape of array into which the indices from multi_index apply.
mode : {'raise', 'wrap', 'clip'}, optional
    Specifies how out-of-bounds indices are handled. Can specify either one mode or a tuple of modes, one mode per index.
    • 'raise' – raise an error (default)
    • 'wrap' – wrap around
    • 'clip' – clip to the range
    In ‘clip’ mode, a negative index which would normally wrap will clip to 0 instead.
order : {'C', 'F'}, optional

3.15. Indexing routines
Determines whether the multi-index should be viewed as indexing in C (row-major) order or FORTRAN (column-major) order.

Returns

raveled_indices : ndarray

An array of indices into the flattened version of an array of dimensions dims.

See also:
unravel_index

Notes

New in version 1.6.0.

Examples

```python
>>> arr = np.array([[3, 6, 6], [4, 5, 1]])
>>> np.ravel_multi_index(arr, (7, 6))
array([22, 41, 37])
```

```python
>>> np.ravel_multi_index(arr, (7, 6), order='F')
array([31, 41, 13])
```

```python
>>> np.ravel_multi_index(arr, (4, 6), mode='clip')
array([22, 23, 19])
```

```python
>>> np.ravel_multi_index(arr, (4, 4), mode=('clip', 'wrap'))
array([12, 13, 13])
```

```python
>>> np.ravel_multi_index((3, 1, 4, 1), (6, 7, 8, 9))
1621
```

`numpy.unravel_index(indices, dims, order='C')`

Converts a flat index or array of flat indices into a tuple of coordinate arrays.

Parameters

- indices : array_like
  An integer array whose elements are indices into the flattened version of an array of dimensions dims. Before version 1.6.0, this function accepted just one index value.

- dims : tuple of ints
  The shape of the array to use for unraveling indices.

- order : {'C', 'F'}, optional
  New in version 1.6.0.
  Determines whether the indices should be viewed as indexing in C (row-major) order or FORTRAN (column-major) order.

Returns

- unraveled_coords : tuple of ndarray
  Each array in the tuple has the same shape as the indices array.

See also:
ravel_multi_index

Examples
```python
>>> np.unravel_index([22, 41, 37], (7,6))
(array([3, 6, 6]), array([4, 5, 1]))
>>> np.unravel_index([31, 41, 13], (7,6), order='F')
(array([3, 6, 6]), array([4, 5, 1]))
```

```python
np.unravel_index(1621, (6,7,8,9))
(3, 1, 4, 1)
```

**numpy.diag_indices (n, ndim=2)**

Return the indices to access the main diagonal of an array.

This returns a tuple of indices that can be used to access the main diagonal of an array `a` with `a.ndim` >= 2 dimensions and shape `(n, n, ..., n)`. For `a.ndim = 2` this is the usual diagonal, for `a.ndim > 2` this is the set of indices to access `a[i, i, ..., i]` for `i = [0..n-1]`.

**Parameters**

- `n` : int
  The size, along each dimension, of the arrays for which the returned indices can be used.

- `ndim` : int, optional
  The number of dimensions.

**See also:**

diag_indices_from

**Notes**

New in version 1.4.0.

**Examples**

Create a set of indices to access the diagonal of a `(4, 4)` array:

```python
>>> di = np.diag_indices(4)
>>> di
(array([0, 1, 2, 3]), array([0, 1, 2, 3]))
>>> a = np.arange(16).reshape(4, 4)
>>> a
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11],
       [12, 13, 14, 15]])
>>> a[di] = 100
>>> a
array([[ 100,   1,   2,   3],
       [  4, 100,   6,   7],
       [  8,   9, 100,  11],
       [ 12,  13,  14, 100]])
```

Now, we create indices to manipulate a 3-D array:

```python
>>> d3 = np.diag_indices(2, 3)
>>> d3
(array([0, 1]), array([0, 1]), array([0, 1]))
```

And use it to set the diagonal of an array of zeros to 1:

```python
```
```python
>>> a = np.zeros((2, 2, 2), dtype=np.int)
>>> a[d3] = 1
>>> a
array([[[1, 0],
         [0, 0]],
        [[0, 0],
         [0, 1]]])
```

`numpy.diag_indices_from(arr)`

Return the indices to access the main diagonal of an n-dimensional array.

See `diag_indices` for full details.

**Parameters**

- arr : array, at least 2-D

**See also:**

diag_indices

**Notes**

New in version 1.4.0.

`numpy.mask_indices(n, mask_func, k=0)`

Return the indices to access (n, n) arrays, given a masking function.

Assume `mask_func` is a function that, for a square array `a` of size `(n, n)` with a possible offset argument `k`, when called as `mask_func(a, k)` returns a new array with zeros in certain locations (functions like `triu` or `tril` do precisely this). Then this function returns the indices where the non-zero values would be located.

**Parameters**

- n : int
  
The returned indices will be valid to access arrays of shape `(n, n)`.

- mask_func : callable
  
  A function whose call signature is similar to that of `triu`, `tril`. That is, `mask_func(x, k)` returns a boolean array, shaped like `x`. `k` is an optional argument to the function.

- k : scalar
  
  An optional argument which is passed through to `mask_func`. Functions like `triu`, `tril` take a second argument that is interpreted as an offset.

**Returns**

- indices : tuple of arrays.
  
  The `n` arrays of indices corresponding to the locations where `mask_func(np.ones((n, n)), k)` is True.

**See also:**

triu, tri, triu_indices, tril_indices

**Notes**

New in version 1.4.0.
Examples

These are the indices that would allow you to access the upper triangular part of any 3x3 array:

```python
>>> iu = np.mask_indices(3, np.triu)
```

For example, if `a` is a 3x3 array:

```python
>>> a = np.arange(9).reshape(3, 3)
>>> a
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])

>>> a[iu]
array([0, 1, 2, 4, 5, 8])
```

An offset can be passed also to the masking function. This gets us the indices starting on the first diagonal right of the main one:

```python
>>> iu1 = np.mask_indices(3, np.triu, 1)
```

with which we now extract only three elements:

```python
>>> a[iu1]
array([1, 2, 5])
```

`numpy.tril_indices`(n, k=0, m=None)

Return the indices for the lower-triangle of an (n, m) array.

Parameters

- `n` : int
  - The row dimension of the arrays for which the returned indices will be valid.

- `k` : int, optional
  - Diagonal offset (see `tril` for details).

- `m` : int, optional
  - New in version 1.9.0.
  - The column dimension of the arrays for which the returned arrays will be valid. By default `m` is taken equal to `n`.

Returns

- `inds` : tuple of arrays
  - The indices for the triangle. The returned tuple contains two arrays, each with the indices along one dimension of the array.

See also:

- `triu_indices`
  - similar function, for upper-triangular.

- `mask_indices`
  - generic function accepting an arbitrary mask function.

- `tril`, `triu`

Notes

New in version 1.4.0.
Examples

Compute two different sets of indices to access 4x4 arrays, one for the lower triangular part starting at the main diagonal, and one starting two diagonals further right:

```python
>>> il1 = np.tril_indices(4)
>>> il2 = np.tril_indices(4, 2)
```

Here is how they can be used with a sample array:

```python
>>> a = np.arange(16).reshape(4, 4)
>>> a
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11],
       [12, 13, 14, 15]])
```

Both for indexing:

```python
>>> a[il1]
array([ 0,  4,  5,  8,  9, 10, 12, 13, 14, 15])
```

And for assigning values:

```python
>>> a[il1] = -1

>>> a
array([[ -1,  1,  2,  3],
       [ -1, -1,  6,  7],
       [ -1, -1, -1, 11],
       [ -1, -1, -1, -1]])
```

These cover almost the whole array (two diagonals right of the main one):

```python
>>> a[il2] = -10

>>> a
array([[ -10, -10, -10,  3],
       [ -10, -10, -10, -10],
       [ -10, -10, -10, -10],
       [ -10, -10, -10, -10]])
```

**numpy.tril_indices_from(arr, k=0)**

Return the indices for the lower-triangle of arr.

See `tril_indices` for full details.

Parameters

- **arr**: array_like
  The indices will be valid for square arrays whose dimensions are the same as arr.

- **k**: int, optional
  Diagonal offset (see `tril` for details).

See also:

- `tril_indices`, `tril`

Notes

New in version 1.4.0.

**numpy.triu_indices(n, k=0, m=None)**

Return the indices for the upper-triangle of an (n, m) array.
Parameters

n : int
   The size of the arrays for which the returned indices will be valid.

k : int, optional
   Diagonal offset (see triu for details).

m : int, optional
   New in version 1.9.0.
   The column dimension of the arrays for which the returned arrays will be valid. By default m is taken equal to n.

Returns

inds : tuple, shape(2) of ndarrays, shape(n)
   The indices for the triangle. The returned tuple contains two arrays, each with the indices along one dimension of the array. Can be used to slice a ndarray of shape(n, n).

See also:

tril_indices
   similar function, for lower-triangular.

mask_indices
   generic function accepting an arbitrary mask function.

triu, tril

Notes

New in version 1.4.0.

Examples

Compute two different sets of indices to access 4x4 arrays, one for the upper triangular part starting at the main diagonal, and one starting two diagonals further right:

```python
>>> iu1 = np.triu_indices(4)
>>> iu2 = np.triu_indices(4, 2)
```

Here is how they can be used with a sample array:

```python
>>> a = np.arange(16).reshape(4, 4)
>>> a
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11],
       [12, 13, 14, 15]])
```

Both for indexing:

```python
>>> a[iu1]
array([ 0,  1,  2,  3,  5,  6,  7, 10, 11, 15])
```

And for assigning values:

```python
>>> a[iu1] = -1
>>> a
array([[-1, -1, -1, -1],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11],
       [12, 13, 14, 15]])
```
These cover only a small part of the whole array (two diagonals right of the main one):

```python
>>> a[iu2] = -10
>>> a
array([[ -1, -1, -10, -10],
       [ 4, -1, -1, -10],
       [ 8,  9, -1,  -1],
       [12, 13, 14,  -1]])
```

```
numpy.triu_indices_from(arr, k=0)
```

Return the indices for the upper-triangle of arr.

See `triu_indices` for full details.

Parameters

- **arr**: ndarray, shape(N, N)
  
The indices will be valid for square arrays.

- **k**: int, optional
  
  Diagonal offset (see `triu` for details).

Returns

- **triu_indices_from**: tuple, shape(2) of ndarray, shape(N)
  
  Indices for the upper-triangle of `arr`.

See also:

- `triu_indices, triu`

Notes

New in version 1.4.0.

### 3.15.2 Indexing-like operations

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<td>Take elements from an array along an axis.</td>
</tr>
<tr>
<td><code>choose(a, choices[, out, mode])</code></td>
<td>Construct an array from an index array and a set of arrays to choose from.</td>
</tr>
<tr>
<td><code>compress(condition, a[, axis, out])</code></td>
<td>Return selected slices of an array along given axis.</td>
</tr>
<tr>
<td><code>diag(v[, k])</code></td>
<td>Extract a diagonal or construct a diagonal array.</td>
</tr>
<tr>
<td><code>diagonal(a[, offset, axis1, axis2])</code></td>
<td>Return specified diagonals.</td>
</tr>
<tr>
<td><code>select</code>(condlist, choicelist[, default])</td>
<td>Return an array drawn from elements in choicelist, depending on conditions.</td>
</tr>
</tbody>
</table>

```
numpy.take(a, indices[, axis=None, out=None, mode='raise'])
```

Take elements from an array along an axis.

This function does the same thing as “fancy” indexing (indexing arrays using arrays); however, it can be easier to use if you need elements along a given axis.

Parameters

- **a**: array_like
  
The source array.
indices : array_like

The indices of the values to extract.

New in version 1.8.0.

Also allow scalars for indices.

axis : int, optional

The axis over which to select values. By default, the flattened input array is used.

out : ndarray, optional

If provided, the result will be placed in this array. It should be of the appropriate shape and dtype.

mode : {'raise', ‘wrap’, ‘clip’}, optional

Specifies how out-of-bounds indices will behave.

• ‘raise’ – raise an error (default)
• ‘wrap’ – wrap around
• ‘clip’ – clip to the range

‘clip’ mode means that all indices that are too large are replaced by the index that addresses the last element along that axis. Note that this disables indexing with negative numbers.

Returns

subarray : ndarray

The returned array has the same type as a.

See also:

compress
Take elements using a boolean mask

ndarray.take
equivalent method

Examples

>>> a = [4, 3, 5, 7, 6, 8]
>>> indices = [0, 1, 4]
>>> np.take(a, indices)
array([4, 3, 6])

In this example if a is an ndarray, “fancy” indexing can be used.

>>> a = np.array(a)
>>> a[indices]
array([4, 3, 6])

If indices is not one dimensional, the output also has these dimensions.

>>> np.take(a, [[0, 1], [2, 3]])
array([[4, 3],
       [5, 7]])
numpy.choose(a, choices, out=None, mode='raise')

Construct an array from an index array and a set of arrays to choose from.

First of all, if confused or uncertain, definitely look at the Examples - in its full generality, this function is less simple than it might seem from the following code description (below ndi = numpy.lib.index_tricks):

np.choose(a,c) == np.array([c[a[I]][I] for I in ndi.ndindex(a.shape)]).

But this omits some subtleties. Here is a fully general summary:

Given an “index” array (a) of integers and a sequence of n arrays (choices), a and each choice array are first broadcast, as necessary, to arrays of a common shape; calling these Ba and Bchoices[i], i = 0,...,n-1 we have that, necessarily, Ba.shape == Bchoices[i].shape for each i. Then, a new array with shape Ba.shape is created as follows:

• if mode=raise (the default), then, first of all, each element of a (and thus Ba) must be in the range [0, n-1]; now, suppose that i (in that range) is the value at the (j0, j1, ..., jm) position in Ba - then the value at the same position in the new array is the value in Bchoices[i] at that same position;
• if mode=wrap, values in a (and thus Ba) may be any (signed) integer; modular arithmetic is used to map integers outside the range [0, n-1] back into that range; and then the new array is constructed as above;
• if mode=clip, values in a (and thus Ba) may be any (signed) integer; negative integers are mapped to 0; values greater than n-1 are mapped to n-1; and then the new array is constructed as above.

Parameters

a : int array
   This array must contain integers in [0, n-1], where n is the number of choices, unless mode=wrap or mode=clip, in which cases any integers are permissible.

choices : sequence of arrays
   Choice arrays. a and all of the choices must be broadcastable to the same shape. If choices is itself an array (not recommended), then its outermost dimension (i.e., the one corresponding to choices.shape[0]) is taken as defining the “sequence”.

out : array, optional
   If provided, the result will be inserted into this array. It should be of the appropriate shape and dtype.

mode : {'raise' (default), 'wrap', 'clip'}, optional
   Specifies how indices outside [0, n-1] will be treated:
   • 'raise' : an exception is raised
   • 'wrap' : value becomes value mod n
   • 'clip' : values < 0 are mapped to 0, values > n-1 are mapped to n-1

Returns

merged_array : array
   The merged result.

Raises

ValueError: shape mismatch
   If a and each choice array are not all broadcastable to the same shape.
**ndarray.choose**

Equivalent method

**Notes**

To reduce the chance of misinterpretation, even though the following “abuse” is nominally supported, choices should neither be, nor be thought of as, a single array, i.e., the outermost sequence-like container should be either a list or a tuple.

**Examples**

```python
>>> choices = [[0, 1, 2, 3], [10, 11, 12, 13], ... [20, 21, 22, 23], [30, 31, 32, 33]]
>>> np.choose([2, 3, 1, 0], choices, mode='clip') # 4 goes to 3 (4-1)
array([20, 31, 12, 3])
>>> np.choose([2, 4, 1, 0], choices, mode='wrap') # 4 goes to (4 mod 4)
array([20, 1, 12, 3])
```

A couple examples illustrating how choose broadcasts:

```python
>>> a = [[1, 0, 1], [0, 1, 0], [1, 0, 1]]
>>> choices = [-10, 10]
>>> np.choose(a, choices)
array([[ 10, -10, 10],
       [-10, 10, -10],
       [ 10, -10, 10]])
```

**numpy.compress**

Return selected slices of an array along given axis.

When working along a given axis, a slice along that axis is returned in output for each index where condition evaluates to True. When working on a 1-D array, compress is equivalent to extract.

**Parameters**

- **condition**: 1-D array of bools

Array that selects which entries to return. If len(condition) is less than the size of a along the given axis, then output is truncated to the length of the condition array.
a : array_like

Array from which to extract a part.

axis : int, optional

Axis along which to take slices. If None (default), work on the flattened array.

out : ndarray, optional

Output array. Its type is preserved and it must be of the right shape to hold the output.

Returns

compressed_array : ndarray

A copy of a without the slices along axis for which condition is false.

See also:

take, choose, diag, diagonal, select

ndarray.compress

Equivalent method in ndarray

np.extract

Equivalent method when working on 1-D arrays

numpy.doc.ufuncs

Section “Output arguments”

Examples

>>> a = np.array([[1, 2], [3, 4], [5, 6]])

>>> a

array([[1, 2],
       [3, 4],
       [5, 6]])

>>> np.compress([0, 1], a, axis=0)

array([3, 4])

>>> np.compress([False, True, True], a, axis=0)

array([[3, 4],
       [5, 6]])

>>> np.compress([False, True], a, axis=1)

array([2,
       [4],
       [6]])

Working on the flattened array does not return slices along an axis but selects elements.

>>> np.compress([False, True], a)

array([2])

numpy.diag(v, k=0)

Extract a diagonal or construct a diagonal array.

See the more detailed documentation for numpy.diagonal if you use this function to extract a diagonal and wish to write to the resulting array; whether it returns a copy or a view depends on what version of numpy you are using.

Parameters

v : array_like

If v is a 2-D array, return a copy of its k-th diagonal. If v is a 1-D array, return a 2-D array with v on the k-th diagonal.
k : int, optional
    Diagonal in question. The default is 0. Use k>0 for diagonals above the main diagonal,
    and k<0 for diagonals below the main diagonal.

Returns
    out : ndarray
        The extracted diagonal or constructed diagonal array.

See also:

diagonal
    Return specified diagonals.
diagflat
    Create a 2-D array with the flattened input as a diagonal.
trace
    Sum along diagonals.
triu
    Upper triangle of an array.
tril
    Lower triangle of an array.

Examples
>>> x = np.arange(9).reshape((3,3))
>>> x
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])

>>> np.diag(x)
array([0, 4, 8])

>>> np.diag(x, k=1)
array([1, 5])

>>> np.diag(x, k=-1)
array([3, 7])

>>> np.diag(np.diag(x))
array([[0, 0, 0],
       [0, 4, 0],
       [0, 0, 8]])

numpy.diagonal(a, offset=0, axis1=0, axis2=1)
    Return specified diagonals.

If a is 2-D, returns the diagonal of a with the given offset, i.e., the collection of elements of the form a[i,i+offset]. If a has more than two dimensions, then the axes specified by axis1 and axis2 are used to determine the 2-D sub-array whose diagonal is returned. The shape of the resulting array can be determined by removing axis1 and axis2 and appending an index to the right equal to the size of the resulting diagonals.

In versions of NumPy prior to 1.7, this function always returned a new, independent array containing a copy of the values in the diagonal.

In NumPy 1.7 and 1.8, it continues to return a copy of the diagonal, but depending on this fact is deprecated. Writing to the resulting array continues to work as it used to, but a FutureWarning is issued.
In NumPy 1.9 it returns a read-only view on the original array. Attempting to write to the resulting array will produce an error.

In NumPy 1.10, it will return a read/write view. Writing to the returned array will alter your original array.

If you don’t write to the array returned by this function, then you can just ignore all of the above.

If you depend on the current behavior, then we suggest copying the returned array explicitly, i.e., use `np.diagonal(a).copy()` instead of just `np.diagonal(a)`. This will work with both past and future versions of NumPy.

**Parameters**

- **a**: array_like
  
  Array from which the diagonals are taken.

- **offset**: int, optional
  
  Offset of the diagonal from the main diagonal. Can be positive or negative. Defaults to main diagonal (0).

- **axis1**: int, optional
  
  Axis to be used as the first axis of the 2-D sub-arrays from which the diagonals should be taken. Defaults to first axis (0).

- **axis2**: int, optional
  
  Axis to be used as the second axis of the 2-D sub-arrays from which the diagonals should be taken. Defaults to second axis (1).

**Returns**

- **array_of_diagonals**: ndarray
  
  If `a` is 2-D, a 1-D array containing the diagonal is returned. If the dimension of `a` is larger, then an array of diagonals is returned, “packed” from left-most dimension to right-most (e.g., if `a` is 3-D, then the diagonals are “packed” along rows).

**Raises**

- **ValueError**
  
  If the dimension of `a` is less than 2.

**See also:**

- **diag**: MATLAB work-a-like for 1-D and 2-D arrays.

- **diagflat**: Create diagonal arrays.

- **trace**: Sum along diagonals.

**Examples**

```python
>>> a = np.arange(4).reshape(2,2)
>>> a
array([[0, 1],
        [2, 3]])
>>> a.diagonal()
array([0, 3])
>>> a.diagonal(1)
array([1])
```
A 3-D example:

```python
>>> a = np.arange(8).reshape(2,2,2); a
array([[0, 1],
       [2, 3],
       [4, 5],
       [6, 7]])
>>> a.diagonal(0, # Main diagonals of two arrays created by skipping...
       ... 0, # across the outer(left)-most axis last and...
       ... 1) # the "middle" (row) axis first.
array([[0, 6],
       [1, 7]])
```

The sub-arrays whose main diagonals we just obtained; note that each corresponds to fixing the right-most (column) axis, and that the diagonals are “packed” in rows.

```python
>>> a[:,:,0] # main diagonal is [0 6]
array([[0, 2],
       [4, 6]])
>>> a[:,:,1] # main diagonal is [1 7]
array([[1, 3],
       [5, 7]])
```

**numpy.select** *(condlist, choicelist, default=0)*

Return an array drawn from elements in choicelist, depending on conditions.

**Parameters**

- **condlist**: list of bool ndarrays
  
The list of conditions which determine from which array in choicelist the output elements are taken. When multiple conditions are satisfied, the first one encountered in condlist is used.

- **choicelist**: list of ndarrays
  
The list of arrays from which the output elements are taken. It has to be of the same length as condlist.

- **default**: scalar, optional
  
The element inserted in output when all conditions evaluate to False.

**Returns**

- **output**: ndarray
  
The output at position m is the m-th element of the array in choicelist where the m-th element of the corresponding array in condlist is True.

**See also:**

**where**

Return elements from one of two arrays depending on condition.

**Examples**

```python
>>> x = np.arange(10)
>>> condlist = [x<3, x>5]
>>> choicelist = [x, x**2]
>>> np.select(condlist, choicelist)
array([ 0,  1,  2,  0,  0,  36, 49, 64, 81])
```
3.15.3 Inserting data into arrays

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<td>Change elements of an array based on conditional and input values.</td>
</tr>
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<td><code>put(a, ind, v[, mode])</code></td>
<td>Replaces specified elements of an array with given values.</td>
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<tr>
<td><code>putmask(a, mask, values)</code></td>
<td>Changes elements of an array based on conditional and input values.</td>
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<tr>
<td><code>fill_diagonal(a, val[, wrap])</code></td>
<td>Fill the main diagonal of the given array of any dimensionality.</td>
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`numpy.place(arr, mask, vals)`
Change elements of an array based on conditional and input values.

Similar to `np.copyto(arr, vals, where=mask)`, the difference is that `place` uses the first N elements of `vals`, where N is the number of True values in `mask`, while `copyto` uses the elements where `mask` is True.

Note that `extract` does the exact opposite of `place`.

**Parameters**
- `arr`: array_like
  Array to put data into.
- `mask`: array_like
  Boolean mask array. Must have the same size as `a`.
- `vals`: 1-D sequence
  Values to put into `a`. Only the first N elements are used, where N is the number of True values in `mask`. If `vals` is smaller than N it will be repeated.

**See also:**
`copyto, put, take, extract`

**Examples**

```python
>>> arr = np.arange(6).reshape(2, 3)
>>> np.place(arr, arr>2, [44, 55])
>>> arr
array([[ 0,  1,  2],
       [44, 55, 44]])
```

`numpy.put(a, ind, v, mode='raise')`
Replaces specified elements of an array with given values.

The indexing works on the flattened target array. `put` is roughly equivalent to:

```python
a.flat[ind] = v
```

**Parameters**
- `a`: ndarray
  Target array.
- `ind`: array_like
  Target indices, interpreted as integers.
- `v`: array_like
  Values to place in `a` at target indices. If `v` is shorter than `ind` it will be repeated as necessary.
mode : {'raise', 'wrap', 'clip'}, optional

Specifies how out-of-bounds indices will behave.

- 'raise' – raise an error (default)
- 'wrap' – wrap around
- 'clip' – clip to the range

'clip' mode means that all indices that are too large are replaced by the index that addresses the last element along that axis. Note that this disables indexing with negative numbers.

See also:

putmask, place

Examples

```python
define_code
>>> a = np.arange(5)
>>> np.put(a, [0, 2], [-44, -55])
>>> a
array([-44,  1, -55,  3,  4])
```

```python
>>> a = np.arange(5)
>>> np.put(a, 22, -5, mode='clip')
>>> a
array([ 0,  1,  2,  3, -5])
```

```python
numpy.putmask(a, mask, values)
Changes elements of an array based on conditional and input values.


If values is not the same size as a and mask then it will repeat. This gives behavior different from a[mask] = values.

Parameters

- a : array_like
  Target array.

- mask : array_like
  Boolean mask array. It has to be the same shape as a.

- values : array_like
  Values to put into a where mask is True. If values is smaller than a it will be repeated.

See also:

place, put, take, copyto

Examples

```python
>>> x = np.arange(6).reshape(2, 3)
>>> np.putmask(x, x>2, x**2)
>>> x
array([[ 0,  1,  2],
       [ 9, 16, 25]])
```

If values is smaller than a it is repeated:
```python
>>> x = np.arange(5)
>>> np.putmask(x, x>1, [-33, -44])
>>> x
array([ 0,  1, -33, -44, -33])
```

```
numpy.fill_diagonal(a, val, wrap=False)
Fill the main diagonal of the given array of any dimensionality.

For an array a with a.ndim > 2, the diagonal is the list of locations with indices a[i, i, ..., i] all identical. This function modifies the input array in-place, it does not return a value.

Parameters

a : array, at least 2-D.
Array whose diagonal is to be filled, it gets modified in-place.

val : scalar
Value to be written on the diagonal, its type must be compatible with that of the array a.

wrap : bool
For tall matrices in NumPy version up to 1.6.2, the diagonal “wrapped” after N columns.
You can have this behavior with this option. This affect only tall matrices.

See also:

``diag_indices, diag_indices_from``
```
Notes

New in version 1.4.0.

This functionality can be obtained via `diag_indices`, but internally this version uses a much faster implementation that never constructs the indices and uses simple slicing.

Examples

```python
>>> a = np.zeros((3, 3), int)
>>> np.fill_diagonal(a, 5)
```  
```  
>>> a
array([[5, 0, 0],
       [0, 5, 0],
       [0, 0, 5]])
```

The same function can operate on a 4-D array:

```python
>>> a = np.zeros((3, 3, 3, 3), int)
>>> np.fill_diagonal(a, 4)
```

We only show a few blocks for clarity:

```python
>>> a[0, 0]
array([[4, 0, 0],
       [0, 0, 0],
       [0, 0, 0]])
```  
```  
>>> a[1, 1]
array([[0, 0, 0],
       [4, 0, 0],
       [0, 0, 0]])
```  
```  
>>> a[2, 2]
array([[0, 0, 0],
       [0, 0, 0],
       [0, 0, 0]])
```
NumPy Reference, Release 1.9.2

```python
[0, 0, 0],
[0, 0, 4]])
```

# tall matrices no wrap >>> a = np.zeros((5, 3),int) >>> fill_diagonal(a, 4) array(
[0, 4, 0], [0, 0, 4], [0, 0, 0], [0, 0, 0])

# tall matrices wrap >>> a = np.zeros((5, 3),int) >>> fill_diagonal(a, 4) array(
[0, 4, 0], [0, 0, 4], [0, 0, 0], [4, 0, 0])

# wide matrices >>> a = np.zeros((3, 5),int) >>> fill_diagonal(a, 4) array(
[4, 0, 0, 0, 0], [0, 4, 0, 0, 0], [0, 0, 4, 0, 0])

3.15.4 Iterating over arrays

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**class numpy.nditer**

Efficient multi-dimensional iterator object to iterate over arrays. To get started using this object, see the introductory guide to array iteration.

**Parameters**

- **op**: ndarray or sequence of array_like
  The array(s) to iterate over.

- **flags**: sequence of str, optional
  Flags to control the behavior of the iterator.
  - “buffered” enables buffering when required.
  - “c_index” causes a C-order index to be tracked.
  - “f_index” causes a Fortran-order index to be tracked.
  - “multi_index” causes a multi-index, or a tuple of indices with one per iteration dimension, to be tracked.
  - “common_dtype” causes all the operands to be converted to a common data type, with copying or buffering as necessary.
  - “delay_bufalloc” delays allocation of the buffers until a reset() call is made. Allows “allocate” operands to be initialized before their values are copied into the buffers.
  - “external_loop” causes the values given to be one-dimensional arrays with multiple values instead of zero-dimensional arrays.
  - “grow_inner” allows the value array sizes to be made larger than the buffer size when both “buffered” and “external_loop” is used.
  - “ranged” allows the iterator to be restricted to a sub-range of the iterindex values.
  - “refs_ok” enables iteration of reference types, such as object arrays.
  - “reduce_ok” enables iteration of “readwrite” operands which are broadcasted, also known as reduction operands.

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• “zerosize_ok” allows itersize to be zero.

**op_flags**: list of list of str, optional

This is a list of flags for each operand. At minimum, one of “readonly”, “readwrite”, or “writeonly” must be specified.

- “readonly” indicates the operand will only be read from.
- “readwrite” indicates the operand will be read from and written to.
- “writeonly” indicates the operand will only be written to.
- “no_broadcast” prevents the operand from being broadcasted.
- “contig” forces the operand data to be contiguous.
- “aligned” forces the operand data to be aligned.
- “nbo” forces the operand data to be in native byte order.
- “copy” allows a temporary read-only copy if required.
- “updateifcopy” allows a temporary read-write copy if required.
- “allocate” causes the array to be allocated if it is None in the op parameter.
- “no_subtype” prevents an “allocate” operand from using a subtype.
- “arraymask” indicates that this operand is the mask to use for selecting elements when writing to operands with the ‘writemasked’ flag set. The iterator does not enforce this, but when writing from a buffer back to the array, it only copies those elements indicated by this mask.
- ‘writemasked’ indicates that only elements where the chosen ‘arraymask’ operand is True will be written to.

**op_dtypes**: dtype or tuple of dtype(s), optional

The required data type(s) of the operands. If copying or buffering is enabled, the data will be converted to/from their original types.

**order**: {'C', 'F', 'A', 'K'}, optional

Controls the iteration order. ‘C’ means C order, ‘F’ means Fortran order, ‘A’ means ‘F’ order if all the arrays are Fortran contiguous, ‘C’ order otherwise, and ‘K’ means as close to the order the array elements appear in memory as possible. This also affects the element memory order of “allocate” operands, as they are allocated to be compatible with iteration order. Default is ‘K’.

**casting**: {'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional

Controls what kind of data casting may occur when making a copy or buffering. Setting this to ‘unsafe’ is not recommended, as it can adversely affect accumulations.

- ‘no’ means the data types should not be cast at all.
- ‘equiv’ means only byte-order changes are allowed.
- ‘safe’ means only casts which can preserve values are allowed.
- ‘same_kind’ means only safe casts or casts within a kind, like float64 to float32, are allowed.
- ‘unsafe’ means any data conversions may be done.

**op_axes**: list of list of ints, optional
If provided, is a list of ints or None for each operands. The list of axes for an operand is a mapping from the dimensions of the iterator to the dimensions of the operand. A value of -1 can be placed for entries, causing that dimension to be treated as "newaxis".

**itershape**: tuple of ints, optional

The desired shape of the iterator. This allows “allocate” operands with a dimension mapped by op_axes not corresponding to a dimension of a different operand to get a value not equal to 1 for that dimension.

**buffersize**: int, optional

When buffering is enabled, controls the size of the temporary buffers. Set to 0 for the default value.

**Notes**

`nditer` supersedes `flatiter`. The iterator implementation behind `nditer` is also exposed by the Numpy C API.

The Python exposure supplies two iteration interfaces, one which follows the Python iterator protocol, and another which mirrors the C-style do-while pattern. The native Python approach is better in most cases, but if you need the iterator’s coordinates or index, use the C-style pattern.

**Examples**

Here is how we might write an `iter_add` function, using the Python iterator protocol:

```python
def iter_add_py(x, y, out=None):
    addop = np.add
    it = np.nditer([x, y, out], [],
                    [['readonly'], ['readonly'], ['writeonly','allocate']])
    for (a, b, c) in it:
        addop(a, b, out=c)
    return it.operands[2]
```

Here is the same function, but following the C-style pattern:

```python
def iter_add(x, y, out=None):
    addop = np.add
    it = np.nditer([x, y, out], [],
                    [['readonly'], ['readonly'], ['writeonly','allocate']])

    while not it.finished:
        addop(it[0], it[1], out=it[2])
        it.iternext()

    return it.operands[2]
```

Here is an example outer product function:

```python
def outer_it(x, y, out=None):
    mulop = np.multiply
    it = np.nditer([x, y, out], ['external_loop'],
                    [['readonly'], ['readonly'], ['writeonly', 'allocate']],
                    op_axes=[range(x.ndim)+[-1]*y.ndim,
                             [-1]*x.ndim+range(y.ndim),
                             None])
```
for (a, b, c) in it:
    mulop(a, b, out=c)

    return it.operands[2]

>>> a = np.arange(2)+1
>>> b = np.arange(3)+1
>>> outer_it(a, b)
array([[1, 2, 3],
       [2, 4, 6]])

Here is an example function which operates like a “lambda” ufunc:

def luf(lamdaexpr, *args, **kwargs):
    "luf(lambdaexpr, op1, ..., opn, out=None, order='K', casting='safe', buffersize=0)"
    nargs = len(args)
    op = (kwargs.get('out',None),) + args
    it = np.nditer(op, ['buffered','external_loop'],
                   [[['writeonly', 'allocate', 'no_broadcast']] +
                    [['readonly', 'nbo', 'aligned']]*nargs,
                     order=kwargs.get('order','K'),
                     casting=kwargs.get('casting','safe'),
                     buffersize=kwargs.get('buffersize',0))
    while not it.finished:
        it[0] = lamdaexpr(*it[1:])
        it.iternext()
    return it.operands[0]

>>> a = np.arange(5)
>>> b = np.ones(5)
>>> luf(lambda i,j:i*i + j/2, a, b)
array([ 0.5,  1.5,  4.5,  9.5, 16.5])
Attributes

dtypes : (tuple of dtype(s)) The data types of the values provided in value. This may be different from the operand data types if buffering is enabled.

finished : (bool) Whether the iteration over the operands is finished or not.

has_delayed_bufalloc : (bool) If True, the iterator was created with the “delay_bufalloc” flag, and no reset() function was called on it yet.

has_index : (bool) If True, the iterator was created with either the “c_index” or the “f_index” flag, and the property index can be used to retrieve it.

has_multi_index : (bool) If True, the iterator was created with the “multi_index” flag, and the property multi_index can be used to retrieve it.

index : When the “c_index” or “f_index” flag was used, this property provides access to the index. Raises a ValueError if accessed and has_index is False.

iterneed-sapi : (bool) Whether iteration requires access to the Python API, for example if one of the operands is an object array.

iterindex : (int) An index which matches the order of iteration.

itersize : (int) Size of the iterator.

itviews : Structured view(s) of operands in memory, matching the reordered and optimized iterator access pattern.

multi_index : When the “multi_index” flag was used, this property provides access to the index. Raises a ValueError if accessed and has_multi_index is False.

ndim : (int) The iterator’s dimension.

nop : (int) The number of iterator operands.

operands : (tuple of operand(s)) The array(s) to be iterated over.

shape : (tuple of ints) Shape tuple, the shape of the iterator.

value : Value of operands at current iteration. Normally, this is a tuple of array scalars, but if the flag “external_loop” is used, it is a tuple of one dimensional arrays.

Methods

copy() Get a copy of the iterator in its current state.
debug_print() Print the current state of the nditer instance and debug info to stdout.
enable_external_loop() When the “external_loop” was not used during construction, but is desired, this modifies the iterator to behave as if the flag was specified.

iternext() Check whether iterations are left, and perform a single internal iteration without returning the result.
next x.next() -> the next value, or raise StopIteration

remove_axis(i) Removes axis i from the iterator.

remove_multi_index() When the “multi_index” flag was specified, this removes it, allowing the internal iteration structure to be optimized further.

reset() Reset the iterator to its initial state.

Examples

>>> x = np.arange(10)
>>> y = x + 1
>>> it = np.nditer([x, y])
>>> it.next()
(array(0), array(1))
>>> it2 = it.copy()
>>> it2.next()
(array(1), array(2))

nditer.debug_print()
Print the current state of the `nditer` instance and debug info to stdout.

```
nditer.enable_external_loop()
```

When the “external_loop” was not used during construction, but is desired, this modifies the iterator to behave as if the flag was specified.

```
nditer.iternext()
```

Check whether iterations are left, and perform a single internal iteration without returning the result. Used in the C-style pattern do-while pattern. For an example, see `nditer`.

Returns
---

`iternext` : bool

Whether or not there are iterations left.

```
nditer.next()
```

x.next() -> the next value, or raise StopIteration

```
nditer.remove_axis(i)
```

Removes axis `i` from the iterator. Requires that the flag “multi_index” be enabled.

```
nditer.remove_multi_index()
```

When the “multi_index” flag was specified, this removes it, allowing the internal iteration structure to be optimized further.

```
nditer.reset()
```

Reset the iterator to its initial state.

### class `numpy.ndenumerate(arr)`

Multidimensional index iterator.

Return an iterator yielding pairs of array coordinates and values.

Parameters
---

`a` : ndarray

Input array.

See also:

`ndindex`, `flatiter`

### Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> for index, x in np.ndenumerate(a):
...     print index, x
(0, 0) 1
(0, 1) 2
(1, 0) 3
(1, 1) 4
```

### Methods

```
ndenumerate.next()
```

Standard iterator method, returns the index tuple and array value.

```
ndenumerate.next()
```

Standard iterator method, returns the index tuple and array value.

Returns
---

`coords` : tuple of ints
The indices of the current iteration.

val : scalar

The array element of the current iteration.

class numpy.ndindex(*shape)

An N-dimensional iterator object to index arrays.

Given the shape of an array, an ndindex instance iterates over the N-dimensional index of the array. At each iteration a tuple of indices is returned, the last dimension is iterated over first.

Parameters

*args : ints

The size of each dimension of the array.

See also:

ndenumerate, flatiter

Examples

>>> for index in np.ndindex(3, 2, 1):
... print index
(0, 0, 0)
(0, 1, 0)
(1, 0, 0)
(1, 1, 0)
(2, 0, 0)
(2, 1, 0)

Methods

ndincr()  Increment the multi-dimensional index by one.
next()  Standard iterator method, updates the index and returns the index tuple.

ndindex.ndincr()

Increment the multi-dimensional index by one.

This method is for backward compatibility only: do not use.

ndindex.next()

Standard iterator method, updates the index and returns the index tuple.

Returns

val : tuple of ints

Returns a tuple containing the indices of the current iteration.

class numpy.flatiter

Flat iterator object to iterate over arrays.

A flatiter iterator is returned by x.flat for any array x. It allows iterating over the array as if it were a 1-D array, either in a for-loop or by calling its next method.

Iteration is done in C-contiguous style, with the last index varying the fastest. The iterator can also be indexed using basic slicing or advanced indexing.

See also:
ndarray.flat
Return a flat iterator over an array.

ndarray.flatten
Returns a flattened copy of an array.

Notes
A flatiter iterator can not be constructed directly from Python code by calling the flatiter constructor.

Examples
>>> x = np.arange(6).reshape(2, 3)
>>> f1 = x.flat
>>> type(f1)
<type 'numpy.flatiter'>
>>> for item in f1:
...     print item
... 0
1
2
3
4
5

>>> f1[2:4]
array([2, 3])

Attributes

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<th>An N-dimensional tuple of current coordinates.</th>
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flatiter.coords
An N-dimensional tuple of current coordinates.

Examples

```python
>>> x = np.arange(6).reshape(2, 3)
>>> f1 = x.flat
>>> f1.coords
(0, 0)
>>> f1.next()
0
>>> f1.coords
(0, 1)
```

Methods

```
copy()  Get a copy of the iterator as a 1-D array.
next x.next() -> the next value, or raise StopIteration
```

flatiter.copy()
Get a copy of the iterator as a 1-D array.
Examples

```python
>>> x = np.arange(6).reshape(2, 3)
>>> x
array([[0, 1, 2],
       [3, 4, 5]])
>>> fl = x.flat
>>> fl.copy()
array([0, 1, 2, 3, 4, 5])
```

```
flatiter.next
  x.next() -> the next value, or raise StopIteration
```

3.16 Input and output

3.16.1 NPZ files

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```python
numpy.load(file[, mmap_mode=None])
```
Load arrays or pickled objects from .npy, .npz or pickled files.

**Parameters**

- `file`: file-like object or string
  The file to read. File-like objects must support the `seek()` and `read()` methods. Pickled files require that the file-like object support the `readline()` method as well.

- `mmap_mode`: {None, ‘r+’, ‘r’, ‘w+’, ‘c’}, optional
  If not None, then memory-map the file, using the given mode (see `numpy.memmap` for a detailed description of the modes). A memory-mapped array is kept on disk. However, it can be accessed and sliced like any ndarray. Memory mapping is especially useful for accessing small fragments of large files without reading the entire file into memory.

**Returns**

- `result`: array, tuple, dict, etc.
  Data stored in the file. For .npz files, the returned instance of NpzFile class must be closed to avoid leaking file descriptors.

**Raises**

- `IOError`
  If the input file does not exist or cannot be read.

**See also:**

- `save`, `savez`, `savez_compressed`, `loadtxt`  
- `memmap`  
  Create a memory-map to an array stored in a file on disk.
### Notes

- If the file contains pickle data, then whatever object is stored in the pickle is returned.
- If the file is a `.npy` file, then a single array is returned.
- If the file is a `.npz` file, then a dictionary-like object is returned, containing `{filename: array}` key-value pairs, one for each file in the archive.
- If the file is a `.npz` file, the returned value supports the context manager protocol in a similar fashion to the open function:

```python
with load('foo.npz') as data:
    a = data['a']
```

The underlying file descriptor is closed when exiting the `with` block.

### Examples

Store data to disk, and load it again:

```python
>>> np.save('/tmp/123', np.array([[1, 2, 3], [4, 5, 6]]))
>>> np.load('/tmp/123.npy')
array([[1, 2, 3],
       [4, 5, 6]])
```

Store compressed data to disk, and load it again:

```python
>>> a=np.array([[1, 2, 3], [4, 5, 6]])
>>> b=np.array([1, 2])
>>> np.savez('/tmp/123.npz', a=a, b=b)
>>> data = np.load('/tmp/123.npz')
>>> data['a']
array([[1, 2, 3],
       [4, 5, 6]])
>>> data['b']
array([1, 2])
>>> data.close()
```

Mem-map the stored array, and then access the second row directly from disk:

```python
>>> X = np.load('/tmp/123.npy', mmap_mode='r')
>>> X[1, :]
memmap([4, 5, 6])
```

#### numpy.save(file, arr)

Save an array to a binary file in NumPy `.npy` format.

**Parameters**

- `file`: file or str
  
  File or filename to which the data is saved. If file is a file-object, then the filename is unchanged. If file is a string, a `.npy` extension will be appended to the file name if it does not already have one.

- `arr`: array_like
  
  Array data to be saved.

**See also:**

- `savez`
  
  Save several arrays into a `.npz` archive
savetxt, load

Notes

For a description of the .npy format, see format.

Examples

```python
>>> from tempfile import TemporaryFile

>>> outf = TemporaryFile()

>>> x = np.arange(10)
>>> np.save(outf, x)

>>> outf.seek(0)  # Only needed here to simulate closing & reopening file
>>> np.load(outf)
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

numpy.savez `file, *args, **kwds`

Save several arrays into a single file in uncompressed .npz format.

If arguments are passed in with no keywords, the corresponding variable names, in the .npz file, are ‘arr_0’, ‘arr_1’, etc. If keyword arguments are given, the corresponding variable names, in the .npz file will match the keyword names.

Parameters

- `file` : str or file
  
  Either the file name (string) or an open file (file-like object) where the data will be saved. If file is a string, the .npz extension will be appended to the file name if it is not already there.

- `args` : Arguments, optional
  
  Arrays to save to the file. Since it is not possible for Python to know the names of the arrays outside savez, the arrays will be saved with names “arr_0”, “arr_1”, and so on. These arguments can be any expression.

- `kwds` : Keyword arguments, optional
  
  Arrays to save to the file. Arrays will be saved in the file with the keyword names.

Returns

None

See also:

- save
  
  Save a single array to a binary file in NumPy format.

- savetxt
  
  Save an array to a file as plain text.

- savez_compressed
  
  Save several arrays into a compressed .npz archive

Notes

The .npz file format is a zipped archive of files named after the variables they contain. The archive is not compressed and each file in the archive contains one variable in .npy format. For a description of the .npy format, see format.
When opening the saved .npz file with load a NpzFile object is returned. This is a dictionary-like object which can be queried for its list of arrays (with the .files attribute), and for the arrays themselves.

**Examples**

```python
>>> from tempfile import TemporaryFile
>>> outfile = TemporaryFile()
>>> x = np.arange(10)
>>> y = np.sin(x)

Using `savez` with *args, the arrays are saved with default names.

```python
>>> np.savez(outfile, x, y)
>>> outfile.seek(0)  # Only needed here to simulate closing & reopening file
>>> npzfile = np.load(outfile)
>>> npzfile.files
['arr_1', 'arr_0']
>>> npzfile['arr_0']
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

Using `savez` with **kwds, the arrays are saved with the keyword names.

```python
>>> outfile = TemporaryFile()
>>> np.savez(outfile, x=x, y=y)
>>> outfile.seek(0)
>>> npzfile = np.load(outfile)
>>> npzfile.files
['y', 'x']
>>> npzfile['x']
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

**numpy.savez_compressed(file, *args, **kwds)**

Save several arrays into a single file in compressed .npz format.

If keyword arguments are given, then filenames are taken from the keywords. If arguments are passed in with no keywords, then stored file names are arr_0, arr_1, etc.

**Parameters**

- `file` : str
  File name of .npz file.

- `args` : Arguments
  Function arguments.

- `kwds` : Keyword arguments
  Keywords.

**See also:**

- **numpy.save**
  Save several arrays into an uncompressed .npz file format

- **numpy.load**
  Load the files created by savez_compressed.

### 3.16.2 Text files
NumPy Reference, Release 1.9.2

```
loadtxt(fname[, dtype, comments, delimiter, ...]) Load data from a text file.
savetxt(fname, X[, fmt, delimiter, newline, ...]) Save an array to a text file.
genfromtxt(fname[, dtype, comments, ...]) Load data from a text file, with missing values handled as specified.
fromregex(file, regexp, dtype) Construct an array from a text file, using regular expression parsing.
fromstring(string[, dtype, count, sep]) A new 1-D array initialized from raw binary or text data in a string.
ndarray.tofile(fid[, sep, format]) Write array to a file as text or binary (default).
ndarray.tolist() Return the array as a (possibly nested) list.
```

```python
numpy.loadtxt (fname=type `float'> comments='#', delimiter=None, converters=None, skiprows=0, usecols=None, unpack=False, ndmin=0)

Load data from a text file.

Each row in the text file must have the same number of values.

**Parameters**

fname : file or str
    File, filename, or generator to read. If the filename extension is .gz or .bz2, the file is first decompressed. Note that generators should return byte strings for Python 3k.

dtype : data-type, optional
    Data-type of the resulting array; default: float. If this is a record data-type, the resulting array will be 1-dimensional, and each row will be interpreted as an element of the array. In this case, the number of columns used must match the number of fields in the data-type.

comments : str, optional
    The character used to indicate the start of a comment; default: ‘#’.

delimiter : str, optional
    The string used to separate values. By default, this is any whitespace.

converters : dict, optional
    A dictionary mapping column number to a function that will convert that column to a float. E.g., if column 0 is a date string: converters = {0: datestr2num}. Converters can also be used to provide a default value for missing data (but see also genfromtxt): converters = {3: lambda s: float(s.strip() or 0)}. Default: None.

skiprows : int, optional
    Skip the first skiprows lines; default: 0.

usecols : sequence, optional
    Which columns to read, with 0 being the first. For example, usecols = (1,4,5) will extract the 2nd, 5th and 6th columns. The default, None, results in all columns being read.

unpack : bool, optional
    If True, the returned array is transposed, so that arguments may be unpacked using x, y, z = loadtxt(...). When used with a record data-type, arrays are returned for each field. Default is False.

ndmin : int, optional
```

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The returned array will have at least \textit{ndmin} dimensions. Otherwise mono-dimensional axes will be squeezed. Legal values: 0 (default), 1 or 2.

New in version 1.6.0.

\textbf{Returns}

\texttt{out} : ndarray

Data read from the text file.

\textbf{See also:}

\texttt{load, fromstring, fromregex}

\texttt{genfromtxt}

Load data with missing values handled as specified.

\texttt{scipy.io.loadmat}

reads MATLAB data files

\textbf{Notes}

This function aims to be a fast reader for simply formatted files. The \texttt{genfromtxt} function provides more sophisticated handling of, e.g., lines with missing values.

\textbf{Examples}

\begin{verbatim}
>>> from StringIO import StringIO  # StringIO behaves like a file object
>>> c = StringIO("0 1
2 3")
>>> np.loadtxt(c)
array([[ 0., 1.],
       [ 2., 3.]])

>>> d = StringIO("M 21 72
F 35 58")
>>> np.loadtxt(d, dtype=('\texttt{gender}', 'age', 'weight'),
\texttt{formats}=('S1', 'i4', 'f4'))
array([('M', 21, 72.0), ('F', 35, 58.0)],
       \texttt{dtype}=[('gender', '|S1'), ('age', '<i4'), ('weight', '<f4')])

>>> c = StringIO("1,0,2
3,0,4")
>>> x, y = np.loadtxt(c, delimiter=',', usecols=(0, 2), unpack=True)
>>> x
array([ 1., 3.])
>>> y
array([2., 4.])
\end{verbatim}

\texttt{numpy.savetxt} \texttt{(fname, X, fmt='%.18e', delimiter=' ', newline='\n', header=' ', footer=' ', comments='\# ')}

Save an array to a text file.

\textbf{Parameters}

\texttt{fname} : filename or file handle

If the filename ends in \texttt{.gz}, the file is automatically saved in compressed gzip format. \texttt{loadtxt} understands gzipped files transparently.

\texttt{X} : array_like

Data to be saved to a text file.

\texttt{fmt} : str or sequence of str, optional
A single format (%10.5f), a sequence of formats, or a multi-format string, e.g. ‘Iteration %d – %10.5f’, in which case delimiter is ignored. For complex X, the legal options for fmt are:

1. a single specifier, fmt='%.4e', resulting in numbers formatted like ‘(%s+%sj)’ % (fmt, fmt)
2. a full string specifying every real and imaginary part, e.g. ‘%.4e %+.4j %.4e %+.4j %.4e %+.4j’ for 3 columns
3. a list of specifiers, one per column - in this case, the real and imaginary part must have separate specifiers, e.g. ['%.3e + %.3ej', ('%.15e%+.15ej')] for 2 columns

**delimiter** : str, optional
String or character separating columns.

**newline** : str, optional
String or character separating lines.
New in version 1.5.0.

**header** : str, optional
String that will be written at the beginning of the file.
New in version 1.7.0.

**footer** : str, optional
String that will be written at the end of the file.
New in version 1.7.0.

**comments** : str, optional
String that will be prepended to the header and footer strings, to mark them as comments. Default: ‘#’, as expected by e.g. numpy.loadtxt.
New in version 1.7.0.

See also:

**save**
Save an array to a binary file in NumPy .npy format

**savetz**
Save several arrays into an uncompressed .npz archive

**savetz_compressed**
Save several arrays into a compressed .npz archive

Notes

Further explanation of the fmt parameter(%[flag]width[.precision]specifier):

**flags:**
- : left justify
+ : Forces to precede result with + or -. 
0 : Left pad the number with zeros instead of space (see width).
width:
Minimum number of characters to be printed. The value is not truncated if it has more characters.

precision:

- For integer specifiers (eg. d, i, o, x), the minimum number of digits.
- For e, E and f specifiers, the number of digits to print after the decimal point.
- For g and G, the maximum number of significant digits.
- For s, the maximum number of characters.

specifiers:

- c: character
- d or i: signed decimal integer
- e or E: scientific notation with e or E.
- f: decimal floating point
- g, G: use the shorter of e, E or f
- o: signed octal
- s: string of characters
- u: unsigned decimal integer
- x, X: unsigned hexadecimal integer

This explanation of fmt is not complete, for an exhaustive specification see [R244].

References

[R244]

Examples

```python
>>> x = y = z = np.arange(0.0,5.0,1.0)
>>> np.savetxt('test.out', x, delimiter=',')  # X is an array
>>> np.savetxt('test.out', (x,y,z))  # x,y,z equal sized 1D arrays
>>> np.savetxt('test.out', x, fmt='%.4e')  # use exponential notation
```

`numpy.genfromtxt` (fname, dtype=<type 'float'>, comments='#', delimiter=None, skiprows=0, skip_header=0, skip_footer=0, converters=None, missing='', missing_values=None, filling_values=None, usecols=None, names=None, excludelist=None, deletechars=None, replace_space='_', autostrip=False, case_sensitive=True, defaultfmt='%i', unpack=None, usemask=False, loose=True, invalid_raise=True)

Load data from a text file, with missing values handled as specified.

Each line past the first skip_header lines is split at the delimiter character, and characters following the comments character are discarded.

Parameters

- **fname**: file or str
  File, filename, or generator to read. If the filename extension is gz or bzip2, the file is first decompressed. Note that generators must return byte strings in Python 3k.

- **dtype**: dtype, optional
  Data type of the resulting array. If None, the dtypes will be determined by the contents of each column, individually.
comments : str, optional
The character used to indicate the start of a comment. All the characters occurring on a 
line after a comment are discarded

delimiter : str, int, or sequence, optional
The string used to separate values. By default, any consecutive whitespaces act as 
delimiter. An integer or sequence of integers can also be provided as width(s) of each 
field.

skip_rows : int, optional
skip_rows was deprecated in numpy 1.5, and will be removed in numpy 2.0. Please use 
skip_header instead.

skip_header : int, optional
The number of lines to skip at the beginning of the file.

skip_footer : int, optional
The number of lines to skip at the end of the file.

converters : variable, optional
The set of functions that convert the data of a column to a value. The converters can also 
be used to provide a default value for missing data: converters = {3: lambda 
  s: float(s or 0)}.

missing : variable, optional
missing was deprecated in numpy 1.5, and will be removed in numpy 2.0. Please use 
missing_values instead.

missing_values : variable, optional
The set of strings corresponding to missing data.

filling_values : variable, optional
The set of values to be used as default when the data are missing.

usecols : sequence, optional
Which columns to read, with 0 being the first. For example, usecols = (1, 4, 
5) will extract the 2nd, 5th and 6th columns.

names : {None, True, str, sequence}, optional
If names is True, the field names are read from the first valid line after the first 
skip_header lines. If names is a sequence or a single-string of comma-separated names, 
the names will be used to define the field names in a structured dtype. If names is None, 
the names of the dtype fields will be used, if any.

excludelist : sequence, optional
A list of names to exclude. This list is appended to the default list ['return', 'file', 'print']. 
Excluded names are appended an underscore: for example, file would become file_.

deletechars : str, optional
A string combining invalid characters that must be deleted from the names.

defaultfmt : str, optional
A format used to define default field names, such as “f%i” or “f_%02i”.

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autostricp : bool, optional
    Whether to automatically strip white spaces from the variables.

replace_space : char, optional
    Character(s) used in replacement of white spaces in the variables names. By default, use a '_'

case_sensitive : {True, False, ‘upper’, ‘lower’}, optional
    If True, field names are case sensitive. If False or ‘upper’, field names are converted to upper case. If ‘lower’, field names are converted to lower case.

unpack : bool, optional
    If True, the returned array is transposed, so that arguments may be unpacked using x, y, z = loadtxt(...) 

usemask : bool, optional
    If True, return a masked array. If False, return a regular array.

loose : bool, optional
    If True, do not raise errors for invalid values.

invalid_raise : bool, optional
    If True, an exception is raised if an inconsistency is detected in the number of columns. If False, a warning is emitted and the offending lines are skipped.

Returns
out : ndarray
    Data read from the text file. If usemask is True, this is a masked array.

See also:
numpy.loadtxt
    equivalent function when no data is missing.

Notes

• When spaces are used as delimiters, or when no delimiter has been given as input, there should not be any missing data between two fields.

• When the variables are named (either by a flexible dtype or with names, there must not be any header in the file (else a ValueError exception is raised).

• Individual values are not stripped of spaces by default. When using a custom converter, make sure the function does remove spaces.

References
[R20]

Examples
>>> from StringIO import StringIO
>>> import numpy as np

Comma delimited file with mixed dtype
>>> s = StringIO("1,1.3,abcde")
>>> data = np.genfromtxt(s, dtype=[('myint','i8'),('myfloat','f8'),
... ('mystring','S5')], delimiter="","")
array((1, 1.3, 'abcde'),
      dtype=[('myint', '<i8'), ('myfloat', '<f8'), ('mystring', '|S5')])

Using dtype = None
>>> s.seek(0)  # needed for StringIO example only
>>> data = np.genfromtxt(s, dtype=None,
... names = ['myint','myfloat','mystring'], delimiter="",")
array((1, 1.3, 'abcde'),
      dtype=[('myint', '<i8'), ('myfloat', '<f8'), ('mystring', '|S5')])

Specifying dtype and names
>>> s.seek(0)
>>> data = np.genfromtxt(s, dtype="i8,f8,S5",
... names=['myint','myfloat','mystring'], delimiter="",")
array((1, 1.3, 'abcde'),
      dtype=[('myint', '<i8'), ('myfloat', '<f8'), ('mystring', '|S5')])

An example with fixed-width columns
>>> s = StringIO("11.3abcde")
>>> data = np.genfromtxt(s, dtype=None, names=['intvar','fltvar','strvar'],
... delimiter=[1,3,5])
array((1, 1.3, 'abcde'),
      dtype=[('intvar', '<i8'), ('fltvar', '<f8'), ('strvar', '|S5')])

numpy.fromregex

Construct an array from a text file, using regular expression parsing.

The returned array is always a structured array, and is constructed from all matches of the regular expression in
the file. Groups in the regular expression are converted to fields of the structured array.

Parameters
    file : str or file
        File name or file object to read.
    regexp : str or regexp
        Regular expression used to parse the file. Groups in the regular expression correspond
to fields in the dtype.
    dtype : dtype or list of dtypes
        Dtype for the structured array.

Returns
    output : ndarray
        The output array, containing the part of the content of file that was matched by regexp.
output is always a structured array.

Raises
    TypeError
When `dtype` is not a valid dtype for a structured array.

See also:

`fromstring`, `loadtxt`

Notes

Dtypes for structured arrays can be specified in several forms, but all forms specify at least the data type and field name. For details see `doc.structured_arrays`.

Examples

```python
>>> f = open('test.dat', 'w')
>>> f.write("1312 foo\n1534 bar\n444 qux")
>>> f.close()

>>> regexp = r"\d+(?:\s+\d+)*"  # match \d+ \s+ (\d+)*
>>> output = np.fromregex('test.dat', regexp,
...                       [('num', np.int64), ('key', 'S3')])

>>> output
array([(1312L, 'foo'), (1534L, 'bar'), (444L, 'qux')],
dtype=[('num', '<i8'), ('key', '|S3')])
```

np.fromstring(string, dtype=float, count=-1, sep='')

A new 1-D array initialized from raw binary or text data in a string.

Parameters

- `string` : str
  
  A string containing the data.

- `dtype` : data-type, optional
  
  The data type of the array; default: float. For binary input data, the data must be in exactly this format.

- `count` : int, optional
  
  Read this number of `dtype` elements from the data. If this is negative (the default), the count will be determined from the length of the data.

- `sep` : str, optional
  
  If not provided or, equivalently, the empty string, the data will be interpreted as binary data; otherwise, as ASCII text with decimal numbers. Also in this latter case, this argument is interpreted as the string separating numbers in the data; extra whitespace between elements is also ignored.

Returns

- `arr` : ndarray
  
  The constructed array.

Raises

- `ValueError`
  
  If the string is not the correct size to satisfy the requested `dtype` and `count`.

See also:

`frombuffer`, `fromfile`, `fromiter`
NumPy Reference, Release 1.9.2

Examples
>>> np.fromstring(’\x01\x02’, dtype=np.uint8)
array([1, 2], dtype=uint8)
>>> np.fromstring(’1 2’, dtype=int, sep=’ ’)
array([1, 2])
>>> np.fromstring(’1, 2’, dtype=int, sep=’,’)
array([1, 2])
>>> np.fromstring(’\x01\x02\x03\x04\x05’, dtype=np.uint8, count=3)
array([1, 2, 3], dtype=uint8)

ndarray.tofile(fid, sep=”“, format=”%s”)
Write array to a file as text or binary (default).
Data is always written in ‘C’ order, independent of the order of a. The data produced by this method can be
recovered using the function fromfile().
Parameters
fid : file or str
An open file object, or a string containing a filename.
sep : str
Separator between array items for text output. If “” (empty), a binary file is written,
equivalent to file.write(a.tobytes()).
format : str
Format string for text file output. Each entry in the array is formatted to text by first
converting it to the closest Python type, and then using “format” % item.
Notes
This is a convenience function for quick storage of array data. Information on endianness and precision is lost,
so this method is not a good choice for files intended to archive data or transport data between machines with
different endianness. Some of these problems can be overcome by outputting the data as text files, at the expense
of speed and file size.
ndarray.tolist()
Return the array as a (possibly nested) list.
Return a copy of the array data as a (nested) Python list. Data items are converted to the nearest compatible
Python type.
Parameters
none
Returns
y : list
The possibly nested list of array elements.
Notes
The array may be recreated, a = np.array(a.tolist()).
Examples
>>>
>>>
[1,
>>>

a = np.array([1, 2])
a.tolist()
2]
a = np.array([[1, 2], [3, 4]])

3.16. Input and output

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>>> list(a)
[array([1, 2]), array([3, 4])]
>>> a.tolist()
[[1, 2], [3, 4]]

3.16.3 Raw binary files

```
fromfile(file[, dtype, count, sep]) Construct an array from data in a text or binary file.
ndarray.tofile(fid[, sep, format]) Write array to a file as text or binary (default).
```

3.16.4 String formatting

```
array_repr(arr[, max_line_width, precision, ...]) Return the string representation of an array.
array_str(a[, max_line_width, precision, ...]) Return a string representation of the data in an array.
```

numpy.array_repr(arr, max_line_width=None, precision=None, suppress_small=None)
Return the string representation of an array.

**Parameters**
- `arr`: ndarray
  - Input array.
- `max_line_width`: int, optional
  - The maximum number of columns the string should span. Newline characters split the string appropriately after array elements.
- `precision`: int, optional
  - Floating point precision. Default is the current printing precision (usually 8), which can be altered using set_printoptions.
- `suppress_small`: bool, optional
  - Represent very small numbers as zero, default is False. Very small is defined by precision, if the precision is 8 then numbers smaller than 5e-9 are represented as zero.

**Returns**
- `string`: str
  - The string representation of an array.

**See also:**
- array_str, array2string, set_printoptions

**Examples**

```python
>>> np.array_repr(np.array([1,2]))
'array([1, 2])'
>>> np.array_repr(np.ma.array([0.]))
'MaskedArray([ 0.])'
>>> np.array_repr(np.array([], np.int32))
'array([], dtype=int32)'
```
>>> x = np.array([1e-6, 4e-7, 2, 3])
>>> np.array_repr(x, precision=6, suppress_small=True)
'array([ 0.000001,  0.        ,  2.        ,  3.        ])

numpy.array_str(a, max_line_width=None, precision=None, suppress_small=None)

Return a string representation of the data in an array.

The data in the array is returned as a single string. This function is similar to array_repr, the difference being that array_repr also returns information on the kind of array and its data type.

Parameters
   a : ndarray
      Input array.

   max_line_width : int, optional
      Inserts newlines if text is longer than max_line_width. The default is, indirectly, 75.

   precision : int, optional
      Floating point precision. Default is the current printing precision (usually 8), which can be altered using set_printoptions.

   suppress_small : bool, optional
      Represent numbers “very close” to zero as zero; default is False. Very close is defined by precision: if the precision is 8, e.g., numbers smaller (in absolute value) than 5e-9 are represented as zero.

See also:
array2string, array_repr, set_printoptions

Examples

>>> np.array_str(np.arange(3))
'[[0 1 2]]'

3.16.5 Memory mapping files

memmap

Create a memory-map to an array stored in a binary file on disk.

class numpy.memmap

Create a memory-map to an array stored in a binary file on disk.

Memory-mapped files are used for accessing small segments of large files on disk, without reading the entire file into memory. NumPy’s memmap’s are array-like objects. This differs from Python’s mmap module, which uses file-like objects.

This subclass of ndarray has some unpleasant interactions with some operations, because it doesn’t quite fit properly as a subclass. An alternative to using this subclass is to create the mmap object yourself, then create an ndarray with ndarray.__new__ directly, passing the object created in its ‘buffer’ parameter.

This class may at some point be turned into a factory function which returns a view into an mmap buffer.

Delete the memmap instance to close.

Parameters
   filename : str or file-like object
The file name or file object to be used as the array data buffer.

**dtype** : data-type, optional

The data-type used to interpret the file contents. Default is uint8.

**mode** : {'r+', 'r', 'w+', 'c'}, optional

The file is opened in this mode:

```
<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>'r'</td>
<td>Open existing file for reading only.</td>
</tr>
<tr>
<td>'r+'</td>
<td>Open existing file for reading and writing.</td>
</tr>
<tr>
<td>'w+'</td>
<td>Create or overwrite existing file for reading and writing.</td>
</tr>
<tr>
<td>'c'</td>
<td>Copy-on-write: assignments affect data in memory, but changes are not saved to disk. The file on disk is read-only.</td>
</tr>
</tbody>
</table>
```

Default is ‘r+’.

**offset** : int, optional

In the file, array data starts at this offset. Since `offset` is measured in bytes, it should normally be a multiple of the byte-size of `dtype`. When `mode` != ‘r’, even positive offsets beyond end of file are valid; The file will be extended to accommodate the additional data. By default, `memmap` will start at the beginning of the file, even if `filename` is a file pointer `fp` and `fp.tell()` != 0.

**shape** : tuple, optional

The desired shape of the array. If `mode` == ‘r’ and the number of remaining bytes after `offset` is not a multiple of the byte-size of `dtype`, you must specify `shape`. By default, the returned array will be 1-D with the number of elements determined by file size and data-type.

**order** : {'C', 'F'}, optional

Specify the order of the ndarray memory layout: C (row-major) or Fortran (column-major). This only has an effect if the shape is greater than 1-D. The default order is ‘C’.

**Notes**

The memmap object can be used anywhere an ndarray is accepted. Given a memmap `fp`, `isinstance(fp, numpy.ndarray)` returns `True`.

Memory-mapped arrays use the Python memory-map object which (prior to Python 2.5) does not allow files to be larger than a certain size depending on the platform. This size is always < 2GB even on 64-bit systems.

**Examples**

```python
>>> data = np.arange(12, dtype='float32')
>>> data.resize((3,4))
```

This example uses a temporary file so that doctest doesn’t write files to your directory. You would use a ‘normal’ filename.

```python
>>> from tempfile import mkdtemp
>>> import os.path as path

>>> filename = path.join(mkdtemp(), 'newfile.dat')
```

Create a memmap with dtype and shape that matches our data:
>>> fp = np.memmap(filename, dtype='float32', mode='w+', shape=(3,4))
>>> fp
memmap([[ 0., 0., 0., 0.],
        [ 0., 0., 0., 0.],
        [ 0., 0., 0., 0.]], dtype=float32)

Write data to memmap array:
>>> fp[:] = data[:]
>>> fp
memmap([[ 0., 1., 2., 3.],
        [ 4., 5., 6., 7.],
        [ 8., 9., 10., 11.]], dtype=float32)

>>> fp.filename == path.abspath(filename)
True

Deletion flushes memory changes to disk before removing the object:
>>> del fp

Load the memmap and verify data was stored:
>>> newfp = np.memmap(filename, dtype='float32', mode='r', shape=(3,4))
>>> newfp
memmap([[ 0., 1., 2., 3.],
        [ 4., 5., 6., 7.],
        [ 8., 9., 10., 11.]], dtype=float32)

Read-only memmap:
>>> fpr = np.memmap(filename, dtype='float32', mode='r', shape=(3,4))
>>> fpr.flags.writeable
False

Copy-on-write memmap:
>>> fpc = np.memmap(filename, dtype='float32', mode='c', shape=(3,4))
>>> fpc.flags.writeable
True

It’s possible to assign to copy-on-write array, but values are only written into the memory copy of the array, and not written to disk:
>>> fpc
memmap([[ 0., 1., 2., 3.],
        [ 4., 5., 6., 7.],
        [ 8., 9., 10., 11.]], dtype=float32)

File on disk is unchanged:
>>> fpr
memmap([[ 0., 1., 2., 3.],
        [ 4., 5., 6., 7.],
        [ 8., 9., 10., 11.]], dtype=float32)
Offset into a memmap:

```python
>>> fpo = np.memmap(filename, dtype='float32', mode='r', offset=16)
>>> fpo
memmap([ 4., 5., 6., 7., 8., 9., 10., 11.], dtype=float32)
```

**Attributes**

<table>
<thead>
<tr>
<th>filename</th>
<th>(str) Path to the mapped file.</th>
</tr>
</thead>
<tbody>
<tr>
<td>offset</td>
<td>(int) Offset position in the file.</td>
</tr>
<tr>
<td>mode</td>
<td>(str) File mode.</td>
</tr>
</tbody>
</table>

**Methods**

```python
memmap.flush()
```

Write any changes in the array to the file on disk.

For further information, see `memmap`.

**Parameters**

None

**See also:**

`memmap`

### 3.16.6 Text formatting options

- `set_printoptions([precision, threshold, ...])` Set printing options.
- `get_printoptions()` Return the current print options.
- `set_string_function(f[, repr])` Set a Python function to be used when pretty printing arrays.

**numpy.set_printoptions** *(precision=None, threshold=None, edgeitems=None, linewidth=None, suppress=None, nanstr=None, infstr=None, formatter=None)*

Set printing options.

These options determine the way floating point numbers, arrays and other NumPy objects are displayed.

**Parameters**

- `precision` : int, optional
  Number of digits of precision for floating point output (default 8).
- `threshold` : int, optional
  Total number of array elements which trigger summarization rather than full repr (default 1000).
- `edgeitems` : int, optional
  Number of array items in summary at beginning and end of each dimension (default 3).
- `linewidth` : int, optional
  The number of characters per line for the purpose of inserting line breaks (default 75).
- `suppress` : bool, optional
  suppress
Whether or not suppress printing of small floating point values using scientific notation (default False).

**nanstr** : str, optional

String representation of floating point not-a-number (default nan).

**infstr** : str, optional

String representation of floating point infinity (default inf).

**formatter** : dict of callables, optional

If not None, the keys should indicate the type(s) that the respective formatting function applies to. Callables should return a string. Types that are not specified (by their corresponding keys) are handled by the default formatters. Individual types for which a formatter can be set are:

- `'bool'`
- `'int'`
- `'timedelta'` : a `numpy.timedelta64`
- `'datetime'` : a `numpy.datetime64`
- `'float'`
- `'longfloat'` : 128-bit floats
- `'complexfloat'`
- `'longcomplexfloat'` : composed of two 128-bit floats
- `'numpy_str'` : types `numpy.string_` and `numpy.unicode_`
- `'str'` : all other strings

Other keys that can be used to set a group of types at once are:

- `'all'` : sets all types
- `'int_kind'` : sets `'int'`
- `'float_kind'` : sets `'float'` and `'longfloat'`
- `'complex_kind'` : sets `'complexfloat'` and `'longcomplexfloat'`
- `'str_kind'` : sets `'str'` and `'numpystr'`

**See also:**

`get_printoptions`, `set_string_function`, `array2string`

**Notes**

`formatter` is always reset with a call to `set_printoptions`.

**Examples**

Floating point precision can be set:

```python
>>> np.set_printoptions(precision=4)
>>> print np.array([1.123456789])
[ 1.1235]
```

Long arrays can be summarised:

```python
>>> np.set_printoptions(threshold=5)
>>> print np.arange(10)
[0 1 2 ..., 7 8 9]
```

Small results can be suppressed:
```python
>>> eps = np.finfo(float).eps
>>> x = np.arange(4.)
>>> x**2 - (x + eps)**2
array([-4.9304e-32, -4.4409e-16, 0.0000e+00, 0.0000e+00])

>>> np.set_printoptions(suppress=True)
>>> x**2 - (x + eps)**2
array([-0., -0., 0., 0.])

A custom formatter can be used to display array elements as desired:

```python
>>> np.set_printoptions(formatter={'all': lambda x: 'int: ' + str(-x)})
```  
```python
>>> x = np.arange(3)
```  
```python
>>> x
array([int: 0, int: -1, int: -2])
```  
```python
>>> np.set_printoptions()  # formatter gets reset
```  
```python
>>> x
array([0, 1, 2])
```

To put back the default options, you can use:

```python
>>> np.set_printoptions(edgeitems=3, infstr='inf', ... linewidth=75, nanstr='nan', precision=8, ... suppress=False, threshold=1000, formatter=None)
```

**numpy\texttt{.get\textunderscore print\textunderscore options()**

Return the current print options.

**Returns**

- **print\_opts**: dict
  
  Dictionary of current print options with keys
  
  - precision : int
  - threshold : int
  - edgeitems : int
  - linewidth : int
  - suppress : bool
  - nanstr : str
  - infstr : str
  - formatter : dict of callables

  For a full description of these options, see \texttt{set\_print\_options.}

**See also:**

- \texttt{set\_print\_options, set\_string\_function}

**numpy\texttt{.set\_string\_function** \(f, repr=True\)**

Set a Python function to be used when pretty printing arrays.

**Parameters**

- **f**: function or None

  Function to be used to pretty print arrays. The function should expect a single array argument and return a string of the representation of the array. If None, the function is reset to the default NumPy function to print arrays.

- **repr**: bool, optional
If True (default), the function for pretty printing (\_\_repr\_\_) is set, if False the function that returns the default string representation (\_\_str\_\_) is set.

**See also:**

`set_printoptions`, `get_printoptions`

**Examples**

```python
>>> def pprint(arr):
...     return 'HA! - What are you going to do now?'
... >>> np.set_string_function(pprint)
>>> a = np.arange(10)
>>> a
HA! - What are you going to do now?
>>> print a
[0 1 2 3 4 5 6 7 8 9]
```

We can reset the function to the default:

```python
>>> np.set_string_function(None)
>>> a
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

`repr` affects either pretty printing or normal string representation. Note that \_\_repr\_\_ is still affected by setting \_\_str\_\_ because the width of each array element in the returned string becomes equal to the length of the result of \_\_str\_\_().

```python
>>> x = np.arange(4)
>>> np.set_string_function(lambda x: 'random', repr=False)
>>> x.__str__()
'random'
>>> x.__repr__()
'array([ 0, 1, 2, 3])'
```

## 3.16.7 Base-n representations

**binary\_repr** (num[, width])

Return the binary representation of the input number as a string.

**base\_repr** (number[, base, padding])

Return a string representation of a number in the given base system.

```
numpy.binary\_repr(num, width=None)
```

Return the binary representation of the input number as a string.

For negative numbers, if width is not given, a minus sign is added to the front. If width is given, the two's complement of the number is returned, with respect to that width.

In a two's-complement system negative numbers are represented by the two's complement of the absolute value. This is the most common method of representing signed integers on computers [R16]. A N-bit two's-complement system can represent every integer in the range \(-2^{N-1}\) to \(+2^{N-1}-1\).

**Parameters**

- `num`: int
  - Only an integer decimal number can be used.
- `width`: int, optional
The length of the returned string if `num` is positive, the length of the two’s complement if `num` is negative.

**Returns**

- `bin`: str

  Binary representation of `num` or two’s complement of `num`.

**See also:**

- **base_repr**
  Return a string representation of a number in the given base system.

**Notes**

`binary_repr` is equivalent to using `base_repr` with base 2, but about 25x faster.

**References**

[R16]

**Examples**

```python
>>> np.binary_repr(3)
'11'
>>> np.binary_repr(-3)
'-11'
>>> np.binary_repr(3, width=4)
'0011'
```

The two’s complement is returned when the input number is negative and width is specified:

```python
>>> np.binary_repr(-3, width=4)
'1101'
```

**numpy.base_repr(number, base=2, padding=0)**

Return a string representation of a number in the given base system.

**Parameters**

- `number`: int

  The value to convert. Only positive values are handled.

- `base`: int, optional

  Convert `number` to the `base` number system. The valid range is 2-36, the default value is 2.

- `padding`: int, optional

  Number of zeros padded on the left. Default is 0 (no padding).

**Returns**

- `out`: str

  String representation of `number` in `base` system.

**See also:**

- **binary_repr**
  Faster version of `base_repr` for base 2.
Examples

```python
>>> np.base_repr(5)
'101'
>>> np.base_repr(6, 5)
'11'
>>> np.base_repr(7, base=5, padding=3)
'00012'
>>> np.base_repr(10, base=16)
'A'
>>> np.base_repr(32, base=16)
'20'
```

3.16.8 Data sources

```python
class numpy.DataSource(destpath='.)
    A generic data source file (file, http, ftp, ...).
```

DataSources can be local files or remote files/URLs. The files may also be compressed or uncompressed. DataSource hides some of the low-level details of downloading the file, allowing you to simply pass in a valid file path (or URL) and obtain a file object.

Parameters

- **destpath**: str or None, optional
  - Path to the directory where the source file gets downloaded to for use. If `destpath` is None, a temporary directory will be created. The default path is the current directory.

Notes

URLs require a scheme string (`http://`) to be used, without it they will fail:

```python
>>> repos = DataSource()
>>> repos.exists('www.google.com/index.html')
False
>>> repos.exists('http://www.google.com/index.html')
True
```

Temporary directories are deleted when the DataSource is deleted.

Examples

```python
>>> ds = DataSource('/home/guido')
>>> urlname = 'http://www.google.com/index.html'
>>> gfile = ds.open('http://www.google.com/index.html') # remote file
>>> ds.abspath(urlname)
'/home/guido/www.google.com/site/index.html'

>>> ds = DataSource(None)  # use with temporary file
>>> ds.open('/home/guido/foobar.txt')
<open file '/home/guido/foobar.txt', mode 'r' at 0x91d4430>
>>> ds.abspath('/home/guido/foobar.txt')
'/tmp/tmpy4pgsP/home/guido/foobar.txt'
```
Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>abspath(path)</code></td>
<td>Return absolute path of file in the DataSource directory.</td>
</tr>
<tr>
<td><code>exists(path)</code></td>
<td>Test if path exists.</td>
</tr>
<tr>
<td><code>open(path[, mode])</code></td>
<td>Open and return file-like object.</td>
</tr>
</tbody>
</table>

**DataSource.abspath(path)**

Return absolute path of file in the DataSource directory.

If `path` is an URL, then `abspath` will return either the location the file exists locally or the location it would exist when opened using the `open` method.

**Parameters**

- `path`: str
  - Can be a local file or a remote URL.

**Returns**

- `out`: str
  - Complete path, including the DataSource destination directory.

**Notes**

The functionality is based on `os.path.abspath`.

**DataSource.exists(path)**

Test if path exists.

Test if `path` exists as (and in this order):

- a local file.
- a remote URL that has been downloaded and stored locally in the DataSource directory.
- a remote URL that has not been downloaded, but is valid and accessible.

**Parameters**

- `path`: str
  - Can be a local file or a remote URL.

**Returns**

- `out`: bool
  - True if `path` exists.

**Notes**

When `path` is an URL, `exists` will return True if it’s either stored locally in the DataSource directory, or is a valid remote URL. DataSource does not discriminate between the two, the file is accessible if it exists in either location.

**DataSource.open(path, mode='r')**

Open and return file-like object.

If `path` is an URL, it will be downloaded, stored in the DataSource directory and opened from there.

**Parameters**

- `path`: str
  - Local file path or URL to open.
mode : {‘r’, ‘w’, ‘a’}, optional

Mode to open path. Mode ‘r’ for reading, ‘w’ for writing, ‘a’ to append. Available
modes depend on the type of object specified by path. Default is ‘r’.

Returns
out : file object

File object.

3.17 Linear algebra (numpy.linalg)

3.17.1 Matrix and vector products

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`numpy.dot(a, b, out=None)`

Dot product of two arrays.

For 2-D arrays it is equivalent to matrix multiplication, and for 1-D arrays to inner product of vectors (without complex conjugation). For N dimensions it is a sum product over the last axis of a and the second-to-last of b:

\[
dot(a, b)[i, j, k, m] = \sum(a[i, j, :] * b[k, :, m])
\]

Parameters
a : array_like

First argument.
b : array_like

Second argument.
out : ndarray, optional

Output argument. This must have the exact kind that would be returned if it was not used. In particular, it must have the right type, must be C-contiguous, and its dtype must be the dtype that would be returned for `dot(a, b)`. This is a performance feature. Therefore, if these conditions are not met, an exception is raised, instead of attempting to be flexible.

Returns
output : ndarray

Returns the dot product of a and b. If a and b are both scalars or both 1-D arrays then a scalar is returned; otherwise an array is returned. If `out` is given, then it is returned.

Raises
ValueError
If the last dimension of \(a\) is not the same size as the second-to-last dimension of \(b\).

See also:

**vdot**
Complex-conjugating dot product.

**tensordot**
Sum products over arbitrary axes.

**einsum**
Einstein summation convention.

**Examples**

```python
>>> np.dot(3, 4)
12
```

Neither argument is complex-conjugated:

```python
>>> np.dot([2j, 3j], [2j, 3j])
(-13+0j)
```

For 2-D arrays it’s the matrix product:

```python
>>> a = [[1, 0], [0, 1]]
>>> b = [[4, 1], [2, 2]]
>>> np.dot(a, b)
array([[4, 1],
       [2, 2]])
```

```python
>>> a = np.arange(3*4*5*6).reshape((3,4,5,6))
>>> b = np.arange(3*4*5*6)[::-1].reshape((5,4,6,3))
>>> np.dot(a, b)[2,3,2,1,2,2]
499128
```

```python
>>> sum(a[2,3,2,:] * b[1,2,:,2])
499128
```

**numpy.vdot(a, b)**

Return the dot product of two vectors.

The vdot\((a, b)\) function handles complex numbers differently than dot\((a, b)\). If the first argument is complex the complex conjugate of the first argument is used for the calculation of the dot product.

Note that vdot handles multidimensional arrays differently than dot: it does not perform a matrix product, but flattens input arguments to 1-D vectors first. Consequently, it should only be used for vectors.

**Parameters**

- **a**: array_like
  
  If \(a\) is complex the complex conjugate is taken before calculation of the dot product.
  
- **b**: array_like
  
  Second argument to the dot product.

**Returns**

- **output**: ndarray
  
  Dot product of \(a\) and \(b\). Can be an int, float, or complex depending on the types of \(a\) and \(b\).

See also:
dot

Return the dot product without using the complex conjugate of the first argument.

Examples

```python
>>> a = np.array([1+2j,3+4j])
>>> b = np.array([5+6j,7+8j])
>>> np.vdot(a, b)
(70-8j)
>>> np.vdot(b, a)
(70+8j)
```

Note that higher-dimensional arrays are flattened!

```python
>>> a = np.array([[[1,4], [5,6]]])
>>> b = np.array([[[4,1], [2,2]]])
>>> np.vdot(a, b)
30
>>> np.vdot(b, a)
30
>>> 1*4 + 4*1 + 5*2 + 6*2
30
```

`numpy.inner(a, b)`

Inner product of two arrays.

Ordinary inner product of vectors for 1-D arrays (without complex conjugation), in higher dimensions a sum product over the last axes.

**Parameters**

- `a, b` : array_like

  If `a` and `b` are nonscalar, their last dimensions of must match.

**Returns**

- `out` : ndarray

  `out.shape = a.shape[:-1] + b.shape[:-1]`

**Raises**

- `ValueError`

  If the last dimension of `a` and `b` has different size.

**See also:**

- `tensordot`

  Sum products over arbitrary axes.

- `dot`

  Generalised matrix product, using second last dimension of `b`.

- `einsum`

  Einstein summation convention.

**Notes**

For vectors (1-D arrays) it computes the ordinary inner-product:

```python
np.inner(a, b) = sum(a[:] * b[:])
```

More generally, if `ndim(a) = r > 0` and `ndim(b) = s > 0`:
np.inner(a, b) = np.tensordot(a, b, axes=(-1,-1))

or explicitly:
np.inner(a, b)[i0,...,ir-1,j0,...,js-1]
    = sum(a[i0,...,ir-1,:]*b[j0,...,js-1,:])

In addition a or b may be scalars, in which case:
np.inner(a,b) = a*b

Examples

Ordinary inner product for vectors:
>>> a = np.array([1,2,3])
>>> b = np.array([0,1,0])
>>> np.inner(a, b)
2

A multidimensional example:
>>> a = np.arange(24).reshape((2,3,4))
>>> b = np.arange(4)
>>> np.inner(a, b)
array([[ 14,  38,  62],
       [ 86, 110, 134]])

An example where b is a scalar:
>>> np.inner(np.eye(2), 7)
array([[ 7.,  0.],
       [ 0.,  7.]])

numpy.outer(a, b, out=None)
Compute the outer product of two vectors.

Given two vectors, a = [a0, a1, ..., aM] and b = [b0, b1, ..., bN], the outer product [R55] is:

[[a0*b0  a0*b1     ...
  a0*bN ]
 [a1*b0  ...
  a1*bN ]
 [...            ...
  [aM*b0 aM*bN]]

Parameters

a : (M,) array_like
    First input vector. Input is flattened if not already 1-dimensional.

b : (N,) array_like
    Second input vector. Input is flattened if not already 1-dimensional.

out : (M, N) ndarray, optional
    A location where the result is stored

New in version 1.9.0.

Returns

out : (M, N) ndarray
out[i, j] = a[i] * b[j]

See also:
inner, einsum

References

[R55]

Examples

Make a (very coarse) grid for computing a Mandelbrot set:

```python
>>> rl = np.outer(np.ones((5,)), np.linspace(-2, 2, 5))
>>> rl
array([[ -2., -1.,  0.,  1.,  2.],
        [ -2., -1.,  0.,  1.,  2.],
        [ -2., -1.,  0.,  1.,  2.],
        [ -2., -1.,  0.,  1.,  2.],
        [ -2., -1.,  0.,  1.,  2.]])

>>> im = np.outer(1j*np.linspace(2, -2, 5), np.ones((5,)))
>>> im
array([[ 0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j],
        [ 0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j],
        [ 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j],
        [ 0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j],
        [ 0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j]])

>>> grid = rl + im
>>> grid
array([[-2.+2.j, -1.+2.j,  0.+2.j,  1.+2.j,  2.+2.j],
        [-2.+1.j, -1.+1.j,  0.+1.j,  1.+1.j,  2.+1.j],
        [-2.+0.j, -1.+0.j,  0.+0.j,  1.+0.j,  2.+0.j],
        [-2.-1.j, -1.-1.j,  0.-1.j,  1.-1.j,  2.-1.j],
        [-2.-2.j, -1.-2.j,  0.-2.j,  1.-2.j,  2.-2.j]])
```

An example using a “vector” of letters:

```python
>>> x = np.array(['a', 'b', 'c'], dtype=object)
>>> np.outer(x, [1, 2, 3])
array([['a', 'aa', 'aaa'],
       ['b', 'bb', 'bbb'],
       ['c', 'cc', 'ccc']], dtype=object)
```

numpy.tensordot (a, b, axes=2)

Compute tensor dot product along specified axes for arrays >= 1-D.

Given two tensors (arrays of dimension greater than or equal to one), `a` and `b`, and an array_like object containing two array_like objects, `(a_axes, b_axes)`, sum the products of `a`'s and `b`'s elements (components) over the axes specified by `a_axes` and `b_axes`. The third argument can be a single non-negative integer_like scalar, `N`; if it is such, then the last `N` dimensions of `a` and the first `N` dimensions of `b` are summed over.

Parameters

- `a, b` : array_like, len(shape) >= 1
  Tensors to “dot”.

  - `axes` : variable type
    - integer_like scalar Number of axes to sum over (applies to both arrays); or
(2,) array_like, both elements array_like of the same length List of axes to be summed over, first sequence applying to a, second to b.

See also:
dot, einsum

Notes

When there is more than one axis to sum over - and they are not the last (first) axes of a (b) - the argument axes should consist of two sequences of the same length, with the first axis to sum over given first in both sequences, the second axis second, and so forth.

Examples

A “traditional” example:

```python
>>> a = np.arange(60.).reshape(3,4,5)
>>> b = np.arange(24.).reshape(4,3,2)
>>> c = np.tensordot(a,b, axes=[[1,0],[0,1]])
>>> c.shape
(5, 2)
>>> c
array([[ 4400., 4730.],
       [ 4532., 4874.],
       [ 4664., 5018.],
       [ 4796., 5162.],
       [ 4928., 5306.]])
>>> # A slower but equivalent way of computing the same...
>>> d = np.zeros((5,2))
>>> for i in range(5):
...     for j in range(2):
...         for k in range(3):
...             for n in range(4):
...                 d[i,j] += a[k,n,i] * b[n,k,j]
>>> c == d
array([[ True, True],
       [ True, True],
       [ True, True],
       [ True, True],
       [ True, True]], dtype=bool)
```

An extended example taking advantage of the overloading of + and *:

```python
>>> a = np.array(range(1, 9))
>>> a.shape = (2, 2, 2)
>>> A = np.array(('a', 'b', 'c', 'd'), dtype=object)
>>> A.shape = (2, 2)
>>> a; A
array([[1, 2],
       [3, 4]], dtype=object)
array([['a', 'b'],
       ['c', 'd']], dtype=object)
>>> np.tensordot(a, A) # third argument default is 2
array(['abbccddddd', 'aaaaabbbbbccccccccdddddddd'], dtype=object)
```
```python
>>> np.tensordot(a, A, 1)
array([[[[acc, bdd],
        [aaacccc, bbbddddd]],
       [[[aaacccc, bbbddddd],
        [aaaacccc, bbbbdffddddd]], dtype=object])

>>> np.tensordot(a, A, 0)  # "Left for reader" (result too long to incl.)
array([[[[a, b],
        [c, d]],
       ...]]

>>> np.tensordot(a, A, (0, 1))
array([[abbbbb, cddddd],
       [aabbbb, ccdddddd],
       [aaaabbbbbb, cccddddddd]], dtype=object)

>>> np.tensordot(a, A, (2, 1))
array([[abb, cdd],
       [aaabbb, ccdddd],
       [aaaaabbbbbb, cccccddddddd]], dtype=object)

>>> np.tensordot(a, A, ((0, 1), (0, 1)))
array([abbbccccddddd, aabbbccccddddd], dtype=object)

>>> np.tensordot(a, A, ((2, 1), (1, 0)))
array([acccbbdddd, aaaaaaccccbbbbddddd], dtype=object)
```

def numpy.einsum(subscripts, *operands, out=None, dtype=None, order='K', casting='safe')

Evaluates the Einstein summation convention on the operands.

Using the Einstein summation convention, many common multi-dimensional array operations can be represented in a simple fashion. This function provides a way compute such summations. The best way to understand this function is to try the examples below, which show how many common NumPy functions can be implemented as calls to `einsum`.

Parameters

- **subscripts** : str
  Specifies the subscripts for summation.

- **operands** : list of array_like
  These are the arrays for the operation.

- **out** : ndarray, optional
  If provided, the calculation is done into this array.

- **dtype** : data-type, optional
  If provided, forces the calculation to use the data type specified. Note that you may have to also give a more liberal `casting` parameter to allow the conversions.

- **order** : {'C', 'F', 'A', 'K'}, optional
  Controls the memory layout of the output. ‘C’ means it should be C contiguous. ‘F’ means it should be Fortran contiguous, ‘A’ means it should be ‘F’ if the inputs are all ‘F’, ‘C’ otherwise. ‘K’ means it should be as close to the layout as the inputs as is possible, including arbitrarily permuted axes. Default is ‘K’.

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casting : {’no’, ’equiv’, ’safe’, ’same_kind’, ’unsafe’}, optional

Controls what kind of data casting may occur. Setting this to ‘unsafe’ is not recommended, as it can adversely affect accumulations.

• ‘no’ means the data types should not be cast at all.
• ‘equiv’ means only byte-order changes are allowed.
• ‘safe’ means only casts which can preserve values are allowed.
• ‘same_kind’ means only safe casts or casts within a kind, like float64 to float32, are allowed.
• ‘unsafe’ means any data conversions may be done.

Returns

output : ndarray

The calculation based on the Einstein summation convention.

See also:
dot, inner, outer, tensordot

Notes

New in version 1.6.0.

The subscripts string is a comma-separated list of subscript labels, where each label refers to a dimension of the corresponding operand. Repeated subscripts labels in one operand take the diagonal. For example, np.einsum(’ii’, a) is equivalent to np.trace(a).

Whenever a label is repeated, it is summed, so np.einsum(’i,i’, a, b) is equivalent to np.inner(a, b). If a label appears only once, it is not summed, so np.einsum(’i’, a) produces a view of a with no changes.

The order of labels in the output is by default alphabetical. This means that np.einsum(’ij’, a) doesn’t affect a 2D array, while np.einsum(’ji’, a) takes its transpose.

The output can be controlled by specifying output subscript labels as well. This specifies the label order, and allows summing to be disallowed or forced when desired. The call np.einsum(’i->’, a) is like np.sum(a, axis=-1), and np.einsum(’ii->i’, a) is like np.diag(a). The difference is that einsum does not allow broadcasting by default.

To enable and control broadcasting, use an ellipsis. Default NumPy-style broadcasting is done by adding an ellipsis to the left of each term, like np.einsum(’...ii->...i’, a). To take the trace along the first and last axes, you can do np.einsum(’i...i’, a), or to do a matrix-matrix product with the left-most indices instead of rightmost, you can do np.einsum(’ij...,jk...->ik...’, a, b).

When there is only one operand, no axes are summed, and no output parameter is provided, a view into the operand is returned instead of a new array. Thus, taking the diagonal as np.einsum(’ii->i’, a) produces a view.

An alternative way to provide the subscripts and operands is as einsum(op0, sublist0, op1, sublist1, ..., [sublistout]). The examples below have corresponding einsum calls with the two parameter methods.

Examples

>>> a = np.arange(25).reshape(5,5)
>>> b = np.arange(5)
>>> c = np.arange(6).reshape(2,3)
>> np.einsum('ii', a)
60
>> np.einsum(a, [0,0])
60
>> np.trace(a)
60

>>> np.einsum('ii->i', a)
array([0, 6, 12, 18, 24])

>>> np.einsum('ij,j', a, b)
array([30, 80, 130, 180, 230])

>>> np.einsum('ij,ji', a, b)
array([30, 80, 130, 180, 230])

>>> np.einsum('...j,j', a, b)
array([30, 80, 130, 180, 230])

>>> np.multiply(3, c)
array([[0, 3, 6],
       [9, 12, 15]])

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```python
>>> np.outer(np.arange(2)+1, b)
array([[0, 1, 2, 3, 4],
[0, 2, 4, 6, 8]])

>>> np.einsum('i...->...', a)
array([50, 55, 60, 65, 70])

>>> np.einsum(a, [0,Ellipsis], [Ellipsis])
array([50, 55, 60, 65, 70])

>>> a = np.arange(60.).reshape(3,4,5)
>>> b = np.arange(24.).reshape(4,3,2)
>>> np.einsum('ijk,jil->kl', a, b)
array([[ 4400., 4730.],
[ 4532., 4874.],
[ 4664., 5018.],
[ 4796., 5162.],
[ 4928., 5306.]])

>>> np.einsum(a, [0,1,2], b, [1,0,3], [2,3])
array([[ 4400., 4730.],
[ 4532., 4874.],
[ 4664., 5018.],
[ 4796., 5162.],
[ 4928., 5306.]])

>>> np.tensordot(a,b, axes=(1,0))
array([[ 4400., 4730.],
[ 4532., 4874.],
[ 4664., 5018.],
[ 4796., 5162.],
[ 4928., 5306.]])

>>> a = np.arange(6).reshape((3,2))
>>> b = np.arange(12).reshape((4,3))
>>> np.einsum('ki,jk->ij', a, b)
array([[10, 28, 46, 64],
[13, 40, 67, 94]])

>>> np.einsum('ki,...k->i...', a, b)
array([[10, 28, 46, 64],
[13, 40, 67, 94]])

numpy.linalg.matrix_power(M, n)
Raise a square matrix to the (integer) power n.

For positive integers n, the power is computed by repeated matrix squarings and matrix multiplications. If n == 0, the identity matrix of the same shape as M is returned. If n < 0, the inverse is computed and then raised to the abs(n).

Parameters

M : ndarray or matrix object

Matrix to be "powered." Must be square, i.e. M.shape == (m, m), with m a positive integer.

n : int

Parameters

M : ndarray or matrix object

Matrix to be "powered." Must be square, i.e. M.shape == (m, m), with m a positive integer.

n : int
```
The exponent can be any integer or long integer, positive, negative, or zero.

Returns

\(M^n\) : ndarray or matrix object

The return value is the same shape and type as \(M\); if the exponent is positive or zero then the type of the elements is the same as those of \(M\). If the exponent is negative the elements are floating-point.

Raises

LinAlgError

If the matrix is not numerically invertible.

See also:

matrix

Provides an equivalent function as the exponentiation operator (\(^*\), not \(^\)).

Examples

```python
>>> from numpy import linalg as LA
>>> i = np.array([[0, 1], [-1, 0]])  # matrix equiv. of the imaginary unit
>>> LA.matrix_power(i, 3)  # should = -i
array([[ 0, -1],
       [ 1,  0]])
>>> LA.matrix_power(np.matrix(i), 3)  # matrix arg returns matrix
matrix([[ 0, -1],
       [ 1,  0]])
>>> LA.matrix_power(i, 0)
array([[1, 0],
       [0, 1]])
>>> LA.matrix_power(i, -3)  # should = 1/(-i) = i, but w/ f.p. elements
array([[ 0., 1.],
       [-1., 0.]])
```

Somewhat more sophisticated example

```python
>>> q = np.zeros((4, 4))
>>> q[0:2, 0:2] = -i
>>> q[2:4, 2:4] = i
>>> q  # one of the three quaternion units not equal to 1
array([[ 0., -1., 0., 0.],
       [ 1.,  0., 0., 0.],
       [ 0.,  0., 0., 1.],
       [ 0.,  0., -1., 0.]])
>>> LA.matrix_power(q, 2)  # = -np.eye(4)
array([[-1., 0., 0., 0.],
       [ 0., -1., 0., 0.],
       [ 0.,  0., -1., 0.],
       [ 0.,  0., 0., -1.]])
```

numpy.kron\((a, b)\)

Kronecker product of two arrays.

Computes the Kronecker product, a composite array made of blocks of the second array scaled by the first.

Parameters

\(a, b: array_like\)
Returns

out : ndarray

See also:

outer

The outer product

Notes

The function assumes that the number of dimensions of \(a\) and \(b\) are the same, if necessary prepending the smallest with ones. If \(a.shape = (r_{0}, r_{1}, \ldots, r_{N})\) and \(b.shape = (s_{0}, s_{1}, \ldots, s_{N})\), the Kronecker product has shape \((r_{0} \times s_{0}, r_{1} \times s_{1}, \ldots, r_{N} \times s_{N})\). The elements are products of elements from \(a\) and \(b\), organized explicitly by:

\[
\text{kron}(a, b)[k_0, k_1, \ldots, k_N] = a[i_0, i_1, \ldots, i_N] \times b[j_0, j_1, \ldots, j_N]
\]

where:

\[k_t = i_t \times s_t + j_t, \quad t = 0, \ldots, N\]

In the common 2-D case \((N=1)\), the block structure can be visualized:

\[
\begin{bmatrix}
    a[0,0] \times b, & a[0,1] \times b, & \ldots, & a[0,-1] \times b \\
    \vdots & \vdots & \ddots & \vdots \\
    a[-1,0] \times b, & a[-1,1] \times b, & \ldots, & a[-1,-1] \times b
\end{bmatrix}
\]

Examples

```python
>>> np.kron([1,10,100], [5,6,7])
array([ 5, 6, 7, 50, 60, 70, 500, 600, 700])
>>> np.kron([5,6,7], [1,10,100])
array([ 5, 50, 500, 6, 60, 600, 7, 70, 700])
>>> np.kron(np.eye(2), np.ones((2,2)))
array([[ 1., 1.],
       [ 1., 1.]])
>>> a = np.arange(100).reshape((2,5,2,5))
>>> b = np.arange(24).reshape((2,3,4))
>>> c = np.kron(a,b)
>>> c.shape
(2, 10, 6, 20)
>>> I = (1,3,0,2)
>>> J = (0,2,1)
>>> J1 = (0,) + J  # extend to ndim=4
>>> S1 = (1,) + b.shape
>>> K = tuple(np.array(I) * np.array(S1) + np.array(J1))
>>> c[K] == a[I] * b[J]
True
```

3.17.2 Decompositions

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<td>Cholesky decomposition.</td>
</tr>
<tr>
<td><code>linalg.qr(a, mode)</code></td>
<td>Compute the QR factorization of a matrix.</td>
</tr>
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**numpy.linalg.cholesky**

Cholesky decomposition.

Return the Cholesky decomposition, \( L \ast L.H \), of the square matrix \( a \), where \( L \) is lower-triangular and \( .H \) is the conjugate transpose operator (which is the ordinary transpose if \( a \) is real-valued). \( a \) must be Hermitian (symmetric if real-valued) and positive-definite. Only \( L \) is actually returned.

**Parameters**

\( a : (...) \times M \times M \) array_like

Hermitian (symmetric if all elements are real), positive-definite input matrix.

**Returns**

\( L : (...) \times M \times M \) array_like

Upper or lower-triangular Cholesky factor of \( a \). Returns a matrix object if \( a \) is a matrix object.

**Raises**

LinAlgError

If the decomposition fails, for example, if \( a \) is not positive-definite.

**Notes**

Broadcasting rules apply, see the numpy.linalg documentation for details.

The Cholesky decomposition is often used as a fast way of solving

\[
Ax = b
\]

(when \( A \) is both Hermitian/symmetric and positive-definite).

First, we solve for \( y \) in

\[
Ly = b,
\]

and then for \( x \) in

\[
L.Hx = y.
\]

**Examples**

```python
>>> A = np.array([[1,-2j],[2j,5]])
>>> A
array([[ 1.+0.j, 0.-2.j],
       [ 0.+2.j, 5.+0.j]])
>>> L = np.linalg.cholesky(A)
>>> L
array([[ 1.+0.j, 0.+0.j],
       [ 0.+2.j, 1.+0.j]])
>>> np.dot(L, L.T.conj()) # verify that L \ast L.H = A
array([[ 1.+0.j, 0.-2.j],
       [ 0.+2.j, 5.+0.j]])
>>> A = [[1,-2j],[2j,5]] # what happens if A is only array_like?
>>> np.linalg.cholesky(A) # an ndarray object is returned
array([[ 1.+0.j, 0.-2.j],
       [ 0.+2.j, 1.+0.j]])
```
>>> # But a matrix object is returned if A is a matrix object
>>> LA.cholesky(np.matrix(A))
matrix([[ 1.+0.j, 0.+0.j],
        [ 0.+2.j, 1.+0.j]])

numpy.linalg.qr (a, mode='reduced')

Compute the qr factorization of a matrix.

Factor the matrix a as qr, where q is orthonormal and r is upper-triangular.

Parameters

a : array_like, shape (M, N)
    Matrix to be factored.

mode : {'reduced', 'complete', 'r', 'raw', 'full', 'economic'}, optional
    If K = min(M, N), then
    'reduced' : returns q, r with dimensions (M, K), (K, N) (default) 'complete' : returns
                 q, r with dimensions (M, M), (M, N) 'r' : returns r only with dimensions (K, N) 'raw'
                 : returns h, tau with dimensions (N, M), (K,) 'full' : alias of 'reduced', deprecated
                 'economic' : returns h from 'raw', deprecated.

The options 'reduced', 'complete, and 'raw' are new in numpy 1.8, see the notes for
more information. The default is 'reduced' and to maintain backward compatibility
with earlier versions of numpy both it and the old default 'full' can be omitted. Note
that array h returned in 'raw' mode is transposed for calling Fortran. The 'economic'
mode is deprecated. The modes 'full' and 'economic' may be passed using only the
first letter for backwards compatibility, but all others must be spelled out. See the Notes
for more explanation.

Returns

q : ndarray of float or complex, optional
    A matrix with orthonormal columns. When mode = 'complete' the result is an ortho-
    normal/unitary matrix depending on whether or not a is real/complex. The determinant may
    be either +/- 1 in that case.

r : ndarray of float or complex, optional
    The upper-triangular matrix.

(h, tau) : ndarrays of np.double or np.cdouble, optional
    The array h contains the Householder reflectors that generate q along with r. The tau
    array contains scaling factors for the reflectors. In the deprecated 'economic' mode only
    h is returned.

Raises

LinAlgError
    If factoring fails.

Notes

This is an interface to the LAPACK routines dgeqrf, zgeqrf, dorgqr, and zungqr.
For more information on the qr factorization, see for example: http://en.wikipedia.org/wiki/QR_factorization
Subclasses of ndarray are preserved except for the 'raw' mode. So if a is of type matrix, all the return values
will be matrices too.
New ‘reduced’, ‘complete’, and ‘raw’ options for mode were added in Numpy 1.8 and the old option ‘full’ was made an alias of ‘reduced’. In addition the options ‘full’ and ‘economic’ were deprecated. Because ‘full’ was the previous default and ‘reduced’ is the new default, backward compatibility can be maintained by letting mode default. The ‘raw’ option was added so that LAPACK routines that can multiply arrays by q using the Householder reflectors can be used. Note that in this case the returned arrays are of type np.double or np.cdouble and the h array is transposed to be FORTRAN compatible. No routines using the ‘raw’ return are currently exposed by numpy, but some are available in lapack_lite and just await the necessary work.

Examples

```python
>>> a = np.random.randn(9, 6)
```
```python
>>> q, r = np.linalg.qr(a)
```
```python
>>> np.allclose(a, np.dot(q, r))  # a does equal qr
True
```
```python
>>> r2 = np.linalg.qr(a, mode='r')
```
```python
>>> r3 = np.linalg.qr(a, mode='economic')
```
```python
>>> np.allclose(r, r2)    # mode='r' returns the same r as mode='full'
True
```
```python
>>> # But only triu parts are guaranteed equal when mode='economic'
```
```python
>>> np.allclose(r, np.triu(r3[:6,:6], k=0))
```
```python
Example illustrating a common use of qr: solving of least squares problems
```
What are the least-squares-best m and y0 in y = y0 + mx for the following data: {(0,1), (1,0), (1,2), (2,1)}. (Graph the points and you’ll see that it should be y0 = 0, m = 1.) The answer is provided by solving the over-determined matrix equation Ax = b, where:

A = array([[0, 1], [1, 1], [1, 1], [2, 1]])
x = array([[y0], [m]])
b = array([[1], [0], [2], [1]])

If A = qr such that q is orthonormal (which is always possible via Gram-Schmidt), then x = inv(r) * (q.T) * b. (In numpy practice, however, we simply use lstsq.)

```python
>>> A = np.array([[0, 1], [1, 1], [1, 1], [2, 1]])
```
```python
>>> A
```
```python
array([[0, 1],
       [1, 1],
       [1, 1],
       [2, 1]])
```
```python
>>> b = np.array([[1], [0], [2], [1]])
```
```python
>>> q, r = LA.qr(A)
```
```python
>>> q, r = LA.qr(A)
```
```python
>>> p = np.dot(q.T, b)
```
```python
>>> np.dot(LA.inv(r), p)
```
```python
array([ 1.0e-16, 1.0e+00])
```
```python
numpy.linalg.svd(a, full_matrices=1, compute_uv=1)
```
Singular Value Decomposition.

Factors the matrix a as u * np.diag(s) * v, where u and v are unitary and s is a 1-d array of a’s singular values.

Parameters

- `a`: (..., M, N) array_like
  - A real or complex matrix of shape `(M, N)`.
- `full_matrices`: bool, optional
If True (default), \( u \) and \( v \) have the shapes \((M, M)\) and \((N, N)\), respectively. Otherwise, the shapes are \((M, K)\) and \((K, N)\), respectively, where \(K = \min(M, N)\).

**compute_uv**: bool, optional

Whether or not to compute \( u \) and \( v \) in addition to \( s \). True by default.

**Returns**

\( u \): \{ \(\ldots, M, M\), \(\ldots, M, K\) \} array

Unitary matrices. The actual shape depends on the value of \texttt{full_matrices}. Only returned when \texttt{compute_uv} is True.

\( s \): \(\ldots, K\) array

The singular values for every matrix, sorted in descending order.

\( v \): \{ \(\ldots, N, N\), \(\ldots, K, N\) \} array

Unitary matrices. The actual shape depends on the value of \texttt{full_matrices}. Only returned when \texttt{compute_uv} is True.

**Raises**

\texttt{LinAlgError}

If SVD computation does not converge.

**Notes**

Broadcasting rules apply, see the \texttt{numpy.linalg} documentation for details.

The decomposition is performed using LAPACK routine \_gesdd.

The SVD is commonly written as \(a = U S V.H\). The \(v\) returned by this function is \(V.H\) and \(u = U\).

If \(U\) is a unitary matrix, it means that it satisfies \(U.H = \text{inv}(U)\).

The rows of \(v\) are the eigenvectors of \(a.H a\). The columns of \(u\) are the eigenvectors of \(a a.H\). For row \(i\) in \(v\) and column \(i\) in \(u\), the corresponding eigenvalue is \(s[i]**2\).

If \(a\) is a matrix object (as opposed to an \texttt{ndarray}), then so are all the return values.

**Examples**

```python
>>> a = np.random.randn(9, 6) + 1j*np.random.randn(9, 6)
```

Reconstruction based on full SVD:

```python
>>> U, s, V = np.linalg.svd(a, full_matrices=True)
>>> U.shape, V.shape, s.shape
((9, 9), (6, 6), (6,))
>>> S = np.zeros((9, 6), dtype=complex)
>>> S[:6, :6] = np.diag(s)
>>> np.allclose(a, np.dot(U, np.dot(S, V)))
True
```

Reconstruction based on reduced SVD:

```python
>>> U, s, V = np.linalg.svd(a, full_matrices=False)
>>> U.shape, V.shape, s.shape
((9, 6), (6, 6), (6,))
>>> S = np.diag(s)
>>> np.allclose(a, np.dot(U, np.dot(S, V)))
True
```
3.17.3 Matrix eigenvalues

- `linalg.eig(a)`: Compute the eigenvalues and right eigenvectors of a square array.
- `linalg.eigh(a[, UPLO])`: Return the eigenvalues and eigenvectors of a Hermitian or symmetric matrix.
- `linalg.eigvals(a)`: Compute the eigenvalues of a general matrix.
- `linalg.eigvalsh(a[, UPLO])`: Compute the eigenvalues of a Hermitian or real symmetric matrix.

```
numpy.linalg.eig(a)
```

Compute the eigenvalues and right eigenvectors of a square array.

**Parameters**

- `a : (...) M, M array`
  
  Matrices for which the eigenvalues and right eigenvectors will be computed

**Returns**

- `w : (...) M array`
  
  The eigenvalues, each repeated according to its multiplicity. The eigenvalues are not
  necessarily ordered. The resulting array will be always be of complex type. When `a`
  is real the resulting eigenvalues will be real (0 imaginary part) or occur in
  conjugate pairs

- `v : (...) M, M array`
  
  The normalized (unit “length”) eigenvectors, such that the column
  `v[:,i]` is the eigen-
  vector corresponding to the eigenvalue `w[i]`.

**Raises**

- `LinAlgError`
  
  If the eigenvalue computation does not converge.

**See also:**

- `eigvalsh`
  
  eigenvalues of a symmetric or Hermitian (conjugate symmetric) array.

- `eigvals`
  
  eigenvalues of a non-symmetric array.

**Notes**

Broadcasting rules apply, see the `numpy.linalg` documentation for details.

This is implemented using the `_geev LAPACK routines which compute the eigenvalues and eigenvectors of
general square arrays.

The number `w` is an eigenvalue of `a` if there exists a vector `v` such that
`\dot{a} v = w \times v`. Thus, the arrays `a, w,` and `v` satisfy the equations
`\dot{a} [i, i] = w[i] \times v[i] for i \in \{0, ..., M - 1\}`.

The array `v` of eigenvectors may not be of maximum rank, that is, some of the columns may be linearly de-
pendant, although round-off error may obscure that fact. If the eigenvalues are all different, then theoretically
the eigenvectors are linearly independent. Likewise, the (complex-valued) matrix of eigenvectors `v` is unitary if the
matrix `a` is normal, i.e., if `\dot{a} = \dot{a.H, a}`, where `a.H` denotes the conjugate transpose of `a`.

Finally, it is emphasized that `v` consists of the *right* (as in right-hand side) eigenvectors of `a`. A vector `y`
satisfying `\dot{y.T, a} = z * y.T` for some number `z` is called a *left* eigenvector of `a`, and, in general, the left and
right eigenvectors of a matrix are not necessarily the (perhaps conjugate) transposes of each other.
References


Examples

```python
>>> from numpy import linalg as LA
```

(Almost) trivial example with real e-values and e-vectors.

```python
>>> w, v = LA.eig(np.diag((1, 2, 3)))
```

```python
>>> w; v
array([ 1., 2., 3.])
array([[ 1., 0., 0.],
       [ 0., 1., 0.],
       [ 0., 0., 1.]])
```

Real matrix possessing complex e-values and e-vectors; note that the e-values are complex conjugates of each other.

```python
>>> w, v = LA.eig(np.array([[1, -1], [1, 1]]))
```

```python
>>> w; v
array([ 1. + 1.j, 1. - 1.j])
array([[ 0.70710678+0.j, 0.70710678+0.j],
       [ 0.00000000-0.70710678j, 0.00000000+0.70710678j]])
```

Complex-valued matrix with real e-values (but complex-valued e-vectors); note that a.conj().T = a, i.e., a is Hermitian.

```python
>>> a = np.array([[1, 1j], [-1j, 1]])
```

```python
>>> w, v = LA.eig(a)
```

```python
>>> w; v
array([2.00000000e+00+0.j, 5.98651912e-36+0.j]) # i.e., {2, 0}
array([[ 0.70710678+0.j, 0.70710678+0.j],
       [ 0.00000000-0.70710678j, 0.00000000+0.70710678j]])
```

Be careful about round-off error!

```python
>>> a = np.array([[1 + 1e-9, 0], [0, 1 - 1e-9]])
```

```python
>>> w, v = LA.eig(a)
```

```python
>>> w; v
array([ 1., 1.])
array([[ 1., 0.],
       [ 0., 1.]])
```

```python
numpy.linalg.eigh(a, UPLO='L')
```

Return the eigenvalues and eigenvectors of a Hermitian or symmetric matrix.

Returns two objects, a 1-D array containing the eigenvalues of `a`, and a 2-D square array or matrix (depending on the input type) of the corresponding eigenvectors (in columns).

Parameters

- **A**: (..., M, M) array
  - Hermitian/Symmetric matrices whose eigenvalues and eigenvectors are to be computed.

- **UPLO** : {'L', 'U'}, optional
  - Specifies whether the calculation is done with the lower triangular part of `a` ('L', default) or the upper triangular part ('U').
Returns

\(w: (..., M) \text{ndarray}\)

The eigenvalues, not necessarily ordered.

\(v: \{(..., M, M) \text{ndarray}, (..., M, M) \text{matrix}\}\)

The column \(v[:, i]\) is the normalized eigenvector corresponding to the eigenvalue \(w[i]\). Will return a matrix object if \(a\) is a matrix object.

Raises

LinAlgError

If the eigenvalue computation does not converge.

See also:

eigvalsh
eigenvalues of symmetric or Hermitian arrays.
eig
eigenvalues and right eigenvectors for non-symmetric arrays.eigvals
eigenvalues of non-symmetric arrays.

Notes

Broadcasting rules apply, see the numpy.linalg documentation for details.

The eigenvalues/eigenvectors are computed using LAPACK routines _ssyevd, _heevd.

The eigenvalues of real symmetric or complex Hermitian matrices are always real. [R38] The array \(v\) of (column) eigenvectors is unitary and \(a, w, v\) satisfy the equations \(\text{dot}(a, v[:, i]) = w[i] \times v[:, i]\).

References

[R38]

Examples

```python
>>> from numpy import linalg as LA
>>> a = np.array([[1, -2j], [2j, 5]])
>>> a
array([[ 1.+0.j, 0.-2.j],
       [ 0.+2.j, 5.+0.j]])
>>> w, v = LA.eigh(a)
>>> w; v
array([ 0.17157288, 5.82842712]),
array([[ 0.92387953+0.j, 0.38268343+0.j ],
       [-0.38268343+0.j, 0.92387953+0.j]])
```

```python
>>> np.dot(a, v[:, 0]) - w[0] * v[:, 0] # verify 1st e-val/vec pair
array([2.77555756e-17 +0.j, 0. +1.38777878e-16j])
```

```python
>>> np.dot(a, v[:, 1]) - w[1] * v[:, 1] # verify 2nd e-val/vec pair
array([ 0. +0.j, 0. +0.j])
```

```python
>>> A = np.matrix(a) # what happens if input is a matrix object
>>> A
matrix([[ 1.+0.j, 0.-2.j],
        [ 0.+2.j, 5.+0.j]])
>>> w, v = LA.eigh(A)
```
numpy.linalg.eigvals(a)

Compute the eigenvalues of a general matrix.

Main difference between `eigvals` and `eig`: the eigenvectors aren't returned.

Parameters

- a : (..., M, M) array_like
  A complex- or real-valued matrix whose eigenvalues will be computed.

Returns

- w : (..., M,) ndarray
  The eigenvalues, each repeated according to its multiplicity. They are not necessarily
  ordered, nor are they necessarily real for real matrices.

Raises

- LinAlgError
  If the eigenvalue computation does not converge.

See also:

- `eig`  
  eigenvalues and right eigenvectors of general arrays
- `eigvalsh`  
  eigenvalues of symmetric or Hermitian arrays.
- `eigh`  
  eigenvalues and eigenvectors of symmetric/Hermitian arrays.

Notes

Broadcasting rules apply, see the `numpy.linalg` documentation for details.

This is implemented using the `_geev` LAPACK routines which compute the eigenvalues and eigenvectors of
general square arrays.

Examples

Illustration, using the fact that the eigenvalues of a diagonal matrix are its diagonal elements, that multiplying
a matrix on the left by an orthogonal matrix, \( Q \), and on the right by \( Q^T \) (the transpose of \( Q \)), preserves the
eigenvalues of the “middle” matrix. In other words, if \( Q \) is orthogonal, then \( Q \times A \times Q^T \) has the same
eigenvalues as \( A \):

```python
>>> from numpy import linalg as LA
>>> x = np.random.random()
>>> Q = np.array([[np.cos(x), -np.sin(x)], [np.sin(x), np.cos(x)]])
>>> LA.norm(Q[0, :]), LA.norm(Q[1, :]), np.dot(Q[0, :], Q[1, :])
(1.0, 1.0, 0.0)
```

Now multiply a diagonal matrix by \( Q \) on one side and by \( Q^T \) on the other:

```python
>>> D = np.diag([-1, 1])
>>> LA.eigvals(D)
array([-1.,  1.])
```
```python
>>> A = np.dot(Q, D)
>>> A = np.dot(A, Q.T)
>>> LA.eigvals(A)
array([ 1., -1.])
```

```
numpy.linalg.eigvalsh(a, UPLO='L')

Compute the eigenvalues of a Hermitian or real symmetric matrix.

Main difference from eigh: the eigenvectors are not computed.

Parameters
a : (..., M, M) array_like
    A complex- or real-valued matrix whose eigenvalues are to be computed.

UPLO : {'L', 'U'}, optional
    Same as lower, with ‘L’ for lower and ‘U’ for upper triangular. Deprecated.

Returns
w : (..., M,) ndarray
    The eigenvalues, not necessarily ordered, each repeated according to its multiplicity.

Raises
LinAlgError
    If the eigenvalue computation does not converge.

See also:
eigh
eigvals
eig
```

```
Examples
>>> from numpy import linalg as LA
>>> a = np.array([[1, -2j], [2j, 5]])
>>> LA.eigvalsh(a)
array([ 0.17157288+0.j, 5.82842712+0.j])
```

3.17.4 Norms and other numbers

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<th>Description</th>
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</thead>
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<tr>
<td>linalg.cond(x, p)</td>
<td>Compute the condition number of a matrix.</td>
</tr>
<tr>
<td>linalg.det(a)</td>
<td>Compute the determinant of an array.</td>
</tr>
<tr>
<td>linalg.matrix_rank(M[, tol])</td>
<td>Return matrix rank of array using SVD method. Rank of the array is the number of SVD.</td>
</tr>
</tbody>
</table>

3.17. Linear algebra (numpy.linalg)
numpylinalg.norm(x, ord=None, axis=None)

Matrix or vector norm.

This function is able to return one of seven different matrix norms, or one of an infinite number of vector norms (described below), depending on the value of the ord parameter.

Parameters

- **x**: array_like
  - Input array. If axis is None, x must be 1-D or 2-D.
- **ord**: {non-zero int, inf, -inf, ‘fro’}, optional
  - Order of the norm (see table under Notes). inf means numpy’s inf object.
- **axis**: {int, 2-tuple of ints, None}, optional
  - If axis is an integer, it specifies the axis of x along which to compute the vector norms. If axis is a 2-tuple, it specifies the axes that hold 2-D matrices, and the matrix norms of these matrices are computed. If axis is None then either a vector norm (when x is 1-D) or a matrix norm (when x is 2-D) is returned.

Returns

- **n**: float or ndarray
  - Norm of the matrix or vector(s).

Notes

For values of ord <= 0, the result is, strictly speaking, not a mathematical ‘norm’, but it may still be useful for various numerical purposes.

The following norms can be calculated:

<table>
<thead>
<tr>
<th>ord</th>
<th>norm for matrices</th>
<th>norm for vectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Frobenius norm</td>
<td>2-norm</td>
</tr>
<tr>
<td>‘fro’</td>
<td>Frobenius norm</td>
<td>–</td>
</tr>
<tr>
<td>inf</td>
<td>max(sum(abs(x), axis=1))</td>
<td>max(abs(x))</td>
</tr>
<tr>
<td>-inf</td>
<td>min(sum(abs(x), axis=1))</td>
<td>min(abs(x))</td>
</tr>
<tr>
<td>0</td>
<td>–</td>
<td>sum(x != 0)</td>
</tr>
<tr>
<td>1</td>
<td>max(sum(abs(x), axis=0))</td>
<td>as below</td>
</tr>
<tr>
<td>-1</td>
<td>min(sum(abs(x), axis=0))</td>
<td>as below</td>
</tr>
<tr>
<td>2</td>
<td>2-norm (largest sing. value)</td>
<td>as below</td>
</tr>
<tr>
<td>-2</td>
<td>smallest singular value</td>
<td>as below</td>
</tr>
<tr>
<td>other</td>
<td>–</td>
<td>sum(abs(x)<strong>ord)</strong>(1./ord)</td>
</tr>
</tbody>
</table>

The Frobenius norm is given by [R41]:

\[
\|A\|_F = \left( \sum_{i,j} |a_{i,j}|^2 \right)^{1/2}
\]

References

[R41]
Examples

```python
>>> from numpy import linalg as LA
>>> a = np.arange(9) - 4
>>> a
array([-4, -3, -2, -1,  0,  1,  2,  3,  4])
>>> b = a.reshape((3, 3))
>>> b
array([[ -4,  -3,  -2],
        [ -1,   0,   1],
        [  2,   3,   4]])

>>> LA.norm(a) 7.745966692414834
>>> LA.norm(b) 7.745966692414834
>>> LA.norm(b, 'fro') 7.745966692414834
>>> LA.norm(a, np.inf) 4
>>> LA.norm(b, np.inf) 9
>>> LA.norm(a, -np.inf) 0
>>> LA.norm(b, -np.inf) 2
>>> LA.norm(a, 1) 20
>>> LA.norm(b, 1) 7
>>> LA.norm(a, -1) -4.6566128774142013e-010
>>> LA.norm(b, -1) 6
>>> LA.norm(a, 2) 7.74596692414834
>>> LA.norm(b, 2) 7.484692283495345

>>> LA.norm(a, -2) nan
>>> LA.norm(b, -2) 1.857034764257312
>>> LA.norm(a, 3) 5.8480354764257312
>>> LA.norm(b, -3) nan

Using the axis argument to compute vector norms:

>>> c = np.array([ [ 1,  2,  3],
...                [-1,  1,  4]])
>>> LA.norm(c, axis=0) array([1.41421356, 2.23606798, 5.])
>>> LA.norm(c, axis=1) array([3.74165739, 4.24264069])
>>> LA.norm(c, ord=1, axis=1) array([6, 6])
```
Using the \textit{axis} argument to compute matrix norms:

```python
>>> m = np.arange(8).reshape(2,2,2)
>>> LA.norm(m, axis=(1,2))
array([3.74165739, 11.22497216])
>>> LA.norm(m[0, :, :], LA.norm(m[1, :, :])
(3.7416573867739413, 11.224972160321824)
```

\texttt{numpy.linalg.cond(x, p=None)}

Compute the condition number of a matrix.

This function is capable of returning the condition number using one of seven different norms, depending on the value of \textit{p} (see Parameters below).

**Parameters**

- \texttt{x} : (M, N) array_like
  The matrix whose condition number is sought.

- \texttt{p} : \{None, 1, -1, 2, -2, inf, -inf, ‘fro’\}, optional
  Order of the norm:

<table>
<thead>
<tr>
<th>\texttt{p}</th>
<th>norm for matrices</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>2-norm, computed directly using the SVD Frobenius norm</td>
</tr>
<tr>
<td>‘fro’</td>
<td>max(abs(x), axis=1)</td>
</tr>
<tr>
<td>inf</td>
<td>min(abs(x), axis=1)</td>
</tr>
<tr>
<td>-inf</td>
<td>max(abs(x), axis=0)</td>
</tr>
<tr>
<td>1</td>
<td>min(abs(x), axis=0)</td>
</tr>
<tr>
<td>-1</td>
<td>2-norm (largest sing. value)</td>
</tr>
<tr>
<td>2</td>
<td>smallest singular value</td>
</tr>
</tbody>
</table>

\texttt{inf} means the \texttt{numpy.inf} object, and the Frobenius norm is the root-of-sum-of-squares norm.

**Returns**

- \texttt{c} : {float, inf}
  The condition number of the matrix. May be infinite.

**See also:**

\texttt{numpy.linalg.norm}

**Notes**

The condition number of \texttt{x} is defined as the norm of \texttt{x} times the norm of the inverse of \texttt{x} \texttt{[R37]}; the norm can be the usual L2-norm (root-of-sum-of-squares) or one of a number of other matrix norms.

**References**

[R37]

**Examples**

```python
>>> from numpy import linalg as LA
>>> a = np.array([[1, 0, -1], [0, 1, 0], [1, 0, 1]])
>>> a
array([[ 1, 0, -1],
       [ 0, 1, 0],
       [ 1, 0, 1]])
>>> LA.cond(a)
```
>>> LA.cond(a, 'fro')
3.1622776601683795
>>> LA.cond(a, np.inf)
2.0
>>> LA.cond(a, -np.inf)
1.0
>>> LA.cond(a, 1)
2.0
>>> LA.cond(a, -1)
1.0
>>> LA.cond(a, 2)
1.4142135623730951
>>> LA.cond(a, -2)
0.70710678118654746
>>> min(LA.svd(a, compute_uv=0))*min(LA.svd(LA.inv(a), compute_uv=0))
0.70710678118654746

numpy.linalg.det(a)
Compute the determinant of an array.

Parameters
    a : (..., M, M) array_like
       Input array to compute determinants for.

Returns
    det : (...) array_like
       Determinant of a.

See also:

slogdet
Another way to representing the determinant, more suitable for large matrices where underflow/overflow may occur.

Notes
Broadcasting rules apply, see the numpy.linalg documentation for details.
The determinant is computed via LU factorization using the LAPACK routine z/dgetrf.

Examples
The determinant of a 2-D array [[a, b], [c, d]] is ad - bc:

>>> a = np.array([[1, 2], [3, 4]])
>>> np.linalg.det(a)
-2.0

Computing determinants for a stack of matrices:

>>> a = np.array([[[1, 2], [3, 4]], [[1, 2], [2, 1]], [[1, 3], [3, 1]]])
>>> a.shape
(2, 2, 2)
>>> np.linalg.det(a)
array([-2., -3., -8.])

numpy.linalg.matrix_rank(M, tol=None)
Return matrix rank of array using SVD method
Rank of the array is the number of SVD singular values of the array that are greater than \( tol \).

**Parameters**

- **M**: \{(M,), (M, N)\} array_like
  - array of \( \leq 2 \) dimensions
- **tol**: {None, float}, optional
  - threshold below which SVD values are considered zero. If \( tol \) is None, and \( S \) is an array with singular values for \( M \), and \( \text{eps} \) is the epsilon value for datatype of \( S \), then \( tol \) is set to \( S.\text{max}() * \text{max}(M.\text{shape}) * \text{eps} \).

**Notes**

The default threshold to detect rank deficiency is a test on the magnitude of the singular values of \( M \). By default, we identify singular values less than \( S.\text{max}() * \text{max}(M.\text{shape}) * \text{eps} \) as indicating rank deficiency (with the symbols defined above). This is the algorithm MATLAB uses [1]. It also appears in *Numerical recipes* in the discussion of SVD solutions for linear least squares [2].

This default threshold is designed to detect rank deficiency accounting for the numerical errors of the SVD computation. Imagine that there is a column in \( M \) that is an exact (in floating point) linear combination of other columns in \( M \). Computing the SVD on \( M \) will not produce a singular value exactly equal to 0 in general: any difference of the smallest SVD value from 0 will be caused by numerical imprecision in the calculation of the SVD. Our threshold for small SVD values takes this numerical imprecision into account, and the default threshold will detect such numerical rank deficiency. The threshold may declare a matrix \( M \) rank deficient even if the linear combination of some columns of \( M \) is not exactly equal to another column of \( M \) but only numerically very close to another column of \( M \).

We chose our default threshold because it is in wide use. Other thresholds are possible. For example, elsewhere in the 2007 edition of *Numerical recipes* there is an alternative threshold of \( S.\text{max}() * \text{np.finfo}(M.\text{dtype}).\text{eps} / 2. * \text{np.sqrt}(m + n + 1.) \). The authors describe this threshold as being based on “expected roundoff error” (p 71).

The thresholds above deal with floating point roundoff error in the calculation of the SVD. However, you may have more information about the sources of error in \( M \) that would make you consider other tolerance values to detect effective rank deficiency. The most useful measure of the tolerance depends on the operations you intend to use on your matrix. For example, if your data come from uncertain measurements with uncertainties greater than floating point epsilon, choosing a tolerance near that uncertainty may be preferable. The tolerance may be absolute if the uncertainties are absolute rather than relative.

**References**

[R39], [R40]

**Examples**

```python
>>> from numpy.linalg import matrix_rank
>>> matrix_rank(np.eye(4))  # Full rank matrix
4
>>> I=np.eye(4); I[-1,-1] = 0.  # rank deficient matrix
>>> matrix_rank(I)
3
>>> matrix_rank(np.ones((4,)))  # 1 dimension - rank 1 unless all 0
1
>>> matrix_rank(np.zeros((4,)))
0
```

**numpy.linalg.slogdet(a)**

Compute the sign and (natural) logarithm of the determinant of an array.
If an array has a very small or very large determinant, than a call to `det` may overflow or underflow. This routine is more robust against such issues, because it computes the logarithm of the determinant rather than the determinant itself.

**Parameters**

`a : (...) array_like`

Input array, has to be a square 2-D array.

**Returns**

`sign : (...) array_like`

A number representing the sign of the determinant. For a real matrix, this is 1, 0, or -1. For a complex matrix, this is a complex number with absolute value 1 (i.e., it is on the unit circle), or else 0.

`logdet : (...) array_like`

The natural log of the absolute value of the determinant.

If the determinant is zero, then `sign` will be 0 and `logdet` will be `-Inf`. In all cases, the determinant is equal to `sign * np.exp(logdet)`.

**See also:**

`det`

**Notes**

Broadcasting rules apply, see the numpy.linalg documentation for details.

The determinant is computed via LU factorization using the LAPACK routine z/dgetrf.

New in version 1.6.0.

**Examples**

The determinant of a 2-D array `[[a, b], [c, d]]` is `ad - bc`:

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> (sign, logdet) = np.linalg.slogdet(a)
>>> (sign, logdet)
(-1, 0.69314718055994529)
>>> sign * np.exp(logdet)
-2.0
```

Computing log-determinants for a stack of matrices:

```python
>>> a = np.array([[[1, 2], [3, 4]], [[1, 2], [2, 1]], [[1, 3], [3, 1]]])
>>> a.shape
(3, 2, 2)
>>> sign, logdet = np.linalg.slogdet(a)
>>> (sign, logdet)
(array([-1., -1., -1.]), array([ 0.69314718, 1.09861229, 2.07944154]))
>>> sign * np.exp(logdet)
array([-2., -3., -8.])
```

This routine succeeds where ordinary `det` does not:

```python
>>> np.linalg.det(np.eye(500) * 0.1)
0.0
>>> np.linalg.slogdet(np.eye(500) * 0.1)
(1, -1151.2925464970228)
```
numpy.trace(a, offset=0, axis1=0, axis2=1, dtype=None, out=None)

Return the sum along diagonals of the array.

If a is 2-D, the sum along its diagonal with the given offset is returned, i.e., the sum of elements a[i,i+offset] for all i.

If a has more than two dimensions, then the axes specified by axis1 and axis2 are used to determine the 2-D sub-arrays whose traces are returned. The shape of the resulting array is the same as that of a with axis1 and axis2 removed.

Parameters

- **a**: array_like
  - Input array, from which the diagonals are taken.

- **offset**: int, optional
  - Offset of the diagonal from the main diagonal. Can be both positive and negative. Defaults to 0.

- **axis1, axis2**: int, optional
  - Axes to be used as the first and second axis of the 2-D sub-arrays from which the diagonals should be taken. Defaults are the first two axes of a.

- **dtype**: dtype, optional
  - Determines the data-type of the returned array and of the accumulator where the elements are summed. If dtype has the value None and a is of integer type of precision less than the default integer precision, then the default integer precision is used. Otherwise, the precision is the same as that of a.

- **out**: ndarray, optional
  - Array into which the output is placed. Its type is preserved and it must be of the right shape to hold the output.

Returns

- **sum_along_diagonals**: ndarray
  - If a is 2-D, the sum along the diagonal is returned. If a has larger dimensions, then an array of sums along diagonals is returned.

See also:

- diag, diagonal, diagflat

Examples

```python
>>> np.trace(np.eye(3))
3.0
>>> a = np.arange(8).reshape((2,2))
>>> np.trace(a)
array([6, 8])
>>> a = np.arange(24).reshape((2,2,2,3))
>>> np.trace(a).shape
(2, 3)
```

3.17.5 Solving equations and inverting matrices
**linalg.solve(a, b)**

Solve a linear matrix equation, or system of linear scalar equations.

Computes the “exact” solution, x, of the well-determined, i.e., full rank, linear matrix equation \( ax = b \).

**Parameters**

- **a**: (..., M, M) array_like
  Coefficient matrix.

- **b**: {(..., M,), (..., M, K)}, array_like
  Ordinate or “dependent variable” values.

**Returns**

- **x**: {(..., M,), (..., M, K)} ndarray
  Solution to the system \( ax = b \). Returned shape is identical to \( b \).  

**Raises**

- **LinAlgError**
  If \( a \) is singular or not square.

**Notes**

Broadcasting rules apply, see the numpy.linalg documentation for details.

The solutions are computed using LAPACK routine `_gesv`.

\( a \) must be square and of full-rank, i.e., all rows (or, equivalently, columns) must be linearly independent; if either is not true, use `linalg.lstsq` for the least-squares best “solution” of the system/equation.

**References**

[R43]

**Examples**

Solve the system of equations \( 3 \times x_0 + x_1 = 9 \) and \( x_0 + 2 \times x_1 = 8 \):

```python
>>> a = np.array([[3,1], [1,2]])
>>> b = np.array([9,8])
>>> x = np.linalg.solve(a, b)
>>> x
array([2., 3.])
```

Check that the solution is correct:

```python
>>> np.allclose(np.dot(a, x), b)
True
```

**numpy.linalg.tensorsolve(a, b[, axes])**

Solve the tensor equation \( a \ x = b \) for \( x \).

**linalg.lstsq(a, b[, rcond])**

Return the least-squares solution to a linear matrix equation.

**linalg.inv(a)**

Compute the (multiplicative) inverse of a matrix.

**linalg.pinv(a[, rcond])**

Compute the (Moore-Penrose) pseudo-inverse of a matrix.

**linalg.tensorinv(a[, ind])**

Compute the ‘inverse’ of an N-dimensional array.
It is assumed that all indices of \(x\) are summed over in the product, together with the rightmost indices of \(a\), as is done in, for example, \texttt{tensordot(a, x, axes=len(b.shape))}.

**Parameters**  
\(a\) : array_like  
Coefficient tensor, of shape \(b.shape + Q\), a tuple, equals the shape of that sub-tensor of \(a\) consisting of the appropriate number of its rightmost indices, and must be such that \(\prod(Q) = \prod(b.shape)\) (in which sense \(a\) is said to be ‘square’).  

\(b\) : array_like  
Right-hand tensor, which can be of any shape.  

\(axes\) : tuple of ints, optional  
Axes in \(a\) to reorder to the right, before inversion. If None (default), no reordering is done.  

**Returns**  
\(x\) : ndarray, shape \(Q\)  

**Raises**  
LinAlgError  
If \(a\) is singular or not ‘square’ (in the above sense).

**See also:**  
tensordot, tensorinv, einsum

**Examples**

```python
def example():
    a = np.eye(2*3*4)
    a.shape = (2*3, 4, 2, 3, 4)
    b = np.random.randn(2*3, 4)
    x = np.linalg.tensorsolve(a, b)
    x.shape
    (2, 3, 4)
    np.allclose(np.tensordot(a, x, axes=3), b)
    True
```
Cut-off ratio for small singular values of \( a \). Singular values are set to zero if they are smaller than \( \text{recond} \) times the largest singular value of \( a \).

**Returns**
- **x** : \((N,), (N, K)\) ndarray
  Least-squares solution. If \( b \) is two-dimensional, the solutions are in the \( K \) columns of \( x \).
- **residuals** : \((0, (1,), (K,))\) ndarray
  Sums of residuals; squared Euclidean 2-norm for each column in \( b - a \cdot x \). If the rank of \( a \) is \( < N \) or \( M \leq N \), this is an empty array. If \( b \) is 1-dimensional, this is a \((1,)\) shape array. Otherwise the shape is \((K,)\).
- **rank** : int
  Rank of matrix \( a \).
- **s** : \((\min(M, N),)\) ndarray
  Singular values of \( a \).

**Raises**
- **LinAlgError**
  If computation does not converge.

**Notes**
If \( b \) is a matrix, then all array results are returned as matrices.

**Examples**
Fit a line, \( y = mx + c \), through some noisy data-points:

```python
>>> x = np.array([0, 1, 2, 3])
>>> y = np.array([-1, 0.2, 0.9, 2.1])

By examining the coefficients, we see that the line should have a gradient of roughly 1 and cut the y-axis at, more or less, -1.

We can rewrite the line equation as \( y = A p \), where \( A = \begin{bmatrix} x & 1 \end{bmatrix} \) and \( p = \begin{bmatrix} m \\ c \end{bmatrix} \). Now use `lstsq` to solve for \( p \):

```python
>>> A = np.vstack([x, np.ones(len(x))]).T
>>> A
array([[ 0.,  1.],
       [ 1.,  1.],
       [ 2.,  1.],
       [ 3.,  1.]])
```

```python
>>> m, c = np.linalg.lstsq(A, y)[0]
>>> print m, c
1.0 -0.95
```

Plot the data along with the fitted line:

```python
>>> import matplotlib.pyplot as plt
>>> plt.plot(x, y, 'o', label='Original data', markersize=10)
>>> plt.plot(x, m*x + c, 'r', label='Fitted line')
>>> plt.legend()
>>> plt.show()
```
**numpy.linalg.inv(a)**

Compute the (multiplicative) inverse of a matrix.

Given a square matrix \( a \), return the matrix \( a^{-1} \) satisfying \( \text{dot}(a, a^{-1}) = \text{dot}(a^{-1}, a) = \text{eye}(a.shape[0]) \).

**Parameters**

- **a : (..., M, M) array_like**
  Matrix to be inverted.

**Returns**

- **ainv : (..., M, M) ndarray or matrix**
  (Multiplicative) inverse of the matrix \( a \).

**Raises**

- **LinAlgError**
  If \( a \) is not square or inversion fails.

**Notes**

Broadcasting rules apply, see the numpy.linalg documentation for details.

**Examples**

```python
>>> from numpy.linalg import inv
>>> a = np.array([[1., 2.], [3., 4.]])
>>> ainv = inv(a)
>>> np.allclose(np.dot(a, ainv), np.eye(2))
True
>>> np.allclose(np.dot(ainv, a), np.eye(2))
True
```

If \( a \) is a matrix object, then the return value is a matrix as well:

```python
>>> ainv = inv(np.matrix(a))
>>> ainv
matrix([[-2. , 1. ],
        [ 1.5, -0.5]])
```

Inverses of several matrices can be computed at once:

```python
>>> a = np.array([[[1., 2.], [3., 4.]], [[1., 3], [3., 5]]])
>>> inv(a)
array([[[[-2. , 1. ],
        [ 1.5, -0.5]],
       [[-5. , 2. ],
        [ 3. , -1. ]]]])
```

**numpy.linalg.pinv(a, rcond=1e-15)**

Compute the (Moore-Penrose) pseudo-inverse of a matrix.

Calculate the generalized inverse of a matrix using its singular-value decomposition (SVD) and including all large singular values.

**Parameters**

- **a : (M, N) array_like**
  Matrix to be pseudo-inverted.

- **rcond : float**
Cutoff for small singular values. Singular values smaller (in modulus) than \( rcond \times \) largest_singular_value (again, in modulus) are set to zero.

Returns
- \( B : (N, M) \) ndarray
  
The pseudo-inverse of \( a \). If \( a \) is a matrix instance, then so is \( B \).

Raises
- LinAlgError
  
  If the SVD computation does not converge.

Notes
The pseudo-inverse of a matrix \( A \), denoted \( A^+ \), is defined as: “the matrix that ‘solves’ [the least-squares problem] \( Ax = b \)” i.e., if \( \bar{x} \) is said solution, then \( A^+ \) is that matrix such that \( \bar{x} = A^+ b \).

It can be shown that if \( Q_1 \Sigma Q_2^T = A \) is the singular value decomposition of \( A \), then \( A^+ = Q_2 \Sigma^+ Q_1^T \), where \( Q_{1,2} \) are orthogonal matrices, \( \Sigma \) is a diagonal matrix consisting of \( A \)'s so-called singular values, (followed, typically, by zeros), and then \( \Sigma^+ \) is simply the diagonal matrix consisting of the reciprocals of \( A \)'s singular values (again, followed by zeros). [R42]

References
[R42]

Examples
The following example checks that \( a \ast a^+ \ast a = a \) and \( a^+ \ast a \ast a^+ = a^+ \):

```python
>>> a = np.random.randn(9, 6)
>>> B = np.linalg.pinv(a)
>>> np.allclose(a, np.dot(a, np.dot(B, a)))
True
>>> np.allclose(B, np.dot(B, np.dot(a, B)))
True
```

numpy.linalg.tensorinv(a, ind=2)
Compute the ‘inverse’ of an N-dimensional array.

The result is an inverse for \( a \) relative to the tensordot operation `tensordot(a, b, ind)`, i.e., up to floating-point accuracy, `tensordot(tensorinv(a), a, ind)` is the “identity” tensor for the tensordot operation.

Parameters
- \( a : \) array_like
  
  Tensor to ‘invert’. Its shape must be ‘square’, i.e., `prod(a.shape[:ind]) == prod(a.shape[ind:])`.

- \( \text{ind} : \) int, optional
  
  Number of first indices that are involved in the inverse sum. Must be a positive integer, default is 2.

Returns
- \( b : \) ndarray
  
  \( a \)'s tensordot inverse, shape `a.shape[ind:] + a.shape[:ind]`.

Raises
- LinAlgError
If \( a \) is singular or not ‘square’ (in the above sense).

See also:

tensordot, tensorsolve

Examples

```python
>>> a = np.eye(4*6)
>>> a.shape = (4, 6, 8, 3)
>>> ainv = np.linalg.tensorinv(a, ind=2)
>>> ainv.shape
(8, 3, 4, 6)
>>> b = np.random.randn(4, 6)
>>> np.allclose(np.tensordot(ainv, b), np.linalg.tensorsolve(a, b))
True

>>> a = np.eye(4*6)
>>> a.shape = (24, 8, 3)
>>> ainv = np.linalg.tensorinv(a, ind=1)
>>> ainv.shape
(8, 3, 24)
>>> b = np.random.randn(24)
>>> np.allclose(np.tensordot(ainv, b, 1), np.linalg.tensorsolve(a, b))
True
```

3.17.6 Exceptions

```
  linalg.LinAlgError  Generic Python-exception-derived object raised by linalg functions.

exception numpy.linalg.LinAlgError
  Generic Python-exception-derived object raised by linalg functions.
  General purpose exception class, derived from Python’s exception.Exception class, programmatically raised in 
linalg functions when a Linear Algebra-related condition would prevent further correct execution of the function.

Parameters
  None

Examples

```python
>>> from numpy import linalg as LA
>>> LA.inv(np.zeros((2,2)))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "...linalg.py", line 350,
    in inv return wrap(solve(a, identity(a.shape[0], dtype=a.dtype)))
  File "...linalg.py", line 249,
    in solve
    raise LinAlgError('Singular matrix')
  numpy.linalg.LinAlgError: Singular matrix
```
```
3.17.7 Linear algebra on several matrices at once

Several of the linear algebra routines listed above are able to compute results for several matrices at once, if they are stacked into the same array.

This is indicated in the documentation via input parameter specifications such as a : (..., M, M) array_like. This means that if for instance given an input array a.shape == (N, M, M), it is interpreted as a “stack” of N matrices, each of size M-by-M. Similar specification applies to return values, for instance the determinant has det : (...) and will in this case return an array of shape det(a).shape == (N,). This generalizes to linear algebra operations on higher-dimensional arrays: the last 1 or 2 dimensions of a multidimensional array are interpreted as vectors or matrices, as appropriate for each operation.

3.18 Logic functions

3.18.1 Truth value testing

.. _linalg:truthval:

.. _truthval:

.. _ufuncref:

.. _ufuncs:

.. _ufuncref: doc.ufuncs (Section “Output arguments”) for more details.

.. _ufuncs: doc.ufuncs (Section “Output arguments”) for more details.

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.. _ufuncs: doc.ufuncs (Section “Output arguments”) for more details.
A new boolean or array is returned unless `out` is specified, in which case a reference to `out` is returned.

See also:

- `ndarray.all` equivalent method
- `any` Test whether any element along a given axis evaluates to True.

Notes

Not a Number (NaN), positive infinity and negative infinity evaluate to `True` because these are not equal to zero.

Examples

```python
g = np.array([[True, False], [True, True]])
g.all()  # Returns True

h = np.array([[-1, 4, 5]])
h.all()  # Returns True

i = np.array([1.0, np.nan])
i.all()  # Returns True
```

```python
z = np.array([[[1, 2, 3], [4, 5, 6]], [[7, 8, 9], [10, 11, 12]]])
z.all()  # Returns False
```

```python
n = np.array([[True, False], [True, True]])
n.any()  # Returns True
```

```
np.any(a, axis=None, out=None, keepdims=False)
```

Test whether any array element along a given axis evaluates to True.

Returns single boolean unless `axis` is not `None`.

**Parameters**

- **a**: array_like
  
  Input array or object that can be converted to an array.

- **axis**: None or int or tuple of ints, optional
  
  Axis or axes along which a logical OR reduction is performed. The default (`axis = None`) is to perform a logical OR over all the dimensions of the input array. `axis` may be negative, in which case it counts from the last to the first axis.

  New in version 1.7.0.

  If this is a tuple of ints, a reduction is performed on multiple axes, instead of a single axis or all the axes as before.

- **out**: ndarray, optional
  
  Alternate output array in which to place the result. It must have the same shape as the expected output and its type is preserved (e.g., if it is of type float, then it will remain so, returning 1.0 for True and 0.0 for False, regardless of the type of `a`). See `doc.ufuncs` (Section “Output arguments”) for details.
**keepdims** : bool, optional

If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original `arr`.

**Returns**

any : bool or ndarray

A new boolean or ndarray is returned unless `out` is specified, in which case a reference to `out` is returned.

**See also:**

`ndarray.any`

**ndarray.any**

equivalent method

**all**

Test whether all elements along a given axis evaluate to True.

**Notes**

Not a Number (NaN), positive infinity and negative infinity evaluate to `True` because these are not equal to zero.

**Examples**

```python
code=
>>> np.any([[True, False], [True, True]])
True

>>> np.any([[True, False], [False, False]], axis=0)
array([ True, False], dtype=bool)

>>> np.any([-1, 0, 5])
True

>>> np.any(np.nan)
True

>>> o=np.array([False])
>>> z=np.any([-1, 4, 5], out=o)
>>> z
array([ True], dtype=bool)
>>> o
array([ True], dtype=bool)
>>> # Check now that z is a reference to o
>>> z is o
True
>>> id(z), id(o) # identity of z and o
(191614240, 191614240)
```

### 3.18.2 Array contents

<table>
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<th>Test element-wise for finiteness (not infinity or not Not a Number).</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>isinf(x[, out])</code></td>
<td>Test element-wise for positive or negative infinity.</td>
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<td><code>isnan(x[, out])</code></td>
<td>Test element-wise for NaN and return result as a boolean array.</td>
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<td><code>isneginf(x[, y])</code></td>
<td>Test element-wise for negative infinity, return result as bool array.</td>
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<td><code>isposinf(x[, y])</code></td>
<td>Test element-wise for positive infinity, return result as bool array.</td>
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</table>

`numpy.isfinite(x[, out]) = <ufunc ‘isfinite’>`

Test element-wise for finiteness (not infinity or not Not a Number).
The result is returned as a boolean array.

**Parameters**

- **x**: array_like
  - Input values.

- **out**: optional, ndarray
  - Array into which the output is placed. Its type is preserved and it must be of the right shape to hold the output. See `doc.ufuncs`.

**Returns**

- **y**: ndarray, bool
  - For scalar input, the result is a new boolean with value True if the input is finite; otherwise the value is False (input is either positive infinity, negative infinity or Not a Number).

  For array input, the result is a boolean array with the same dimensions as the input and the values are True if the corresponding element of the input is finite; otherwise the values are False (element is either positive infinity, negative infinity or Not a Number).

**See also:**

- `isinf`, `isneginf`, `isposinf`, `isnan`

**Notes**

Not a Number, positive infinity and negative infinity are considered to be non-finite.

Numpy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity. Also that positive infinity is not equivalent to negative infinity. But infinity is equivalent to positive infinity. Errors result if the second argument is also supplied when x is a scalar input, or if first and second arguments have different shapes.

**Examples**

```python
>>> np.isfinite(1)
True
>>> np.isfinite(0)
True
>>> np.isfinite(np.nan)
False
>>> np.isfinite(np.inf)
False
>>> np.isfinite(np.NINF)
False
>>> np.isfinite([np.log(-1.),1.,np.log(0)])
array([False, True, False], dtype=bool)
```

```python
>>> x = np.array([-np.inf, 0., np.inf])
>>> y = np.array([2, 2, 2])
>>> np.isfinite(x, y)
array([0, 1, 0])
>>> y
array([0, 1, 0])
```

`numpy.isinf(x[, out]) = <ufunc 'isinf'>`

Test element-wise for positive or negative infinity.

Returns a boolean array of the same shape as x, True where x == +/-inf, otherwise False.
Parameters
  x : array_like
      Input values

  out : array_like, optional
      An array with the same shape as x to store the result.

Returns
  y : bool (scalar) or boolean ndarray
      For scalar input, the result is a new boolean with value True if the input is positive or negative infinity; otherwise the value is False.
      For array input, the result is a boolean array with the same shape as the input and the values are True where the corresponding element of the input is positive or negative infinity; elsewhere the values are False. If a second argument was supplied the result is stored there. If the type of that array is a numeric type the result is represented as zeros and ones, if the type is boolean then as False and True, respectively. The return value y is then a reference to that array.

See also:
isneginf, isposinf, isnan, isfinite

Notes
Numpy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754).
Errors result if the second argument is supplied when the first argument is a scalar, or if the first and second arguments have different shapes.

Examples
>>> np.isinf(np.inf)
True
>>> np.isinf(np.nan)
False
>>> np.isinf(np.NINF)
True
>>> np.isinf([np.inf, -np.inf, 1.0, np.nan])
array([ True, False, False, False], dtype=bool)

>>> x = np.array([-np.inf, 0., np.inf])
>>> y = np.array([1, 2, 2])
>>> np.isinf(x, y)
array([1, 0, 1])

numpy.isnan(x[, out]) = <ufunc 'isnan'>
Test element-wise for NaN and return result as a boolean array.

Parameters
  x : array_like
      Input array.

Returns
  y : {ndarray, bool}
For scalar input, the result is a new boolean with value True if the input is NaN; otherwise the value is False.

For array input, the result is a boolean array of the same dimensions as the input and the values are True if the corresponding element of the input is NaN; otherwise the values are False.

See also:

`isinf, isneginf, isposinf, isfinite`

Notes

Numpy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity.

Examples

```python
>>> np.isnan(np.nan)
True
>>> np.isnan(np.inf)
False
>>> np.isnan([np.log(-1.),1.,np.log(0)])
array([ True, False, False], dtype=bool)
```

```
numpy.isneginf(x, y=None)
    Test element-wise for negative infinity, return result as bool array.
```

Parameters

- **x**: array_like
  - The input array.
- **y**: array_like, optional
  - A boolean array with the same shape and type as x to store the result.

Returns

- **y**: ndarray
  - A boolean array with the same dimensions as the input. If second argument is not supplied then a numpy boolean array is returned with values True where the corresponding element of the input is negative infinity and values False where the element of the input is not negative infinity.

  If a second argument is supplied the result is stored there. If the type of that array is a numeric type the result is represented as zeros and ones, if the type is boolean then as False and True. The return value y is then a reference to that array.

See also:

`isinf, isposinf, isnan, isfinite`

Notes

Numpy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754).

Errors result if the second argument is also supplied when x is a scalar input, or if first and second arguments have different shapes.
Examples

```
>>> np.isneginf(np.NINF)
array(True, dtype=bool)
>>> np.isneginf(np.inf)
array(False, dtype=bool)
>>> np.isneginf(np.PINF)
array(False, dtype=bool)
>>> np.isneginf([-np.inf, 0., np.inf])
array([ True, False, False], dtype=bool)
```

```
x = np.array([-np.inf, 0., np.inf])
y = np.array([2, 2, 2])
>>> np.isneginf(x, y)
array([1, 0, 0])
```

```
>>> y
array([1, 0, 0])
```

```
numpy.isposinf(x, y=None)
```
Test element-wise for positive infinity, return result as bool array.

Parameters
```
x : array_like
    The input array.
y : array_like, optional
    A boolean array with the same shape as x to store the result.
```

Returns
```
y : ndarray
    A boolean array with the same dimensions as the input. If second argument is not supplied then
    a boolean array is returned with values True where the corresponding element of the input is
    positive infinity and values False where the element of the input is not positive infinity.

    If a second argument is supplied the result is stored there. If the type of that array is a numeric type
    the result is represented as zeros and ones, if the type is boolean then as False and True. The return
    value y is then a reference to that array.
```

See also:
```
isinf, isneginf, isnfinite, isnan
```

Notes
Numpy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754).
Errors result if the second argument is also supplied when x is a scalar input, or if first and second arguments have different shapes.

Examples

```
>>> np.isposinf(np.PINF)
array(True, dtype=bool)
>>> np.isposinf(np.inf)
array(True, dtype=bool)
>>> np.isposinf(np.NINF)
array(False, dtype=bool)
```
>>> np.isposinf([-np.inf, 0., np.inf])
array([False, False,  True], dtype=bool)

>>> x = np.array([-np.inf, 0., np.inf])
>>> y = np.array([2, 2, 2])
>>> np.isposinf(x, y)
array([0, 0, 1])

3.18.3 Array type testing

<table>
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<th>Description</th>
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<td><code>iscomplex(x)</code></td>
<td>Returns a bool array, where True if input element is complex.</td>
</tr>
<tr>
<td><code>iscomplexobj(x)</code></td>
<td>Check for a complex type or an array of complex numbers.</td>
</tr>
<tr>
<td><code>isfortran(a)</code></td>
<td>Returns True if array is arranged in Fortran-order in memory and not C-order.</td>
</tr>
<tr>
<td><code>isreal(x)</code></td>
<td>Returns a bool array, where True if input element is real.</td>
</tr>
<tr>
<td><code>isrealobj(x)</code></td>
<td>Return True if x is a not complex type or an array of complex numbers.</td>
</tr>
<tr>
<td><code>isscalar(num)</code></td>
<td>Returns True if the type of num is a scalar type.</td>
</tr>
</tbody>
</table>

`numpy.iscomplex(x)`

Returns a bool array, where True if input element is complex.

What is tested is whether the input has a non-zero imaginary part, not if the input type is complex.

Parameters

- `x : array_like`
  
  Input array.

Returns

- `out : ndarray of bools`
  
  Output array.

See also:

- `isreal`
- `iscomplexobj`

Return True if x is a complex type or an array of complex numbers.

Examples

```python
>>> np.iscomplex([1+1j, 1+0j, 4.5, 3, 2, 2j])
array([ True, False, False, False, False,  True], dtype=bool)
```

`numpy.iscomplexobj(x)`

Check for a complex type or an array of complex numbers.

The type of the input is checked, not the value. Even if the input has an imaginary part equal to zero, `iscomplexobj` evaluates to True.

Parameters

- `x : any`
  
  The input can be of any type and shape.
Returns

\texttt{iscomplexobj} : bool

The return value, True if \( x \) is of a complex type or has at least one complex element.

See also:

\texttt{isrealobj, iscomplex}

Examples

\begin{verbatim}
>>> np.iscomplexobj(1)
False
>>> np.iscomplexobj(1+0j)
True
>>> np.iscomplexobj([3, 1+0j, True])
True
\end{verbatim}

\texttt{numpy.isfortran(a)}

Returns True if array is arranged in Fortran-order in memory and not C-order.

Parameters

\begin{verbatim}
a : ndarray
\end{verbatim}

Input array.

Examples

\texttt{np.array} allows to specify whether the array is written in C-contiguous order (last index varies the fastest), or FORTRAN-contiguous order in memory (first index varies the fastest).

\begin{verbatim}
>>> a = np.array([[[1, 2, 3], [4, 5, 6]], order='C'])
>>> a
array([[[1, 2, 3],
        [4, 5, 6]]])
>>> np.isfortran(a)
False

>>> b = np.array([[[1, 2, 3], [4, 5, 6]], order='FORTRAN'])
>>> b
array([[[1, 2, 3],
        [4, 5, 6]]])
>>> np.isfortran(b)
True
\end{verbatim}

The transpose of a C-ordered array is a FORTRAN-ordered array.

\begin{verbatim}
>>> a = np.array([[[1, 2, 3], [4, 5, 6]], order='C'])
>>> a
array([[[1, 2, 3],
        [4, 5, 6]]])
>>> np.isfortran(a)
False
>>> b = a.T
>>> b
array([[1, 4],
       [2, 5],
       [3, 6]])
>>> np.isfortran(b)
True
\end{verbatim}

C-ordered arrays evaluate as False even if they are also FORTRAN-ordered.
>>> np.isfortran(np.array([1, 2], order='FORTRAN'))
False

numpy.isreal(x)

Returns a bool array, where True if input element is real.
If element has complex type with zero complex part, the return value for that element is True.

Parameters
x : array_like
    Input array.

Returns
out : ndarray, bool
    Boolean array of same shape as x.

See also:
iscomplex
isrealobj

numpy.isrealobj(x)

Return True if x is not a complex type.

The type of the input is checked, not the value. So even if the input has an imaginary part equal to zero, isrealobj evaluates to False if the data type is complex.

Parameters
x : any
    The input can be of any type and shape.

Returns
y : bool
    The return value, False if x is of a complex type.

See also:
iscomplexobj, isreal

Examples
>>> np.isrealobj([1+1j, 1+0j, 4.5, 3, 2, 2j])
array([False, True, True, True, True, False], dtype=bool)

numpy.isscalar(num)

Returns True if the type of num is a scalar type.

Parameters
num : any
Input argument, can be of any type and shape.

**Returns**

**val** : bool

True if `num` is a scalar type, False if it is not.

**Examples**

```python
g >> np.isscalar(3.1)
True
g >> np.isscalar([3.1])
False
g >> np.isscalar(False)
True
```

### 3.18.4 Logical operations

- **`logical_and(x1, x2[, out])`**
  - Compute the truth value of x1 AND x2 element-wise.

  **Parameters**

  x1, x2 : array_like

  Input arrays. x1 and x2 must be of the same shape.

  **Returns**

  y : {ndarray, bool}

  Boolean result with the same shape as x1 and x2 of the logical AND operation on corresponding elements of x1 and x2.

  **See also:**

  `logical_or, logical_not, logical_xor, bitwise_and`

  **Examples**

  ```python
g >>> np.logical_and(True, False)
False
g >>> np.logical_and([True, False], [False, False])
array([False, False], dtype=bool)
```

- **`logical_or(x1, x2[, out])`**
  - Compute the truth value of x1 OR x2 element-wise.

  **Parameters**

  x1, x2 : array_like

  Logical OR is applied to the elements of x1 and x2. They have to be of the same shape.

  ```python
g >>> x = np.arange(5)
g >>> np.logical_or(x>1, x<4)
array([False, False, True, True, False], dtype=bool)
```
Returns

\(y\) : \{ndarray, bool\}

Boolean result with the same shape as \(x1\) and \(x2\) of the logical OR operation on elements of \(x1\) and \(x2\).

See also:

`logical_and`, `logical_not`, `logical_xor`, `bitwise_or`

Examples

```python
g >> np.logical_or(True, False)
True
>>> np.logical_or([True, False], [False, False])
array([ True, False], dtype=bool)
```

```python
g >> x = np.arange(5)
g >> np.logical_or(x < 1, x > 3)
array([ True, False, False, False, True], dtype=bool)
```

```

numpy.logical_not(x[, out]) = <ufunc 'logical_not'>
Compute the truth value of NOT x element-wise.

Parameters

\(x\) : array_like

Logical NOT is applied to the elements of \(x\).

Returns

\(y\) : bool or ndarray of bool

Boolean result with the same shape as \(x\) of the NOT operation on elements of \(x\).

See also:

`logical_and`, `logical_or`, `logical_xor`

Examples

```python
g >> np.logical_not(3)
False
>>> np.logical_not([True, False, 0, 1])
array([False, True, False, False], dtype=bool)
```

```python
g >> x = np.arange(5)
g >> np.logical_not(x<3)
array([False, False, False, True, True], dtype=bool)
```

```

numpy.logical_xor(x1, x2[, out]) = <ufunc 'logical_xor'>
Compute the truth value of x1 XOR x2, element-wise.

Parameters

\(x1\), \(x2\) : array_like

Logical XOR is applied to the elements of \(x1\) and \(x2\). They must be broadcastable to the same shape.

Returns

\(y\) : bool or ndarray of bool

Boolean result of the logical XOR operation applied to the elements of \(x1\) and \(x2\); the shape is determined by whether or not broadcasting of one or both arrays was required.
See also:

```
logical_and, logical_or, logical_not, bitwise_xor
```

**Examples**

```python
code
>>> np.logical_xor(True, False)
True
>>> np.logical_xor([True, True, False, False], [True, False, True, False])
array([False, True, True, False], dtype=bool)
```

```python
code
>>> x = np.arange(5)
>>> np.logical_xor(x < 1, x > 3)
array([ True, False, False, False, True], dtype=bool)
```

Simple example showing support of broadcasting

```python
code
>>> np.logical_xor(0, np.eye(2))
array([[ True, False],
       [False, True]], dtype=bool)
```

### 3.18.5 Comparison

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>allclose(a, b[, rtol, atol])</code></td>
<td>Returns True if two arrays are element-wise equal within a tolerance.</td>
</tr>
<tr>
<td><code>isclose(a, b[, rtol, atol, equal_nan])</code></td>
<td>Returns a boolean array where two arrays are element-wise equal within a tolerance.</td>
</tr>
<tr>
<td><code>array_equal(a1, a2)</code></td>
<td>True if two arrays have the same shape and elements, False otherwise.</td>
</tr>
<tr>
<td><code>array_equiv(a1, a2)</code></td>
<td>Returns True if input arrays are shape consistent and all elements equal.</td>
</tr>
</tbody>
</table>

```python
code
numpy.allclose(a, b, rtol=1e-05, atol=1e-08)
```

Returns True if two arrays are element-wise equal within a tolerance.

The tolerance values are positive, typically very small numbers. The relative difference \((rtol \times abs(b))\) and the absolute difference \(atol\) are added together to compare against the absolute difference between \(a\) and \(b\).

If either array contains one or more NaNs, False is returned. Infs are treated as equal if they are in the same place and of the same sign in both arrays.

**Parameters**

- \(a, b\) : array_like
  - Input arrays to compare.

- `rtol` : float
  - The relative tolerance parameter (see Notes).

- `atol` : float
  - The absolute tolerance parameter (see Notes).

**Returns**

- `allclose` : bool
  - Returns True if the two arrays are equal within the given tolerance; False otherwise.

**See also:**

`isclose`, `all`, `any`
Notes

If the following equation is element-wise True, then allclose returns True.

\[
\text{absolute}(a - b) \leq (\text{atol} + \text{rtol} \times \text{absolute}(b))
\]

The above equation is not symmetric in \(a\) and \(b\), so that allclose\((a, b)\) might be different from allclose\((b, a)\) in some rare cases.

Examples

```python
>>> np.allclose([1e10, 1e-7], [1.00001e10, 1e-8])
False
>>> np.allclose([1e10, 1e-8], [1.00001e10, 1e-9])
True
>>> np.allclose([1e10, 1e-8], [1.0001e10, 1e-9])
False
>>> np.allclose([1.0, np.nan], [1.0, np.nan])
False
```

numpy.\texttt{isclose}\((a, b, \text{rtol}=1e-05, \text{atol}=1e-08, \text{equal纳}=\text{False})\)

Returns a boolean array where two arrays are element-wise equal within a tolerance.

The tolerance values are positive, typically very small numbers. The relative difference \((\text{rtol} \times \text{abs}(b))\) and the absolute difference \(\text{atol}\) are added together to compare against the absolute difference between \(a\) and \(b\).

Parameters

- \(a, b\) : array_like
  Input arrays to compare.

- \texttt{rtol} : float
  The relative tolerance parameter (see Notes).

- \texttt{atol} : float
  The absolute tolerance parameter (see Notes).

- \texttt{equal纳} : bool
  Whether to compare NaN’s as equal. If True, NaN’s in \(a\) will be considered equal to NaN’s in \(b\) in the output array.

Returns

- \(y\) : array_like
  Returns a boolean array of where \(a\) and \(b\) are equal within the given tolerance. If both \(a\) and \(b\) are scalars, returns a single boolean value.

See also:

allclose

Notes

New in version 1.7.0.

For finite values, isclose uses the following equation to test whether two floating point values are equivalent.

\[
\text{absolute}(a - b) \leq (\text{atol} + \text{rtol} \times \text{absolute}(b))
\]

The above equation is not symmetric in \(a\) and \(b\), so that isclose\((a, b)\) might be different from isclose\((b, a)\) in some rare cases.
Examples

```python
>>> np.isclose([1e10, 1e-7], [1.00001e10, 1e-8])
array([True, False])

>>> np.isclose([1e10, 1e-8], [1.00001e10, 1e-9])
array([True, True])

>>> np.isclose([1e10, 1e-8], [1.0001e10, 1e-9])
array([False, True])

>>> np.isclose([1.0, np.nan], [1.0, np.nan])
array([True, False])

>>> np.isclose([1.0, np.nan], [1.0, np.nan], equal_nan=True)
array([True, True])
```

`numpy.array_equal(a1, a2)`

True if two arrays have the same shape and elements, False otherwise.

Parameters

- `a1, a2`: array_like

  Input arrays.

Returns

- `b`: bool

  Returns True if the arrays are equal.

See also:

- `allclose`

  Returns True if two arrays are element-wise equal within a tolerance.

- `array_equiv`

  Returns True if input arrays are shape consistent and all elements equal.

Examples

```python
>>> np.array_equal([1, 2], [1, 2])
True

>>> np.array_equal(np.array([1, 2]), np.array([1, 2]))
True

>>> np.array_equal([1, 2], [1, 2, 3])
False

>>> np.array_equal([1, 2], [1, 4])
False
```

`numpy.array_equiv(a1, a2)`

Returns True if input arrays are shape consistent and all elements equal.

Shape consistent means they are either the same shape, or one input array can be broadcasted to create the same shape as the other one.

Parameters

- `a1, a2`: array_like

  Input arrays.

Returns

- `out`: bool

  True if equivalent, False otherwise.
Examples

```python
>>> np.array_equiv([1, 2], [1, 2])
True
>>> np.array_equiv([1, 2], [1, 3])
False
```

Showing the shape equivalence:

```python
>>> np.array_equiv([1, 2], [[1, 2], [1, 2]])
True
>>> np.array_equiv([1, 2], [[1, 2, 1, 2], [1, 2, 1, 2]])
False
>>> np.array_equiv([1, 2], [[1, 2], [1, 3]])
False
```

### greater(x1, x2[, out])
Return the truth value of (x1 > x2) element-wise.

#### Parameters
- **x1, x2**: array_like
  - Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which may be the shape of one or the other).

#### Returns
- **out**: bool or ndarray of bool
  - Array of bools, or a single bool if `x1` and `x2` are scalars.

#### See also:
- `greater_equal`, `less`, `less_equal`, `equal`, `not_equal`

#### Examples

```python
>>> np.greater([4,2],[2,2])
array([ True, False], dtype=bool)
```

If the inputs are ndarrays, then `np.greater` is equivalent to `>`. 

```python
>>> a = np.array([4,2])
>>> b = np.array([2,2])
>>> a > b
array([ True, False], dtype=bool)
```

### greater_equal(x1, x2[, out])
Return the truth value of (x1 >= x2) element-wise.

#### Parameters
- **x1, x2**: array_like
  - Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which may be the shape of one or the other).

#### Returns
- **out**: bool or ndarray of bool
  - Array of bools, or a single bool if `x1` and `x2` are scalars.
Returns

\[ \text{out} : \text{bool or ndarray of bool} \]

Array of bools, or a single bool if \(x1\) and \(x2\) are scalars.

See also:

\text{greater, less, less_equal, equal, not_equal}

Examples

\[
\begin{array}{l}
>>> \text{np.greater_equal([4, 2, 1], [2, 2, 2])}\\
array([\text{True, True, False}], \text{dtype=bool})
\end{array}
\]

\text{numpy.less}(x1, x2[; out]) = <ufunc ‘less’>

Return the truth value of \((x1 < x2)\) element-wise.

Parameters

\(x1, x2\) : array_like

Input arrays. If \(x1\.shape \neq x2\.shape\), they must be broadcastable to a common shape (which may be the shape of one or the other).

Returns

\[ \text{out} : \text{bool or ndarray of bool} \]

Array of bools, or a single bool if \(x1\) and \(x2\) are scalars.

See also:

\text{greater, less, greater_equal, equal, not_equal}

Examples

\[
\begin{array}{l}
>>> \text{np.less([1, 2], [2, 2])}\\
array([\text{True, False}], \text{dtype=bool})
\end{array}
\]

\text{numpy.less_equal}(x1, x2[; out]) = <ufunc ‘less_equal’>

Return the truth value of \((x1 =< x2)\) element-wise.

Parameters

\(x1, x2\) : array_like

Input arrays. If \(x1\.shape \neq x2\.shape\), they must be broadcastable to a common shape (which may be the shape of one or the other).

Returns

\[ \text{out} : \text{bool or ndarray of bool} \]

Array of bools, or a single bool if \(x1\) and \(x2\) are scalars.

See also:

\text{greater, less, greater_equal, equal, not_equal}

Examples

\[
\begin{array}{l}
>>> \text{np.less_equal([4, 2, 1], [2, 2, 2])}\\
array([\text{False, True, True}], \text{dtype=bool})
\end{array}
\]
numpy.equal(x1, x2[, out]) = <ufunc ‘equal’>
Return (x1 == x2) element-wise.

Parameters
x1, x2 : array_like
Input arrays of the same shape.

Returns
out : {ndarray, bool}
Output array of bools, or a single bool if x1 and x2 are scalars.

See also:
not_equal, greater_equal, less_equal, greater, less

Examples
>>> np.equal([0, 1, 3], np.arange(3))
array([ True,  True, False], dtype=bool)

What is compared are values, not types. So an int (1) and an array of length one can evaluate as True:

>>> np.equal(1, np.ones(1))
array([ True], dtype=bool)

numpy.not_equal(x1, x2[, out]) = <ufunc ‘not_equal’>
Return (x1 != x2) element-wise.

Parameters
x1, x2 : array_like
Input arrays.

out : ndarray, optional
A placeholder the same shape as x1 to store the result. See doc.ufuncs (Section “Output arguments”) for more details.

Returns
not_equal : ndarray bool, scalar bool
For each element in x1, x2, return True if x1 is not equal to x2 and False otherwise.

See also:
equal, greater, greater_equal, less, less_equal

Examples
>>> np.not_equal([1., 2.], [1., 3.])
array([[False,  True],
       [False, False],
       [False, True]], dtype=bool)

3.19 Masked array operations

3.19.1 Constants
NumPy Reference, Release 1.9.2

numpy.ma.MaskType

alias of bool_

3.19.2 Creation

From existing data

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numpy.ma.masked_array

alias of MaskedArray

numpy.ma.array(data, dtype=None, copy=False, order=False, mask=False, fill_value=None, keep_mask=True, hard_mask=None, shrink=True, subok=True, ndmin=0)

An array class with possibly masked values.

Masked values of True exclude the corresponding element from any computation.

Construction:

```python
x = MaskedArray(data, mask=nomask, dtype=None, 
                copy=False, subok=True, ndmin=0, fill_value=None, 
                keep_mask=True, hard_mask=None, shrink=True)
```

Parameters

- **data**: array_like
  - Input data.
- **mask**: sequence, optional
  - Mask. Must be convertible to an array of booleans with the same shape as data. True indicates a masked (i.e. invalid) data.
- **dtype**: dttype, optional
  - Data type of the output. If dtype is None, the type of the data argument (data.dtype) is used. If dtype is not None and different from data.dtype, a copy is performed.
- **copy**: bool, optional
  - Whether to copy the input data (True), or to use a reference instead. Default is False.
- **subok**: bool, optional
  - Whether to return a subclass of MaskedArray if possible (True) or a plain MaskedArray. Default is True.
- **ndmin**: int, optional
  - Minimum number of dimensions. Default is 0.
fill_value : scalar, optional

Value used to fill in the masked values when necessary. If None, a default based on the
data-type is used.

keep_mask : bool, optional

Whether to combine mask with the mask of the input data, if any (True), or to use only
mask for the output (False). Default is True.

hard_mask : bool, optional

Whether to use a hard mask or not. With a hard mask, masked values cannot be un-
masked. Default is False.

shrink : bool, optional

Whether to force compression of an empty mask. Default is True.

numpy.ma.copy = <numpy.ma.core._frommethod instance at 0x4243f50c>

copy a.copy(order='C')

Return a copy of the array.

Parameters

order : {'C', 'F', 'A', 'K'}, optional

Controls the memory layout of the copy. ‘C’ means C-order, ‘F’ means F-order, ‘A’
means ‘F’ if a is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of a as
closely as possible. (Note that this function and :func:numpy.copy are very similar, but
have different default values for their order= arguments.)

Examples

>>> x = np.array([[1, 2, 3], [4, 5, 6]], order='F')

>>> y = x.copy()

>>> x.fill(0)

>>> x
array([[0, 0, 0],
       [0, 0, 0]])

>>> y
array([[1, 2, 3],
       [4, 5, 6]])

>>> y.flags['C_CONTIGUOUS']
True

numpy.ma.frombuffer (buffer, dtype=float, count=-1, offset=0) = <numpy.ma.core._convert2ma in-
stance at 0x4243fb4c>

Interpret a buffer as a 1-dimensional array.

Parameters

buffer : buffer_like

An object that exposes the buffer interface.

dtype : data-type, optional

Data-type of the returned array; default: float.
count : int, optional
    Number of items to read. -1 means all data in the buffer.

offset : int, optional
    Start reading the buffer from this offset; default: 0.

Notes
If the buffer has data that is not in machine byte-order, this should be specified as part of the data-type, e.g.:

```python
>>> dt = np.dtype(int)
>>> dt = dt.newbyteorder('>')
>>> np.frombuffer(buf, dtype=dt)
```

The data of the resulting array will not be byteswapped, but will be interpreted correctly.

Examples
```python
>>> s = 'hello world'
>>> np.frombuffer(s, dtype='S1', count=5, offset=6)
array(['w', 'o', 'r', 'l', 'd'],
      dtype='|S1')
```

numpy.ma.fromfunction(function, shape, **kwargs) = <numpy.ma.core._convert2ma instance at 0x4243fb6c>

Construct an array by executing a function over each coordinate.

The resulting array therefore has a value fn(x, y, z) at coordinate (x, y, z).

Parameters
    function : callable
        The function is called with N parameters, where N is the rank of shape. Each parameter represents the coordinates of the array varying along a specific axis. For example, if shape were (2, 2), then the parameters in turn be (0, 0), (0, 1), (1, 0), (1, 1).

    shape : (N,) tuple of ints
        Shape of the output array, which also determines the shape of the coordinate arrays passed to function.

    dtype : data-type, optional
        Data-type of the coordinate arrays passed to function. By default, dtype is float.

Returns
    fromfunction : any
        The result of the call to function is passed back directly. Therefore the shape of fromfunction is completely determined by function. If function returns a scalar value, the shape of fromfunction would match the shape parameter.

See also:
    indices, meshgrid

Notes
Keywords other than dtype are passed to function.
NumPy Reference, Release 1.9.2

Examples

>>> np.fromfunction(lambda i, j: i == j, (3, 3), dtype=int)
array([[ True, False, False],
       [False,  True, False],
       [False, False,  True]], dtype=bool)

>>> np.fromfunction(lambda i, j: i + j, (3, 3), dtype=int)
array([[0, 1, 2],
       [1, 2, 3],
       [2, 3, 4]])

MaskedArray.copy(order='C')
Return a copy of the array.

Parameters

order : {'C', 'F', 'A', 'K'}, optional
Controls the memory layout of the copy. ‘C’ means C-order, ‘F’ means F-order, ‘A’
means ‘F’ if a is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of a as
closely as possible. (Note that this function and :func:numpy.copy are very similar, but
have different default values for their order= arguments.)

See also:
numpy.copy, numpy.copyto

Examples

>>> x = np.array([[1,2,3],[4,5,6]], order='F')

>>> y = x.copy()

>>> x.fill(0)

>>> x
array([[0, 0, 0],
       [0, 0, 0]])

>>> y
array([[1, 2, 3],
       [4, 5, 6]])

>>> y.flags['C_CONTIGUOUS']
True

Ones and zeros

ma.empty(shape[, dtype, order]) Return a new array of given shape and type, without initializing entries.
ma.empty_like(a[, dtype, order, subok]) Return a new array with the same shape and type as a given array.
ma.masked_all(shape[, dtype]) Empty masked array with all elements masked.
ma.masked_all_like(arr) Empty masked array with the properties of an existing array.
ma.ones(shape[, dtype, order]) Return a new array of given shape and type, filled with ones.
ma.zeros(shape[, dtype, order]) Return a new array of given shape and type, filled with zeros.
numpy.ma.empty(shape, dtype=float, order='C') = <numpy.ma.core._convert2ma instance at 0x4243faec>

Return a new array of given shape and type, without initializing entries.

**Parameters**

- **shape**: int or tuple of int
  
  Shape of the empty array

- **dtype**: data-type, optional
  
  Desired output data-type.

- **order**: {'C', 'F'}, optional
  
  Whether to store multi-dimensional data in C (row-major) or Fortran (column-major) order in memory.

**Returns**

- **out**: ndarray
  
  Array of uninitialized (arbitrary) data with the given shape, dtype, and order.

**See also:**

empty_like, zeros, ones

**Notes**

empty, unlike zeros, does not set the array values to zero, and may therefore be marginally faster. On the other hand, it requires the user to manually set all the values in the array, and should be used with caution.

**Examples**

```python
>>> np.empty([2, 2])
array([[ -9.74499359e+001, 6.69583040e-309],
       [ 2.13182611e-314, 3.06959433e-309]]) #random

>>> np.empty([2, 2], dtype=int)
array([[ 1073741821, -1067949133],
       [ 496041986, 19249760]]) #random
```

numpy.ma.empty_like(a, dtype=None, order='K', subok=True) = <numpy.ma.core._convert2ma instance at 0x4243fb2c>

Return a new array with the same shape and type as a given array.

**Parameters**

- **a**: array_like
  
  The shape and data-type of a define these same attributes of the returned array.

- **dtype**: data-type, optional
  
  New in version 1.6.0.

  Overrides the data type of the result.

- **order**: {'C', 'F', 'A', or 'K'}, optional
  
  New in version 1.6.0.

  Overrides the memory layout of the result. ‘C’ means C-order, ‘F’ means F-order, ‘A’ means ‘F’ if a is Fortran contiguous, ‘C’ otherwise. ‘K’ means match the layout of a as closely as possible.

- **subok**: bool, optional.
If True, then the newly created array will use the sub-class type of ‘a’, otherwise it will
be a base-class array. Defaults to True.

Returns

out : ndarray

Array of uninitialized (arbitrary) data with the same shape and type as a.

See also:

ones_like
Return an array of ones with shape and type of input.

zeros_like
Return an array of zeros with shape and type of input.

dtype
Return a new uninitialized array.

ones
Return a new array setting values to one.

zeros
Return a new array setting values to zero.

Notes

This function does not initialize the returned array; to do that use zeros_like or ones_like instead. It may be
marginally faster than the functions that do set the array values.

Examples

```python
>>> a = ([1,2,3], [4,5,6])
# a is array-like
>>> np.empty_like(a)
array([[-1073741821, -1073741821, 3],
       [0, 0, -1073741821]]) #random
>>> a = np.array([[1., 2., 3.],[4.,5.,6.]])
>>> np.empty_like(a)
array([[ -2.00000715e+000, 1.48219694e-323, -2.00000572e+000],
       [ 4.38791518e-305, -2.00000715e+000, 4.17269252e-309]])
```

numpy.ma.masked_all(shape, dtype=<type 'float'>)
Empty masked array with all elements masked.

Return an empty masked array of the given shape and dtype, where all the data are masked.

Parameters

shape : tuple
Shape of the required MaskedArray.

dtype : dtype, optional
Data type of the output.

Returns

a : MaskedArray
A masked array with all data masked.

See also:
**masked_all_like**

Empty masked array modelled on an existing array.

**Examples**

```python
>>> import numpy.ma as ma
>>> ma.masked_all((3, 3))
masked_array(data =
[[-- -- --]
[-- -- --]
[-- -- --]],
mask =
[[ True  True  True]
[ True  True  True]
[ True  True  True]],
fill_value=1e+20)
```

The `dtype` parameter defines the underlying data type.

```python
>>> a = ma.masked_all((3, 3))
>>> a.dtype
dtype('float64')
>>> a = ma.masked_all((3, 3), dtype=np.int32)
>>> a.dtype
dtype('int32')
```

numpy.ma.masked_all_like(arr)

Empty masked array with the properties of an existing array.

Return an empty masked array of the same shape and dtype as the array `arr`, where all the data are masked.

**Parameters**

- **arr**: ndarray
  
  An array describing the shape and dtype of the required MaskedArray.

**Returns**

- **a**: MaskedArray
  
  A masked array with all data masked.

**Raises**

- **AttributeError**
  
  If `arr` doesn’t have a shape attribute (i.e. not an ndarray)

**See also:**

- **masked_all**
  
  Empty masked array with all elements masked.

**Examples**

```python
>>> import numpy.ma as ma
>>> arr = np.zeros((2, 3), dtype=np.float32)
>>> arr
array([[0., 0., 0.],
       [0., 0., 0.]], dtype=float32)
>>> ma.masked_all_like(arr)
masked_array(data =
[[-- -- --]]
```
The dtype of the masked array matches the dtype of `arr`.

```python
goldenrod>
arr.dtype
dtype('float32')
goldenrod>
ma.masked_all_like(arr).dtype
dtype('float32')
```

`numpy.ma.ones(shape, dtype=None, order=’C’) = <numpy.ma.core._convert2ma instance at 0x4243fc0c>`

Return a new array of given shape and type, filled with ones.

**Parameters**

- `shape`: int or sequence of ints
  
  Shape of the new array, e.g., (2, 3) or 2.

- `dtype`: data-type, optional
  
  The desired data-type for the array, e.g., `numpy.int8`. Default is `numpy.float64`.

- `order`: {'C', 'F'}, optional
  
  Whether to store multidimensional data in C- or Fortran-contiguous (row- or column-wise) order in memory.

**Returns**

- `out`: ndarray
  
  Array of ones with the given shape, dtype, and order.

**See also:**

`zeros`, `ones_like`

**Examples**

```python
goldenrod>>> np.ones(5)
array([1., 1., 1., 1., 1.])
```

```python
goldenrod>>> np.ones((5,), dtype=np.int)
array([1, 1, 1, 1, 1])
```

```python
goldenrod>>> np.ones((2, 1))
array([[1.],
       [1.]])
```

```python
goldenrod>>> s = (2, 2)
goldenrod>>> np.ones(s)
array([[1., 1.],
       [1., 1.]])
```

`numpy.ma.zeros(shape, dtype=float, order=’C’) = <numpy.ma.core._convert2ma instance at 0x4243fc8c>`

Return a new array of given shape and type, filled with zeros.

**Parameters**

- `shape`: int or sequence of ints
Shape of the new array, e.g., (2, 3) or 2.

dtype : data-type, optional

The desired data-type for the array, e.g., numpy.int8. Default is numpy.float64.

order : {'C', 'F'}, optional

Whether to store multidimensional data in C- or Fortran-contiguous (row- or column-wise) order in memory.

Returns
out : ndarray

Array of zeros with the given shape, dtype, and order.

See also:
zeros_like
Return an array of zeros with shape and type of input.

ones_like
Return an array of ones with shape and type of input.

empty_like
Return an empty array with shape and type of input.

ones
Return a new array setting values to one.

empty
Return a new uninitialized array.

Examples

```python
>>> np.zeros(5)
array([ 0., 0., 0., 0., 0.])

>>> np.zeros((5,), dtype=numpy.int)
array([0, 0, 0, 0, 0])

>>> np.zeros((2, 1))
array([[ 0.],
       [ 0.]]

>>> s = (2,2)
>>> np.zeros(s)
array([[ 0., 0.],
       [ 0., 0.]]

>>> np.zeros((2,), dtype=[('x', 'i4'), ('y', 'i4')]) # custom dtype
array([(0, 0)],
      dtype=[('x', '<i4'), ('y', '<i4')])
```

3.19.3 Inspecting the array

```python
ma.all(self[, axis, out]) Check if all of the elements of a are true.
```

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<td>Check if any of the elements of <code>a</code> are true.</td>
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<tr>
<td><code>ma.count(a[, axis])</code></td>
<td>Count the non-masked elements of the array along the given axis.</td>
</tr>
<tr>
<td><code>ma.count_masked(arr[, axis])</code></td>
<td>Count the number of masked elements along the given axis.</td>
</tr>
<tr>
<td><code>ma.getmask(a)</code></td>
<td>Return the mask of a masked array, or nomask.</td>
</tr>
<tr>
<td><code>ma.getmaskarray(arr)</code></td>
<td>Return the mask of a masked array, or full boolean array of False.</td>
</tr>
<tr>
<td><code>ma.getdata(a[, subok])</code></td>
<td>Return the data of a masked array as an ndarray.</td>
</tr>
<tr>
<td><code>ma.nonzero(self)</code></td>
<td>Return the indices of unmasked elements that are not zero.</td>
</tr>
<tr>
<td><code>ma.shape(obj)</code></td>
<td>Return the shape of an array.</td>
</tr>
<tr>
<td><code>ma.size(obj[, axis])</code></td>
<td>Return the number of elements along a given axis.</td>
</tr>
<tr>
<td><code>ma.is_masked(x)</code></td>
<td>Determine whether input has masked values.</td>
</tr>
<tr>
<td><code>ma.is_mask(m)</code></td>
<td>Return True if <code>m</code> is a valid, standard mask.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.data</code></td>
<td>Return the current data, as a view of the original underlying data.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.mask</code></td>
<td>Mask</td>
</tr>
<tr>
<td><code>ma.MaskedArray.recordmask</code></td>
<td>Return the mask of the records.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.all([axis, out])</code></td>
<td>Check if all of the elements of <code>a</code> are true.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.any([axis, out])</code></td>
<td>Check if any of the elements of <code>a</code> are true.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.count([axis])</code></td>
<td>Count the non-masked elements of the array along the given axis.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.nonzero()</code></td>
<td>Return the indices of unmasked elements that are not zero.</td>
</tr>
<tr>
<td><code>ma.shape(obj)</code></td>
<td>Return the shape of an array.</td>
</tr>
<tr>
<td><code>ma.size(obj[, axis])</code></td>
<td>Return the number of elements along a given axis.</td>
</tr>
</tbody>
</table>

**numpy.ma.all**  
`numpy.ma.all(self, axis=None, out=None) = <numpy.ma.core._frommethod instance at 0x4243f2cc>`

Check if all of the elements of `a` are true.

Perform a `logical_and` over the given axis and returns the result. Masked values are considered as True during computation. For convenience, the output array is masked where ALL the values along the current axis are masked: if the output would have been a scalar and that all the values are masked, then the output is masked.

**Parameters**
- **axis**: {None, integer}  
  Axis to perform the operation over. If None, perform over flattened array.
- **out**: {None, array}, optional  
  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**See also:**
- `all`
  equivalent function

**Examples**

```python
>>> np.ma.array([1,2,3]).all()
True
>>> a = np.ma.array([1,2,3], mask=True)
>>> (a.all() is np.ma.masked)
True
```

**numpy.ma.any**  
`numpy.ma.any(self, axis=None, out=None) = <numpy.ma.core._frommethod instance at 0x4243f3ec>`

Check if any of the elements of `a` are true.

Perform a `logical_or` over the given axis and returns the result. Masked values are considered as False during computation.
Parameters

- axis : {None, integer}
  
  Axis to perform the operation over. If None, perform over flattened array and return a scalar.

- out : {None, array}, optional
  
  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

See also:

`any`

equivalent function

`numpy.ma.count(a, axis=None)`

Count the non-masked elements of the array along the given axis.

Parameters

- axis : int, optional
  
  Axis along which to count the non-masked elements. If axis is None, all non-masked elements are counted.

Returns

- result : int or ndarray
  
  If axis is None, an integer count is returned. When axis is not None, an array with shape determined by the lengths of the remaining axes, is returned.

See also:

`count_masked`

Count masked elements in array or along a given axis.

Examples

```python
>>> import numpy.ma as ma
>>> a = ma.arange(6).reshape((2, 3))
>>> a[1, :] = ma.masked
>>> a
masked_array(data =
[[0 1 2]
[-- -- --]],
mask =
[[False False False]
[ True  True  True]],
fill_value = 999999)
>>> a.count()
3

When the axis keyword is specified an array of appropriate size is returned.

```python
>>> a.count(axis=0)
array([1, 1, 1])
```
Parameters
  arr : array_like
      An array with (possibly) masked elements.
  axis : int, optional
      Axis along which to count. If None (default), a flattened version of the array is used.

Returns
  count : int, ndarray
      The total number of masked elements (axis=None) or the number of masked elements
      along each slice of the given axis.

See also:
MaskedArray.count
      Count non-masked elements.

Examples
>>> import numpy.ma as ma
>>> a = np.arange(9).reshape((3,3))
>>> a = ma.array(a)
>>> a[1, 0] = ma.masked
>>> a[1, 2] = ma.masked
>>> a[2, 1] = ma.masked
>>> a
masked_array(data =
    [[0 1 2]   
     [-- 4 --]  
     [6 -- 8]],
    mask =
    [[False False False]  
     [ True False  True]  
     [False  True False]],
    fill_value=999999)
>>> ma.count_masked(a)
3

When the axis keyword is used an array is returned.

>>> ma.count_masked(a, axis=0)
array([1, 1, 1])
>>> ma.count_masked(a, axis=1)
array([0, 2, 1])

numpy.ma.getmask(a)
Return the mask of a masked array, or nomask.

Return the mask of a as an ndarray if a is a MaskedArray and the mask is not nomask, else return nomask.
To guarantee a full array of booleans of the same shape as a, use getmaskarray.

Parameters
  a : array_like
      Input MaskedArray for which the mask is required.

See also:
getdata
Return the data of a masked array as an ndarray.

getmaskarray
Return the mask of a masked array, or full array of False.

Examples
>>> import numpy.ma as ma
>>> a = ma.masked_equal([[1,2],[3,4]], 2)
>>> a
masked_array(data =
[ [ 1 -- ]
[ 3 4 ]],
mask =
[ [False True]
[False False]],
fill_value=999999)
>>> ma.getmask(a)
array([[False, True],
[False, False]], dtype=bool)
Equivalently use the MaskedArray mask attribute.

>>> a.mask
array([[False, True],
[False, False]], dtype=bool)

Result when mask == nomask
>>> b = ma.masked_array([[1,2],[3,4]])
>>> b
masked_array(data =
[ [ 1 2]
[ 3 4 ]],
mask =
False,
fill_value=999999)
>>> ma.nomask
False
>>> ma.getmask(b) == ma.nomask
True
>>> b.mask == ma.nomask
True

numpy.ma.getmaskarray(arr)
Return the mask of a masked array, or full boolean array of False.

Return the mask of arr as an ndarray if arr is a MaskedArray and the mask is not nomask, else return a full boolean array of False of the same shape as arr.

Parameters
arr : array_like
Input MaskedArray for which the mask is required.

See also:

getmask
Return the mask of a masked array, or nomask.
getdata
   Return the data of a masked array as an ndarray.

Examples
>>> import numpy.ma as ma
>>> a = ma.masked_equal([[1, 2], [3, 4]], 2)
>>> a
masked_array(data =
[[1 --]
[3 4]],
   mask =
[[False  True]
[False False]],
   fill_value=999999)
>>> ma.getmaskarray(a)
array([[False, True],
       [False, False]], dtype=bool)

Result when mask == nomask
>>> b = ma.masked_array([[1, 2], [3, 4]])
>>> b
masked_array(data =
[[1 2]
[3 4]],
   mask =
False,
   fill_value=999999)
>>> ma.getmaskarray(b)
array([[False, False],
       [False, False]], dtype=bool)

numpy.ma.getdata(a, subok=True)
   Return the data of a masked array as an ndarray.

   Return the data of a (if any) as an ndarray if a is a MaskedArray, else return a as a ndarray or subclass (depending on subok) if not.

   Parameters
      a : array_like
         Input MaskedArray, alternatively a ndarray or a subclass thereof.

      subok : bool
         Whether to force the output to be a pure ndarray (False) or to return a subclass of ndarray if appropriate (True, default).

   See also:

getmask
   Return the mask of a masked array, or nomask.

getmaskarray
   Return the mask of a masked array, or full array of False.
Examples

```python
>>> import numpy.ma as ma
>>> a = ma.masked_equal([[1, 2], [3, 4]], 2)
```

```python
>>> a
masked_array(data =
[[1 --]
 [3 4]],
mask =
[[False True]
 [False False]],
fill_value=999999)
```

```python
>>> ma.getdata(a)
array([[1, 2],
 [3, 4]])
```

Equivalently use the `MaskedArray data` attribute.

```python
>>> a.data
daarray([[1, 2],
 [3, 4]])
```

```python
numpy.ma.nonzero(self) = <numpy.ma.core._frommethod instance at 0x4243f60c>
```

Return the indices of unmasked elements that are not zero.

Returns a tuple of arrays, one for each dimension, containing the indices of the non-zero elements in that dimension. The corresponding non-zero values can be obtained with:

```python
a[a.nonzero()]
```

To group the indices by element, rather than dimension, use instead:

```python
np.transpose(a.nonzero())
```

The result of this is always a 2d array, with a row for each non-zero element.

Parameters

None

Returns

tuple_of_arrays : tuple

Indices of elements that are non-zero.

See also:

- `numpy.nonzero`
  Function operating on ndarrays.
- `flatnonzero`
  Return indices that are non-zero in the flattened version of the input array.
- `ndarray.nonzero`
  Equivalent ndarray method.
- `count_nonzero`
  Counts the number of non-zero elements in the input array.

Examples
>>> import numpy.ma as ma
>>> x = ma.array(np.eye(3))
>>> x
masked_array(data =
[[ 1.  0.  0.]
 [ 0.  1.  0.]
 [ 0.  0.  1.]],
mask = False,
fill_value=1e+20)
>>> x.nonzero()
(array([0, 1, 2]), array([0, 1, 2]))

Masked elements are ignored.
>>> x[1, 1] = ma.masked
>>> x
masked_array(data =
[[1.0 0.0 0.0]
 [0.0 -- 0.0]
 [0.0 0.0 1.0]],
mask =
[[False False False]
 [False  True False]
 [False False False]],
fill_value=1e+20)
>>> x.nonzero()
(array([0, 2]), array([0, 2]))

Indices can also be grouped by element.
>>> np.transpose(x.nonzero())
array([[0, 0],
 [2, 2]])

A common use for nonzero is to find the indices of an array, where a condition is True. Given an array a, the condition a > 3 is a boolean array and since False is interpreted as 0, ma.nonzero(a > 3) yields the indices of the a where the condition is true.

>>> a = ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])
>>> a > 3
masked_array(data =
[[False False False]
 [ True True True]
 [ True True True]],
mask = False,
fill_value=999999)
>>> ma.nonzero(a > 3)
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))

The nonzero method of the condition array can also be called.

>>> (a > 3).nonzero()
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))

```
numpy.ma.shape(obj)
Return the shape of an array.
```
Parameters
   a : array_like
       Input array.

Returns
   shape : tuple of ints
       The elements of the shape tuple give the lengths of the corresponding array dimensions.

See also:

alen

ndarray.shape
   Equivalent array method.

Examples

>>> np.shape(np.eye(3))
(3, 3)
>>> np.shape([[1, 2]])
(1, 2)
>>> np.shape([0])
(1,)
>>> np.shape(0)
()

>>> a = np.array([[1, 2], [3, 4]], dtype=[('x', 'i4'), ('y', 'i4')])
>>> np.shape(a)
(2,)
>>> a.shape
(2,)

numpy.ma.size(obj, axis=None)
Return the number of elements along a given axis.

Parameters
   a : array_like
       Input data.

axis : int, optional
       Axis along which the elements are counted. By default, give the total number of ele-

Returns
   element_count : int
       Number of elements along the specified axis.

See also:

shape
dimensions of array

ndarray.shape
dimensions of array

ndarray.size
   number of elements in array
Examples

>>> a = np.array([[1,2,3],[4,5,6]])
>>> np.size(a)
6
>>> np.size(a,1)
3
>>> np.size(a,0)
2

numpy.ma.is_masked(x)

Determine whether input has masked values.

Accepts any object as input, but always returns False unless the input is a MaskedArray containing masked values.

Parameters

x : array_like

Array to check for masked values.

Returns

result : bool

True if x is a MaskedArray with masked values, False otherwise.

Examples

>>> import numpy.ma as ma
>>> x = ma.masked_equal([0, 1, 0, 2, 3], 0)
>>> x
masked_array(data = [-- 1 -- 2 3],
       mask = [ True False True False False],
      fill_value=999999)
>>> ma.is_masked(x)
True
>>> x = ma.masked_equal([0, 1, 0, 2, 3], 42)
>>> x
masked_array(data = [0 1 0 2 3],
       mask = False,
      fill_value=999999)
>>> ma.is_masked(x)
False

Always returns False if x isn’t a MaskedArray.

>>> x = [False, True, False]
>>> ma.is_masked(x)
False
>>> x = ‘a string’
>>> ma.is_masked(x)
False

numpy.ma.is_mask(m)

Return True if m is a valid, standard mask.

This function does not check the contents of the input, only that the type is MaskType. In particular, this function returns False if the mask has a flexible dtype.

Parameters

m : array_like
Array to test.

Returns

result : bool

True if m.dtype.type is MaskType, False otherwise.

See also:

isMaskedArray

Test whether input is an instance of MaskedArray.

Examples

>>> import numpy.ma as ma
>>> m = ma.masked_equal([0, 1, 0, 2, 3], 0)
>>> m
masked_array(data = [-- 1 -- 2 3],
mask = [ True False True False False],
fill_value=999999)
>>> ma.is_mask(m)
False
>>> ma.is_mask(m.mask)
True

Input must be an ndarray (or have similar attributes) for it to be considered a valid mask.

>>> m = [False, True, False]
>>> ma.is_mask(m)
False
>>> m = np.array([False, True, False])
>>> m
array([False, True, False], dtype=bool)
>>> ma.is_mask(m)
True

Arrays with complex dtypes don’t return True.

>>> dtype = np.dtype({'names':
| 'monty', 'pithon'
| 'formats':[np.bool, np.bool]})
>>> dtype
dtype([(monty', '|b1'), ('pithon', '|b1')])
>>> m = np.array([(True, False), (False, True), (True, False)],
dtype=dtype)
>>> m
array([(True, False), (False, True), (True, False)],
dtype=[('monty', '|b1'), ('pithon', '|b1')])
>>> ma.is_mask(m)
False

MaskedArray.data

Return the current data, as a view of the original underlying data.

MaskedArray.mask

Mask

MaskedArray.recordmask

Return the mask of the records. A record is masked when all the fields are masked.

MaskedArray.all (axis=None, out=None)

Check if all of the elements of a are true.
Performs a `logical_and` over the given axis and returns the result. Masked values are considered as True during computation. For convenience, the output array is masked where ALL the values along the current axis are masked: if the output would have been a scalar and that all the values are masked, then the output is `masked`.

**Parameters**

- `axis : {None, integer}`
  
  Axis to perform the operation over. If None, perform over flattened array.
  
- `out : {None, array}, optional`

  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**Examples**

```python
>>> np.ma.array([1,2,3]).all()
True
>>> a = np.ma.array([1,2,3], mask=True)
>>> (a.all() is np.ma.masked)
True
```

**See also:**

- `all` equivalent function

**MaskedArray. any (axis=None, out=None)**

Check if any of the elements of `a` are true.

Performs a `logical_or` over the given axis and returns the result. Masked values are considered as False during computation.

**Parameters**

- `axis : {None, integer}`

  Axis to perform the operation over. If None, perform over flattened array and return a scalar.

- `out : {None, array}, optional`

  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**See also:**

- `any` equivalent function

**MaskedArray. count (axis=None)**

Count the non-masked elements of the array along the given axis.

**Parameters**

- `axis : int, optional`

  Axis along which to count the non-masked elements. If `axis` is `None`, all non-masked elements are counted.

**Returns**

- `result : int or ndarray`
If `axis` is `None`, an integer count is returned. When `axis` is not `None`, an array with shape determined by the lengths of the remaining axes, is returned.

See also:

**count_masked**
Count masked elements in array or along a given axis.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = ma.arange(6).reshape((2, 3))
>>> a[1, :] = ma.masked
>>> a
masked_array(data =
[[0 1 2]
 [-- -- --]],
 mask =
[[False False False]
 [ True  True  True]],
 fill_value = 999999)
>>> a.count()
3
```

When the `axis` keyword is specified an array of appropriate size is returned.

```python
>>> a.count(axis=0)
array([1, 1, 1])
>>> a.count(axis=1)
array([3, 0])
```

**MaskedArray.nonzero()**
Return the indices of unmasked elements that are not zero.

Returns a tuple of arrays, one for each dimension, containing the indices of the non-zero elements in that dimension. The corresponding non-zero values can be obtained with:

```python
a[a.nonzero()]
```

To group the indices by element, rather than dimension, use instead:

```python
np.transpose(a.nonzero())
```

The result of this is always a 2d array, with a row for each non-zero element.

**Parameters**

- None

**Returns**

- **tuple_of_arrays**: tuple
  Indices of elements that are non-zero.

See also:

**numpy.nonzero**
Function operating on ndarrays.

**flatnonzero**
Return indices that are non-zero in the flattened version of the input array.
**ndarray.nonzero**
Equivalent ndarray method.

**count_nonzero**
Counts the number of non-zero elements in the input array.

**Examples**

```python
>>> import numpy.ma as ma
>>> x = ma.array(np.eye(3))
>>> x
masked_array(data =
    [[ 1.  0.  0.]
     [ 0.  1.  0.]
     [ 0.  0.  1.]],
    mask =
    [False,
     False,
     False],
    fill_value=1e+20)
>>> x.nonzero()
(array([0, 1, 2]), array([0, 1, 2]))

Masked elements are ignored.

```python
>>> x[1, 1] = ma.masked
>>> x
masked_array(data =
    [[ 1.0  0.0  0.0]
     [ 0.0 --  0.0]
     [ 0.0  0.0  1.0]],
    mask =
    [[False False False]
     [False True False]
     [False False False]],
    fill_value=1e+20)
>>> x.nonzero()
(array([0, 2]), array([0, 2]))

Indices can also be grouped by element.

```python
>>> np.transpose(x.nonzero())
array([[0, 0],
       [2, 2]]
```

A common use for nonzero is to find the indices of an array, where a condition is True. Given an array \(a\), the condition \(a > 3\) is a boolean array and since False is interpreted as 0, `ma.nonzero(a > 3)` yields the indices of the \(a\) where the condition is true.

```python
>>> a = ma.array([[1,2,3],[4,5,6],[7,8,9]])
>>> a > 3
masked_array(data =
    [[False False False]
     [ True True True]
     [ True True True]],
    mask =
    [False False False]
     [ True True True]
     [ True True True]],
    fill_value=999999)
>>> ma.nonzero(a > 3)
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))

The `nonzero` method of the condition array can also be called.
>>> (a > 3).nonzero()
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))

numpy.ma.shape(obj)
Return the shape of an array.

Parameters
a : array_like
   Input array.

Returns
shape : tuple of ints
   The elements of the shape tuple give the lengths of the corresponding array dimensions.

See also:
alen
ndarray.shape
   Equivalent array method.

Examples
>>> np.shape(np.eye(3))
(3, 3)
>>> np.shape([[1, 2]])
(1, 2)
>>> np.shape([0])
(1,
>>> np.shape(0)
()

>>> a = np.array([[1, 2], (3, 4)], dtype=[('x', 'i4'), ('y', 'i4')])
>>> np.shape(a)
(2,
>>> a.shape
(2,

numpy.ma.size(obj, axis=None)
Return the number of elements along a given axis.

Parameters
a : array_like
   Input data.
axis : int, optional
   Axis along which the elements are counted. By default, give the total number of ele-
ments.

Returns
element_count : int
   Number of elements along the specified axis.

See also:
shape
dimensions of array
NumPy Reference, Release 1.9.2

**ndarray.shape**
- dimensions of array

**ndarray.size**
- number of elements in array

### Examples
```python
>>> a = np.array([[1,2,3],[4,5,6]])
>>> np.size(a)
6
>>> np.size(a,1)
3
>>> np.size(a,0)
2
```

---

### 3.19.4 Manipulating a MaskedArray

#### Changing the shape

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
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<tr>
<td><code>ma.ravel(self)</code></td>
<td>Returns a 1D version of self, as a view.</td>
</tr>
<tr>
<td><code>ma.reshape(a, new_shape[, order])</code></td>
<td>Returns an array containing the same data with a new shape.</td>
</tr>
<tr>
<td><code>ma.resize(x, new_shape)</code></td>
<td>Return a new masked array with the specified size and shape.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.flatten([order])</code></td>
<td>Return a copy of the array collapsed into one dimension.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.ravel()</code></td>
<td>Returns a 1D version of self, as a view.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.reshape(*s, **kwags)</code></td>
<td>Give a new shape to the array without changing its data.</td>
</tr>
</tbody>
</table>

```
numpy.ma.ravel(self) = <numpy.ma.core._frommethod instance at 0x4243f72c>
```

- Returns a 1D version of self, as a view.

  **Returns**
  - MaskedArray

  **Output view is of shape**
  - (self.size,)
  - (np.ma.product(self.shape),)

  **Examples**
```python
>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)
>>> print x
[[1 -- 3]
 -- 5 --
[7 -- 9]]
>>> print x.ravel()
[1 -- 3 -- 5 -- 7 -- 9]
```

```
numpy.ma.reshape(a, new_shape, order='C')
```

- Returns an array containing the same data with a new shape.

  **Refer to**
  - `MaskedArray.reshape` for full documentation.

  **See also:**
**MaskedArray.reshape**

equivalent function

`numpy.ma.resize(x, new_shape)`

Return a new masked array with the specified size and shape.

This is the masked equivalent of the `numpy.resize` function. The new array is filled with repeated copies of `x` (in the order that the data are stored in memory). If `x` is masked, the new array will be masked, and the new mask will be a repetition of the old one.

**See also:**

`numpy.resize`

Equivalent function in the top level NumPy module.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = ma.array([[1, 2], [3, 4]])
>>> a[0, 1] = ma.masked
>>> a
masked_array(data =
[[1 --]
[3 4]],
mask =
[[False  True]
[False False]],
fill_value = 999999)
>>> np.resize(a, (3, 3))
array([[1, 2, 3],
[4, 1, 2],
[3, 4, 1]])
>>> ma.resize(a, (3, 3))
masked_array(data =
[[1 -- 3]
[4 1 --]
[3 4 1]],
mask =
[[False  True False]
[False False True]
[False False False]],
fill_value = 999999)
```

A MaskedArray is always returned, regardless of the input type.

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> ma.resize(a, (3, 3))
masked_array(data =
[[1 2 3]
[4 1 2]
[3 4 1]],
mask =
False,
fill_value = 999999)
```

**MaskedArray.flatten**(order='C')

Return a copy of the array collapsed into one dimension.
Parameters

order : {‘C’, ‘F’, ‘A’}, optional

Whether to flatten in C (row-major), Fortran (column-major) order, or preserve the C/Fortran ordering from a. The default is ‘C’.

Returns

y : ndarray

A copy of the input array, flattened to one dimension.

See also:

ravel
Return a flattened array.

flat
A 1-D flat iterator over the array.

Examples

>>> a = np.array([[1,2], [3,4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])

MaskedArray.ravel()
Returns a 1D version of self, as a view.

Returns

MaskedArray

Output view is of shape (self.size,) (or (np.ma.product(self.shape),)).

Examples

>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)
>>> print x
[[1 -- 3]
 [-- 5 --]
[7 -- 9]]
>>> print x.ravel()
[1 -- 3 -- 5 -- 7 -- 9]

MaskedArray.reshape(*s, **kwargs)
Give a new shape to the array without changing its data.

Returns a masked array containing the same data, but with a new shape. The result is a view on the original array; if this is not possible, a ValueError is raised.

Parameters

shape : int or tuple of ints

The new shape should be compatible with the original shape. If an integer is supplied, then the result will be a 1-D array of that length.

order : {‘C’, ‘F’}, optional

Determines whether the array data should be viewed as in C (row-major) or FORTRAN (column-major) order.
Returns

 reshaped_array : array

 A new view on the array.

See also:

 reshape
 Equivalent function in the masked array module.

 numpy.ndarray.reshape
 Equivalent method on ndarray object.

 numpy.reshape
 Equivalent function in the NumPy module.

Notes

The reshaping operation cannot guarantee that a copy will not be made, to modify the shape in place, use
a.shape = s

Examples

>>> x = np.ma.array([[1,2],[3,4]], mask=[1,0,0,1])
>>> print x
[--- 2]
[3 --]
>>> x = x.reshape((4,1))

>>> print x
[[--]
[2]
[3]
[--]]

MaskedArray.resize(newshape, refcheck=True, order=False)

Warning: This method does nothing, except raise a ValueError exception. A masked array does not own
its data and therefore cannot safely be resized in place. Use the numpy.ma.resize function instead.

This method is difficult to implement safely and may be deprecated in future releases of NumPy.

Modifying axes

 ma.swapaxes ma.transpose(a[, axes]) swapaxes ma.MaskedArray.swapaxes(axis1, axis2) Returns a view of the array with axis1 and axis2 interchanged.
 ma.MaskedArray.transpose(*axes) Returns a view of the array with axes transposed.

numpy.ma.swapaxes = <numpy.ma.core._frommethod instance at 0x4243f88c>

swapaxes a.swapaxes(axis1, axis2)

Return a view of the array with axis1 and axis2 interchanged.

Refer to numpy.swapaxes for full documentation.

See also:

 numpy.swapaxes
equivalent function

numpy.ma.transpose(a, axes=None)

Permute the dimensions of an array.

This function is exactly equivalent to numpy.transpose.

See also:

numpy.transpose

Equivalent function in top-level NumPy module.

Examples

>>> import numpy.ma as ma
>>> x = ma.arange(4).reshape((2,2))
>>> x[1, 1] = ma.masked
>>> x
masked_array(data =
[[ 0  1]
[ 2 --]],
mask =
[[False False]
[False  True]],
fill_value = 999999)

>>> ma.transpose(x)
masked_array(data =
[[ 0  2]
[ 1 --]],
mask =
[[False False]
[False  True]],
fill_value = 999999)

MaskedArray.swapaxes(axis1, axis2)

Return a view of the array with axis1 and axis2 interchanged.

Refer to numpy.swapaxes for full documentation.

See also:

numpy.swapaxes

equivalent function

MaskedArray.transpose(*axes)

Returns a view of the array with axes transposed.

For a 1-D array, this has no effect. (To change between column and row vectors, first cast the 1-D array into a matrix object.) For a 2-D array, this is the usual matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided and a.shape = (i[0], i[1], ... i[n-2], i[n-1]), then a.transpose().shape = (i[n-1], i[n-2], ... i[1], i[0]).

Parameters

axes : None, tuple of ints, or n ints

- None or no argument: reverses the order of the axes.
- tuple of ints: i in the j-th place in the tuple means a’s i-th axis becomes a.transpose()’s j-th axis.
• \( n \) ints: same as an \( n \)-tuple of the same ints (this form is intended simply as a “convenience” alternative to the tuple form)

Returns

\[ \text{out} : \text{ndarray} \]

View of \( a \), with axes suitably permuted.

See also:

\texttt{ndarray.T}

Array property returning the array transposed.

Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
```

```python
>>> a
array([[1, 2],
       [3, 4]])
```

```python
>>> a.transpose()
array([[1, 3],
       [2, 4]])
```

```python
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
```

```python
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])
```

Changing the number of dimensions

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\texttt{numpy.ma.atleast_1d(*arys)} = <numpy.ma.extras._fromnxfunction instance at 0x424452ac>

Convert inputs to arrays with at least one dimension.

Scalar inputs are converted to 1-dimensional arrays, whilst higher-dimensional inputs are preserved.

Parameters

\[ \text{arys1, arys2, ...} : \text{array_like} \]
One or more input arrays.

Returns

ret : ndarray

An array, or sequence of arrays, each with a.ndim >= 1. Copies are made only if necessary.

Notes

The function is applied to both the _data and the _mask, if any.

Examples

>>> np.atleast_1d(1.0)
array([ 1.])

>>> x = np.arange(9.0).reshape(3,3)
>>> np.atleast_1d(x)
array([[ 0.,  1.,  2.],
       [ 3.,  4.,  5.],
       [ 6.,  7.,  8.]])

>>> np.atleast_1d(x) is x
True

>>> np.atleast_1d(1, [3, 4])
[array([1]), array([3, 4])]

def numpy.ma.atleast_2d(*arys):
    """View inputs as arrays with at least two dimensions."

Parameters

arys1, arys2, ... : array_like

One or more array-like sequences. Non-array inputs are converted to arrays. Arrays that already have two or more dimensions are preserved.

Returns

res, res2, ... : ndarray

An array, or tuple of arrays, each with a.ndim >= 2. Copies are avoided where possible, and views with two or more dimensions are returned.

Notes

The function is applied to both the _data and the _mask, if any.

Examples

>>> np.atleast_2d(3.0)
array([[ 3.]])

>>> x = np.arange(3.0)
>>> np.atleast_2d(x)
array([[ 0.,  1.,  2.]])

>>> np.atleast_2d(x).base is x
True
```python
>>> np.atleast_2d(1, [1, 2], [[1, 2]])
[array([[1]]), array([[1, 2]]), array([[1, 2]])]
```

```python
numpy.ma.atleast_3d(*arys) = <numpy.ma.extras._fromnxfunction instance at 0x424453ac>
```

View inputs as arrays with at least three dimensions.

**Parameters**

arys1, arys2, ... : array_like

One or more array-like sequences. Non-array inputs are converted to arrays. Arrays that already have three or more dimensions are preserved.

**Returns**

res1, res2, ... : ndarray

An array, or tuple of arrays, each with a.ndim >= 3. Copies are avoided where possible, and views with three or more dimensions are returned. For example, a 1-D array of shape (N,) becomes a view of shape (1, N, 1), and a 2-D array of shape (M, N) becomes a view of shape (M, N, 1).

**Notes**

The function is applied to both the _data and the _mask, if any.

**Examples**

```python
>>> np.atleast_3d(3.0)
array([[[ 3.]]])
```

```python
>>> x = np.arange(3.0)
>>> np.atleast_3d(x).shape
(1, 3, 1)
```

```python
>>> x = np.arange(12.0).reshape(4,3)
>>> np.atleast_3d(x).shape
(4, 3, 1)
```

```python
>>> for arr in np.atleast_3d([1, 2], [[1, 2]], [[[1, 2]]]):
...     print arr, arr.shape
...
[[[1]
 [2]]] (1, 2, 1)
[[[1]
 [2]]] (1, 2, 1)
[[[1 2]]] (1, 1, 2)
```

```python
numpy.ma.expand_dims(x, axis)
```

Expand the shape of an array.

Expands the shape of the array by including a new axis before the one specified by the axis parameter. This function behaves the same as `numpy.expand_dims` but preserves masked elements.

**See also:**

`numpy.expand_dims`

Equivalent function in top-level NumPy module.
Examples

```python
>>> import numpy.ma as ma
>>> x = ma.array([1, 2, 4])
>>> x[1] = ma.masked
>>> x
masked_array(data = [1 -- 4],
            mask = [False True False],
            fill_value = 999999)
>>> np.expand_dims(x, axis=0)
array([[1, 2, 4]])
>>> ma.expand_dims(x, axis=0)
masked_array(data =
[[1 -- 4]],
mask =
[[False True False]],
fill_value = 999999)
```

The same result can be achieved using slicing syntax with `np.newaxis`.

```python
>>> x[np.newaxis, :]
masked_array(data =
[[1 -- 4]],
mask =
[[False True False]],
fill_value = 999999)
```

```
numpy.ma.squeeze(a, axis=None)
Remove single-dimensional entries from the shape of an array.

Parameters

- `a`: array_like
  Input data.

- `axis`: None or int or tuple of ints, optional
  New in version 1.7.0.

  Selects a subset of the single-dimensional entries in the shape. If an axis is selected with shape entry greater than one, an error is raised.

Returns

- `squeezed`: ndarray
  The input array, but with all or a subset of the dimensions of length 1 removed. This is always `a` itself or a view into `a`.

Examples

```python
>>> x = np.array([[0], [1], [2]])
>>> x.shape
(1, 3, 1)
>>> np.squeeze(x).shape
(3,)
>>> np.squeeze(x, axis=(2,)).shape
(1, 3)
```
```

```
MaskedArray.squeeze(axis=None)
Remove single-dimensional entries from the shape of `a`.

Refer to `numpy.squeeze` for full documentation.
```
See also:

**numpy.squeeze**

Equivalent function

```python
numpy.ma.column_stack(tup) = <numpy.ma.extras._fromnxfunction instance at 0x4244548c>
```

Stack 1-D arrays as columns into a 2-D array.

Take a sequence of 1-D arrays and stack them as columns to make a single 2-D array. 2-D arrays are stacked as-is, just like with `hstack`. 1-D arrays are turned into 2-D columns first.

**Parameters**

- `tup` : sequence of 1-D or 2-D arrays.

  Arrays to stack. All of them must have the same first dimension.

**Returns**

- `stacked` : 2-D array

  The array formed by stacking the given arrays.

**Notes**

The function is applied to both the `_data` and the `_mask`, if any.

**Examples**

```python
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.column_stack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])
```

```python
numpy.ma.concatenate(arrays, axis=0)
```

Concatenate a sequence of arrays along the given axis.

**Parameters**

- `arrays` : sequence of array_like

  The arrays must have the same shape, except in the dimension corresponding to `axis` (the first, by default).

- `axis` : int, optional

  The axis along which the arrays will be joined. Default is 0.

**Returns**

- `result` : MaskedArray

  The concatenated array with any masked entries preserved.

**See also:**

- `numpy.concatenate`

  Equivalent function in the top-level NumPy module.
Examples

```python
>>> import numpy.ma as ma
>>> a = ma.arange(3)
>>> a[1] = ma.masked
>>> b = ma.arange(2, 5)
>>> a
masked_array(data = [0 -- 2],
             mask = [False True False],
             fill_value = 999999)
>>> b
masked_array(data = [2 3 4],
             mask = False,
             fill_value = 999999)
>>> ma.concatenate([a, b])
masked_array(data = [0 -- 2 2 3 4],
             mask = [False True False False False False],
             fill_value = 999999)
```

```
numpy.ma.dstack(tup) = <numpy.ma.extras._fromnxfunction instance at 0x424454ac>
```

Stack arrays in sequence depth wise (along third axis).

Takes a sequence of arrays and stack them along the third axis to make a single array. Rebuilds arrays divided by `dsplit`. This is a simple way to stack 2D arrays (images) into a single 3D array for processing.

Parameters

- `tup`: sequence of arrays

  Arrays to stack. All of them must have the same shape along all but the third axis.

Returns

- `stacked`: ndarray

  The array formed by stacking the given arrays.

See also:

- `vstack`
  Stack along first axis.

- `hstack`
  Stack along second axis.

- `concatenate`
  Join arrays.

- `dsplit`
  Split array along third axis.

Notes

The function is applied to both the `_data` and the `_mask`, if any.

Examples

```python
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.dstack((a,b))
```
```python
array([[1, 2],
       [2, 3],
       [3, 4]])
```

```python
>>> a = np.array([[1],[2],[3]])
>>> b = np.array([[2],[3],[4]])
>>> np.hstack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])
```

```python
numpy.ma.hstack(tup) = <numpy.ma.extras._fromnxfunction instance at 0x4244544c>
```

Stack arrays in sequence horizontally (column wise).

Take a sequence of arrays and stack them horizontally to make a single array. Rebuild arrays divided by hsplit.

**Parameters**

```
tup : sequence of ndarrays
```

All arrays must have the same shape along all but the second axis.

**Returns**

```
stacked : ndarray
```

The array formed by stacking the given arrays.

**See also:**

- vstack
  - Stack arrays in sequence vertically (row wise).
- dstack
  - Stack arrays in sequence depth wise (along third axis).
- concatenate
  - Join a sequence of arrays together.
- hsplit
  - Split array along second axis.

**Notes**

The function is applied to both the _data and the _mask, if any.

**Examples**

```python
>>> a = np.array([[1,2,3]])
>>> b = np.array([[2,3,4]])
>>> np.hstack((a,b))
array([[1, 2, 3],
       [2, 3, 4]])
```
**numpy.ma.hsplit** *(ary, indices_or_sections) = <numpy.ma.extras._fromnxfunction instance at 0x4244550c>*

Split an array into multiple sub-arrays horizontally (column-wise).

Please refer to the *split* documentation. *hsplit* is equivalent to *split* with *axis=1*, the array is always split along the second axis regardless of the array dimension.

**See also:**

**split**

Split an array into multiple sub-arrays of equal size.

**Notes**

The function is applied to both the _data and the _mask, if any.

**Examples**

```python
>>> x = np.arange(16.0).reshape(4, 4)
>>> x
array([[ 0.,  1.,  2.,  3.],
       [ 4.,  5.,  6.,  7.],
       [ 8.,  9., 10., 11.],
       [12., 13., 14., 15.]]
>>> np.hsplit(x, 2)
[array([[ 0.,  1.],
        [ 4.,  5.],
        [ 8.,  9.],
        [12., 13.]]),
  array([[ 2.,  3.],
        [ 6.,  7.],
        [10., 11.],
        [14., 15.]])]
```

```python
>>> np.hsplit(x, np.array([3, 6]))
[array([[ 0.,  1.,  2.],
        [ 4.,  5.,  6.],
        [ 8.,  9., 10.],
        [12., 13., 14.]]),
  array([[ 3.],
        [ 7.],
        [11.],
        [15.]]),
  array([], dtype=float64)]
```

With a higher dimensional array the split is still along the second axis.

```python
>>> x = np.arange(8.0).reshape(2, 2, 2)
>>> x
array([[[ 0.,  1.],
        [ 2.,  3.]],
       [[ 4.,  5.],
        [ 6.,  7.]]])
>>> np.hsplit(x, 2)
[array([[[ 0.,  1.]],
        [[ 4.,  5.]]),
       array([[[ 2.,  3.]],
        [[ 6.,  7.]]])]
```
numpy.ma.mr_ = <numpy.ma.extras.mr_class object at 0x4244568c>

Translate slice objects to concatenation along the first axis.

This is the masked array version of lib.index_tricks.RClass.

See also:

lib.index_tricks.RClass

Examples

>>> np.ma.mr_[np.ma.array([1,2,3]), 0, 0, np.ma.array([4,5,6])]
array([1, 2, 3, 0, 0, 4, 5, 6])

numpy.ma.row_stack(tup) = <numpy.ma.extras._fromnxfunction instance at 0x424453ec>

Stack arrays in sequence vertically (row wise).

Take a sequence of arrays and stack them vertically to make a single array. Rebuild arrays divided by vsplit.

Parameters
tup : sequence of ndarrays

Tuple containing arrays to be stacked. The arrays must have the same shape along all but the first axis.

Returns

stacked : ndarray

The array formed by stacking the given arrays.

See also:

hstack
Stack arrays in sequence horizontally (column wise).

dstack
Stack arrays in sequence depth wise (along third dimension).

concatenate
Join a sequence of arrays together.

vsplit
Split array into a list of multiple sub-arrays vertically.

Notes

The function is applied to both the _data and the _mask, if any.

Examples

>>> a = np.array([1, 2, 3])
>>> b = np.array([2, 3, 4])
>>> np.vstack((a,b))
array([[1, 2, 3],
       [2, 3, 4]])
>> a = np.array([[1], [2], [3]])
>> b = np.array([[2], [3], [4]])
>> np.vstack((a,b))
array([[1],
       [2],
       [3],
       [2],
       [3],
       [4]])

numpy.ma.vstack (tup) = <numpy.ma.extras._fromnxfunction instance at 0x424453ec>

Stack arrays in sequence vertically (row wise).

Take a sequence of arrays and stack them vertically to make a single array. Rebuild arrays divided by vsplit.

Parameters
   tup : sequence of ndarrays

   Tuple containing arrays to be stacked. The arrays must have the same shape along all but the first axis.

Returns
   stacked : ndarray

   The array formed by stacking the given arrays.

See also:

hstack
   Stack arrays in sequence horizontally (column wise).

dstack
   Stack arrays in sequence depth wise (along third dimension).

concatenate
   Join a sequence of arrays together.

vsplit
   Split array into a list of multiple sub-arrays vertically.

Notes
The function is applied to both the _data and the _mask, if any.

Examples
>>> a = np.array([1, 2, 3])
>>> b = np.array([2, 3, 4])
>>> np.vstack((a,b))
array([[1, 2, 3],
       [2, 3, 4]])

>>> a = np.array([[[1], [2], [3]]])
>>> b = np.array([[[2], [3], [4]]])
>>> np.vstack((a,b))
array([[[1],
       [2],
       [3]],
      [[2],
       [3],
       [4]]])
Joining arrays

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</table>

```
numpy.ma.column_stack(tup) = <numpy.ma.extras._fromnxfunction instance at 0x4244548c>
```

Stack 1-D arrays as columns into a 2-D array.

Take a sequence of 1-D arrays and stack them as columns to make a single 2-D array. 2-D arrays are stacked as-is, just like with `hstack`. 1-D arrays are turned into 2-D columns first.

**Parameters**

- `tup`: sequence of 1-D or 2-D arrays.
  
  Arrays to stack. All of them must have the same first dimension.

**Returns**

- `stacked`: 2-D array
  
  The array formed by stacking the given arrays.

**Notes**

The function is applied to both the `_data` and the `_mask`, if any.

**Examples**

```python
g = np.array((1,2,3))
gg = np.append(g, 0)
gg
```

```
array([1, 2, 3, 0])
```

```
numpy.ma.concatenate(arrays, axis=0)
```

Concatenate a sequence of arrays along the given axis.

**Parameters**

- `arrays`: sequence of array_like
  
  The arrays must have the same shape, except in the dimension corresponding to `axis` (the first, by default).

- `axis`: int, optional
  
  The axis along which the arrays will be joined. Default is 0.
Returns
   result : MaskedArray

   The concatenated array with any masked entries preserved.

See also:

```
numpy.concatenate
```

Equivalent function in the top-level NumPy module.

Examples

```python
>>> import numpy.ma as ma
>>> a = ma.arange(3)
>>> a[1] = ma.masked
>>> b = ma.arange(2, 5)
>>> a
masked_array(data = [0 -- 2],
       mask = [False True False],
      fill_value = 999999)
>>> b
masked_array(data = [2 3 4],
       mask = False,
      fill_value = 999999)
>>> ma.concatenate([a, b])
masked_array(data = [0 -- 2 2 3 4],
       mask = [False True False False False False],
      fill_value = 999999)
```

```
numpy.ma.append(a, b, axis=None)
```

Append values to the end of an array.

New in version 1.9.0.

Parameters

```
arr : array_like

Values are appended to a copy of this array.
```

```
values : array_like

These values are appended to a copy of arr. It must be of the correct shape (the same shape as arr, excluding axis). If axis is not specified, values can be any shape and will be flattened before use.
```

```
axis : int, optional

The axis along which values are appended. If axis is not given, both arr and values are flattened before use.
```

Returns

```
append : MaskedArray

A copy of arr with values appended to axis. Note that append does not occur in-place: a new array is allocated and filled. If axis is None, the result is a flattened array.
```

See also:

```
numpy.append
```

Equivalent function in the top-level NumPy module.
Examples

```python
>>> import numpy.ma as ma
>>> a = ma.masked_values([1, 2, 3], 2)
>>> b = ma.masked_values([[4, 5, 6], [7, 8, 9]], 7)
>>> print(ma.append(a, b))
[1 -- 3 4 5 6 -- 8 9]
```

```
numpy.ma.dstack(tup) = <numpy.ma.extras._fromnxfunction instance at 0x424454ac>
```

Stack arrays in sequence depth wise (along third axis).

Takes a sequence of arrays and stack them along the third axis to make a single array. Rebuilds arrays divided by `dsplit`. This is a simple way to stack 2D arrays (images) into a single 3D array for processing.

**Parameters**

* `tup` : sequence of arrays
  
  Arrays to stack. All of them must have the same shape along all but the third axis.

**Returns**

* `stacked` : ndarray
  
  The array formed by stacking the given arrays.

**See also:**

* `vstack` - Stack along first axis.
  
* `hstack` - Stack along second axis.

* `concatenate` - Join arrays.

* `dsplit` - Split array along third axis.

**Notes**

The function is applied to both the _data and the _mask, if any.

**Examples**

```python
>>> a = np.array((1, 2, 3))
>>> b = np.array((2, 3, 4))
>>> np.dstack((a, b))
array([[1, 2],
       [2, 3],
       [3, 4]])
```

```python
>>> a = np.array([[1], [2], [3]])
>>> b = np.array([[2], [3], [4]])
>>> np.dstack((a, b))
array([[1, 2],
       [2, 3],
       [3, 4]])
```
Stack arrays in sequence horizontally (column wise).
Take a sequence of arrays and stack them horizontally to make a single array. Rebuild arrays divided by hsplit.

Parameters
tup : sequence of ndarrays

All arrays must have the same shape along all but the second axis.

Returns
stacked : ndarray

The array formed by stacking the given arrays.

See also:

vstack
Stack arrays in sequence vertically (row wise).

dstack
Stack arrays in sequence depth wise (along third axis).

concatenate
Join a sequence of arrays together.

hsplit
Split array along second axis.

Notes
The function is applied to both the _data and the _mask, if any.

Examples

```python
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.hstack((a,b))
array([1, 2, 3, 2, 3, 4])
```
Tuple containing arrays to be stacked. The arrays must have the same shape along all but the first axis.

**Returns**

- **stacked**: ndarray
  
  The array formed by stacking the given arrays.

**See also:**

- **hstack**
  
  Stack arrays in sequence horizontally (column wise).

- **dstack**
  
  Stack arrays in sequence depth wise (along third dimension).

- **concatenate**
  
  Join a sequence of arrays together.

- **vsplit**
  
  Split array into a list of multiple sub-arrays vertically.

**Notes**

The function is applied to both the _data and the _mask, if any.

**Examples**

```python
>>> a = np.array([1, 2, 3])
>>> b = np.array([2, 3, 4])
>>> np.vstack((a,b))
array([[1, 2, 3],
       [2, 3, 4]])

>>> a = np.array([[1], [2], [3]])
>>> b = np.array([[2], [3], [4]])
>>> np.vstack((a,b))
array([[1],
       [2],
       [3],
       [2],
       [3],
       [4]])
```

### 3.19.5 Operations on masks

**Creating a mask**

<table>
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<th>Description</th>
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<td>ma.make_mask(ml, copy, shrink, dty)</td>
<td>Create a boolean mask from an array.</td>
</tr>
<tr>
<td>ma.make_mask_none(newshape, dty)</td>
<td>Return a boolean mask of the given shape, filled with False.</td>
</tr>
<tr>
<td>ma.mask_or(m1, m2, copy, shrink)</td>
<td>Combine two masks with the logical_or operator.</td>
</tr>
<tr>
<td>ma.make_mask_descr(dty)</td>
<td>Construct a dtype description list from a given dty.</td>
</tr>
</tbody>
</table>
numpy.ma.make_mask(m, copy=False, shrink=True, dtype=<type 'numpy.bool_'>)

Create a boolean mask from an array.

Return m as a boolean mask, creating a copy if necessary or requested. The function can accept any sequence that is convertible to integers, or nomask. Does not require that contents must be 0s and 1s, values of 0 are interpreted as False, everything else as True.

Parameters

- **m**: array_like
  Potential mask.

- **copy**: bool, optional
  Whether to return a copy of m (True) or m itself (False).

- **shrink**: bool, optional
  Whether to shrink m to nomask if all its values are False.

- **dtype**: dtype, optional
  Data-type of the output mask. By default, the output mask has a dtype of MaskType (bool). If the dtype is flexible, each field has a boolean dtype.

Returns

- **result**: ndarray
  A boolean mask derived from m.

Examples

```python
>>> import numpy.ma as ma
>>> m = [True, False, True, True]
>>> ma.make_mask(m)
array([ True, False, True, True], dtype=bool)
>>> m = [1, 0, 1, 1]
>>> ma.make_mask(m)
array([ True, False, True, True], dtype=bool)
>>> m = [1, 0, 2, -3]
>>> ma.make_mask(m)
array([ True, False, True, True], dtype=bool)
```

Effect of the **shrink** parameter.

```python
>>> m = np.zeros(4)
>>> m
array([ 0., 0., 0., 0.])
>>> ma.make_mask(m)
False
>>> ma.make_mask(m, shrink=False)
array([False, False, False, False], dtype=bool)
```

Using a flexible **dtype**.

```python
>>> m = [1, 0, 1, 1]
>>> n = [0, 1, 0, 0]
>>> arr = []
>>> for man, mouse in zip(m, n):
...     arr.append((man, mouse))
... >>> arr
[(1, 0), (0, 1), (1, 0), (1, 0)]
>>> dtype = np.dtype({'names': ['man', 'mouse'],
```
numpy.ma.make_mask_none(newshape, dtype=None)

Return a boolean mask of the given shape, filled with False.

This function returns a boolean ndarray with all entries False, that can be used in common mask manipulations. If a complex dtype is specified, the type of each field is converted to a boolean type.

Parameters

newshape : tuple
A tuple indicating the shape of the mask.
dtype : {None, dtype}, optional
If None, use a MaskType instance. Otherwise, use a new datatype with the same fields as dtype, converted to boolean types.

Returns

result : ndarray
An ndarray of appropriate shape and dtype, filled with False.

See also:

numpy.ma.make_mask
Create a boolean mask from an array.
numpy.ma.make_mask_descr
Construct a dtype description list from a given dtype.

Examples

>>> import numpy.ma as ma
>>> ma.make_mask_none((3,))
array([[False, False, False],
       [False, False, False],
       [False, False, False]],
      dtype=bool)

Defining a more complex dtype.

>>> dtype = np.dtype([('names': ['foo', 'bar'],
                      'formats': [np.float32, np.int32])
>>> dtype
dtype([('foo', '<f4'), ('bar', '<i4'))
>>> ma.make_mask_none((3,), dtype=dtype)
array([[False, False, False],
       [False, False, False],
       [False, False, False]],
      dtype=[('foo', '|b1'), ('bar', '|b1')])

numpy.ma.mask_or(m1, m2, copy=False, shrink=True)

Combine two masks with the logical_or operator.

The result may be a view on m1 or m2 if the other is nomask (i.e. False).

Parameters

m1, m2 : array_like

3.19. Masked array operations
Input masks.

**copy**: bool, optional

If copy is False and one of the inputs is *nomask*, return a view of the other input mask. Defaults to False.

**shrink**: bool, optional

Whether to shrink the output to *nomask* if all its values are False. Defaults to True.

**Returns**

**mask**: output mask

The result masks values that are masked in either *m1* or *m2*.

**Raises**

**ValueError**

If *m1* and *m2* have different flexible dtypes.

**Examples**

```python
def main():
    m1 = np.ma.make_mask([0, 1, 1, 0])
    m2 = np.ma.make_mask([1, 0, 0, 0])
    np.ma.mask_or(m1, m2)
```

**numpy.ma.make_mask_descr** *(ndtype)*

Construct a dtype description list from a given dtype.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ndtype</td>
<td>The dtype to convert.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Returns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>result</td>
<td>A dtype that looks like <em>ndtype</em>, the type of all fields is boolean.</td>
</tr>
</tbody>
</table>

**Examples**

```python
def main():
    import numpy.ma as ma
    dtype = np.dtype({'names': ['foo', 'bar'], 'formats': [np.float32, np.int]})
    ma.make_mask_descr(dtype)
```

**Accessing a mask**

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>ma.getmask(a)</td>
<td>Return the mask of a masked array, or nomask.</td>
</tr>
<tr>
<td>ma.getmaskarray(arr)</td>
<td>Return the mask of a masked array, or full boolean array of False.</td>
</tr>
<tr>
<td>ma.masked_array.mask</td>
<td>Mask</td>
</tr>
</tbody>
</table>
numpy.ma.getmask(a)

Return the mask of a masked array, or nomask.

Return the mask of a as an ndarray if a is a MaskedArray and the mask is not nomask, else return nomask.

To guarantee a full array of booleans of the same shape as a, use getmaskarray.

Parameters
a : array_like
Input MaskedArray for which the mask is required.

See also:
getdata
Return the data of a masked array as an ndarray.

getmaskarray
Return the mask of a masked array, or full array of False.

Examples

```python
>>> import numpy.ma as ma
>>> a = ma.masked_equal([[1, 2], [3, 4]], 2)
>>> a
masked_array(data =
 [[ 1 --]
 [ 3  4]],
 mask =
 [[False  True]
 [False False]],
 fill_value=999999)
```

```python
g>>> ma.getmask(a)
array([[False, True],
       [False, False]], dtype=bool)
```

Equivalently use the MaskedArray mask attribute.

```python
>>> a.mask
array([[False,  True],
        [False, False]], dtype=bool)
```

Result when mask == nomask

```python
>>> b = ma.masked_array([[1, 2], [3, 4]])
```

```python
>>> b
masked_array(data =
 [[ 1  2]
 [ 3  4]],
 mask =
 False,
 fill_value=999999)
```

```python
>>> ma.getmask(b) == ma.nomask
False
```

```python
>>> ma.getmask(b) == ma.nomask
True
```

```python
True
```

```python
```

numpy.ma.getmaskarray(arr)

Return the mask of a masked array, or full boolean array of False.
Return the mask of `arr` as an ndarray if `arr` is a `MaskedArray` and the mask is not `nomask`, else return a full boolean array of False of the same shape as `arr`.

**Parameters**

- `arr`: array_like
  
  Input `MaskedArray` for which the mask is required.

**See also:**

- `getmask`  
  Return the mask of a masked array, or `nomask`.

- `getdata`  
  Return the data of a masked array as an ndarray.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = ma.masked_equal([[1, 2], [3, 4]], 2)
>>> a
masked_array(data =
 [[1 --]
  [3 4]],
 mask =
 [[False True]
  [False False]],
fill_value=999999)
>>> ma.getmaskarray(a)
array([[False, True],
  [False, False]], dtype=bool)
```

Result when `mask == nomask`

```python
>>> b = ma.masked_array([[1, 2], [3, 4]])
>>> b
masked_array(data =
 [[1 2]
  [3 4]],
 mask =
 False,
fill_value=999999)
>>> ma.getmaskarray(b)
array([[False, False],
  [False, False]], dtype=bool)
```

**Finding masked data**

- `ma.flatnotmasked_contiguous(a)`: Find contiguous unmasked data in a masked array along the given axis.
- `ma.flatnotmasked_edges(a)`: Find the indices of the first and last unmasked values.
- `ma.notmasked_contiguous(a[, axis])`: Find contiguous unmasked data in a masked array along the given axis.
- `ma.notmasked_edges(a[, axis])`: Find the indices of the first and last unmasked values along an axis.
numpy.ma.flatnotmasked_contiguous(a)
Find contiguous unmasked data in a masked array along the given axis.

Parameters

- a : array
  The input array.

Returns

- slice_list : list
  A sorted sequence of slices (start index, end index).

See also:

- flatnotmasked_edges, notmasked_contiguous, notmasked_edges, clump_masked, clump_unmasked

Notes

Only accepts 2-D arrays at most.

Examples

```python
>>> a = np.ma.arange(10)
>>> np.ma.extras.flatnotmasked_contiguous(a)
slice(0, 10, None)

>>> mask = (a < 3) | (a > 8) | (a == 5)
>>> a[mask] = np.ma.masked
>>> np.array(a[~a.mask])
array([3, 4, 6, 7, 8])

>>> np.ma.extras.flatnotmasked_contiguous(a)
[slice(3, 5, None), slice(6, 9, None)]
>>> a[:] = np.ma.masked
>>> np.print np.ma.extras.flatnotmasked_edges(a)
None
```

numpy.ma.flatnotmasked_edges(a)
Find the indices of the first and last unmasked values.

Expects a 1-D MaskedArray, returns None if all values are masked.

Parameters

- arr : array_like
  Input 1-D MaskedArray

Returns

- edges : ndarray or None
  The indices of first and last non-masked value in the array. Returns None if all values are masked.

See also:

- flatnotmasked_contiguous, notmasked_contiguous, notmasked_edges, clump_masked, clump_unmasked

Notes

Only accepts 1-D arrays.
Examples

```python
>>> a = np.ma.arange(10)
>>> flatnotmasked_edges(a)
[0, -1]

>>> mask = (a < 3) | (a > 8) | (a == 5)
>>> a[mask] = np.ma.masked
>>> np.array(a[~a.mask])
array([3, 4, 6, 7, 8])

>>> flatnotmasked_edges(a)
array([3, 8])

>>> a[:] = np.ma.masked
>>> print flatnotmasked_edges(ma)
None
```

numpy.ma.notmasked_contiguous(a, axis=None)
Find contiguous unmasked data in a masked array along the given axis.

Parameters

- `a`: array_like
  The input array.
- `axis`: int, optional
  Axis along which to perform the operation. If None (default), applies to a flattened version of the array.

Returns

- `endpoints`: list
  A list of slices (start and end indexes) of unmasked indexes in the array.

See also:

flatnotmasked_edges, flatnotmasked_contiguous, notmasked_edges, clump_masked, clump_unmasked

Notes

Only accepts 2-D arrays at most.

Examples

```python
>>> a = np.arange(9).reshape((3, 3))
>>> mask = np.zeros_like(a)
>>> mask[1:, 1:] = 1
>>> ma = np.ma.array(a, mask=mask)
>>> np.array(ma[~ma.mask])
array([0, 1, 2, 3, 6])

>>> np.ma.extras.notmasked_contiguous(ma)
[slice(0, 4, None), slice(6, 7, None)]
```

numpy.ma.notmasked_edges(a, axis=None)
Find the indices of the first and last unmasked values along an axis.

If all values are masked, return None. Otherwise, return a list of two tuples, corresponding to the indices of the first and last unmasked values respectively.
Parameters

- **a**: array_like
  
  The input array.

- **axis**: int, optional
  
  Axis along which to perform the operation. If None (default), applies to a flattened version of the array.

Returns

- **edges**: ndarray or list
  
  An array of start and end indexes if there are any masked data in the array. If there are no masked data in the array, **edges** is a list of the first and last index.

See also:

- `flatnotmasked_contiguous`
- `flatnotmasked_edges`
- `notmasked_contiguous`
- `clump_masked`
- `clump_unmasked`

Examples

```python
g = np.array([0, 1, 2, 3, 6])
np.ma.extras.notmasked_edges(g)
```

Modifying a mask

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<td><code>ma.mask_cols</code></td>
<td>Mask columns of a 2D array that contain masked values.</td>
</tr>
<tr>
<td><code>ma.mask_or</code></td>
<td>Combine two masks with the <code>logical_or</code> operator.</td>
</tr>
<tr>
<td><code>ma.mask_rowcols</code></td>
<td>Mask rows and/or columns of a 2D array that contain masked values.</td>
</tr>
<tr>
<td><code>ma.mask_rows</code></td>
<td>Mask rows of a 2D array that contain masked values.</td>
</tr>
<tr>
<td><code>ma.harden_mask</code></td>
<td>Force the mask to hard.</td>
</tr>
<tr>
<td><code>ma.soften_mask</code></td>
<td>Force the mask to soft.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.harden_mask</code></td>
<td>Force the mask to hard.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.soften_mask</code></td>
<td>Force the mask to soft.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.shrink_mask</code></td>
<td>Reduce a mask to nomask when possible.</td>
</tr>
<tr>
<td><code>ma.MaskedArray.unshare_mask</code></td>
<td>Copy the mask and set the sharedmask flag to False.</td>
</tr>
</tbody>
</table>

```python
numpy.ma.mask_cols(a, axis=None)
```

This function is a shortcut to `mask_rowcols` with `axis` equal to 1.

See also:

- `mask_rowcols`
  
  Mask rows and/or columns of a 2D array.
masked_where

Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.zeros((3, 3), dtype=np.int)
>>> a[1, 1] = 1
>>> a
array([[0, 0, 0],
       [0, 1, 0],
       [0, 0, 0]])
>>> a = ma.masked_equal(a, 1)
>>> a
masked_array(data =
       [[0 0 0],
        [0 -- 0],
        [0 0 0]],
      mask =
       [[False False False],
        [False  True False],
        [False False False]],
    fill_value=999999)
>>> ma.mask_cols(a)
masked_array(data =
       [[0 -- 0],
        [0 -- 0],
        [0 -- 0]],
      mask =
       [[False  True False],
        [False  True False],
        [False  True False]],
    fill_value=999999)
```

```python
numpy.ma.mask_or(m1, m2, copy=False, shrink=True)

Combine two masks with the logical_or operator. The result may be a view on m1 or m2 if the other is nomask (i.e. False).

Parameters

m1, m2 : array_like
    Input masks.

copy : bool, optional
    If copy is False and one of the inputs is nomask, return a view of the other input mask. Defaults to False.

shrink : bool, optional
    Whether to shrink the output to nomask if all its values are False. Defaults to True.

Returns

mask : output mask
    The result masks values that are masked in either m1 or m2.

Raises

ValueError
    If m1 and m2 have different flexible dtypes.
```
Examples

```python
>>> m1 = np.ma.make_mask([0, 1, 1, 0])
>>> m2 = np.ma.make_mask([1, 0, 0, 0])
>>> np.ma.mask_or(m1, m2)
array([ True,  True,  True, False], dtype=bool)
```

**numpy.ma.mask_rowcols** *(a, axis=None)*

Mask rows and/or columns of a 2D array that contain masked values.

Mask whole rows and/or columns of a 2D array that contain masked values. The masking behavior is selected using the `axis` parameter.

- If `axis` is None, rows and columns are masked.
- If `axis` is 0, only rows are masked.
- If `axis` is 1 or -1, only columns are masked.

**Parameters**

- `a` : array_like, MaskedArray
  The array to mask. If not a MaskedArray instance (or if no array elements are masked). The result is a MaskedArray with `mask` set to `nomask` (False). Must be a 2D array.

- `axis` : int, optional
  Axis along which to perform the operation. If None, applies to a flattened version of the array.

**Returns**

- `a` : MaskedArray
  A modified version of the input array, masked depending on the value of the `axis` parameter.

**Raises**

- `NotImplementedError`
  If input array `a` is not 2D.

**See also:**

- **mask_rows**
  Mask rows of a 2D array that contain masked values.

- **mask_cols**
  Mask cols of a 2D array that contain masked values.

- **masked_where**
  Mask where a condition is met.

**Notes**

The input array's mask is modified by this function.

**Examples**

```python
>>> import numpy.ma as ma
>>> a = np.zeros((3, 3), dtype=np.int)
>>> a[1, 1] = 1
>>> a
```

3.19. Masked array operations
array([[0, 0, 0],
       [0, 1, 0],
       [0, 0, 0]])
>>> a = ma.masked_equal(a, 1)
>>> a
masked_array(data =
[[0 0 0]
[0 -- 0]
[0 0 0]],
mask =
[[False False False]
[False True False]
[False False False]],
fill_value=999999)
>>> ma.mask_rowcols(a)
masked_array(data =
[[0 -- 0]
[-- -- --]
[0 -- 0]],
mask =
[[False True False]
[ True True True]
[False True False]],
fill_value=999999)

numpy.ma.mask_rows(a, axis=None)
Mask rows of a 2D array that contain masked values.
This function is a shortcut to `mask_rowcols` with `axis` equal to 0.

See also:

- `mask_rowcols`  
  Mask rows and/or columns of a 2D array.
- `masked_where`  
  Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.zeros((3, 3), dtype=np.int)
>>> a[1, 1] = 1
>>> a
array([[0, 0, 0],
       [0, 1, 0],
       [0, 0, 0]])
>>> a = ma.masked_equal(a, 1)
>>> a
masked_array(data =
[[0 0 0]
[0 -- 0]
[0 0 0]],
mask =
[[False False False]
[False True False]
[False False False]],
fill_value=999999)
>>> ma.mask_rows(a)
```
```python
masked_array(data =
[[0 0 0]
[-- -- --]
[0 0 0]],
  mask =
[[False False False]
[ True  True  True]
[False False False]],
  fill_value=999999)
```
>>> x.shrink_mask()
False

MaskedArray.unshare_mask()
Copy the mask and set the sharedmask flag to False.

Whether the mask is shared between masked arrays can be seen from the sharedmask property. unshare_mask ensures the mask is not shared. A copy of the mask is only made if it was shared.

See also:
sharedmask

3.19.6 Conversion operations

> to a masked array

numpy.ma.asarray(a[, dtype, order])
Convert the input to a masked array of the given data-type. No copy is performed if the input is already an ndarray. If a is a subclass of MaskedArray, a base class MaskedArray is returned.

Parameters

a : array_like
Input data, in any form that can be converted to a masked array. This includes lists, lists of tuples, tuples of tuples, tuples of lists, ndarrays and masked arrays.

dtype : dtype, optional
By default, the data-type is inferred from the input data.

order : {'C', 'F'}, optional
Whether to use row-major ('C') or column-major ('FORTRAN') memory representation. Default is 'C'.
Returns

**out :** MaskedArray

Masked array interpretation of `a`.

See also:

`asanyarray`

Similar to `asarray`, but conserves subclasses.

Examples

```python
>>> x = np.arange(10.).reshape(2, 5)
>>> x
array([[ 0.,  1.,  2.,  3.,  4.],
       [ 5.,  6.,  7.,  8.,  9.]])
>>> np.ma.asarray(x)
masked_array(data =
 [[ 0.  1.  2.  3.  4.]
  [ 5.  6.  7.  8.  9.]],
mask = False,
fill_value = 1e+20)
>>> type(np.ma.asarray(x))
<class 'numpy.ma.core.MaskedArray'>
```

**numpy.ma.asanyarray**(a, dtype=None)

Convert the input to a masked array, conserving subclasses.

If `a` is a subclass of `MaskedArray`, its class is conserved. No copy is performed if the input is already an `ndarray`.

Parameters

- **a : array_like**
  
  Input data, in any form that can be converted to an array.

- **dtype :** dtype, optional
  
  By default, the data-type is inferred from the input data.

- **order :** {'C', 'F'}, optional
  
  Whether to use row-major ('C') or column-major ('FORTRAN') memory representation. Default is 'C'.

Returns

**out :** MaskedArray

MaskedArray interpretation of `a`.

See also:

`asarray`

Similar to `asanyarray`, but does not conserve subclass.

Examples

```python
>>> x = np.arange(10.).reshape(2, 5)
>>> x
array([[ 0.,  1.,  2.,  3.,  4.],
       [ 5.,  6.,  7.,  8.,  9.]])
```
```python
>>> np.ma.asanyarray(x)
masked_array(data =
[[ 0. 1. 2. 3. 4.]
[ 5. 6. 7. 8. 9.]],
    mask =
False,
    fill_value = 1e+20)
>>> type(np.ma.asanyarray(x))
<class 'numpy.ma.core.MaskedArray'>
```

```python
def numpy.ma.fix_invalid(a, mask=False, copy=True, fill_value=None):
    Return input with invalid data masked and replaced by a fill value.
    Invalid data means values of nan, inf, etc.

    Parameters:
    a : array_like
        Input array, a (subclass of) ndarray.
    copy : bool, optional
        Whether to use a copy of a (True) or to fix a in place (False). Default is True.
    fill_value : scalar, optional
        Value used for fixing invalid data. Default is None, in which case the a.fill_value
        is used.

    Returns:
    b : MaskedArray
        The input array with invalid entries fixed.

    Notes
    A copy is performed by default.

    Examples
    >>> x = np.ma.array([1., -1, np.nan, np.inf], mask=[1] + [0]*3)
    >>> x
    masked_array(data =[--, -1.0, nan, inf],
                mask = [ True, False, False, False],
                fill_value = 1e+20)
    >>> np.ma.fix_invalid(x)
    masked_array(data =[--, -1.0, --, --],
                mask = [ True, False, True, True],
                fill_value = 1e+20)
    >>> fixed = np.ma.fix_invalid(x)
    >>> fixed.data
    array([1.00000000e-00, -1.00000000e+00, 1.00000000e+20, 1.00000000e+20])
    >>> x.data
    array([1., -1., NaN, Inf])
```

```python
def numpy.ma.masked_equal(x, value, copy=True):
    Mask an array where equal to a given value.

    This function is a shortcut to masked_where, with condition = (x == value). For floating point arrays, consider using masked_values(x, value).
```
See also:

masked_where
Mask where a condition is met.

masked_values
Mask using floating point equality.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_equal(a, 2)
mixed_array(data = [0 1 -- 3],
    mask = [False False True False],
    fill_value=999999)
```

numpy.ma.masked_greater(x, value, copy=True)
Mask an array where greater than a given value.

This function is a shortcut to masked_where, with condition = (x > value).

See also:

masked_where
Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_greater(a, 2)
mixed_array(data = [0 1 2 --],
    mask = [False False False True],
    fill_value=999999)
```

numpy.ma.masked_greater_equal(x, value, copy=True)
Mask an array where greater than or equal to a given value.

This function is a shortcut to masked_where, with condition = (x >= value).

See also:

masked_where
Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_greater_equal(a, 2)
mixed_array(data = [0 1 -- --],
    mask = [False False True True],
    fill_value=999999)
```
numpy.ma.masked_inside(x, v1, v2, copy=True)
Mask an array inside a given interval.

Shortcut to masked_where, where condition is True for x inside the interval [v1,v2] (v1 <= x <= v2). The boundaries v1 and v2 can be given in either order.

See also:

masked_where
Mask where a condition is met.

Notes
The array x is prefilled with its filling value.

Examples

```python
>>> import numpy.ma as ma
>>> x = [0.31, 1.2, 0.01, 0.2, -0.4, -1.1]
>>> ma.masked_inside(x, -0.3, 0.3)
masked_array(data = [0.31 1.2 -- -- -0.4 -1.1],
              mask = [False False True True False False],
              fill_value=1e+20)
```

The order of v1 and v2 doesn’t matter.

```python
>>> ma.masked_inside(x, 0.3, -0.3)
masked_array(data = [0.31 1.2 -- -- -0.4 -1.1],
              mask = [False False True True False False],
              fill_value=1e+20)
```

numpy.ma.masked_invalid(a, copy=True)
Mask an array where invalid values occur (NaNs or infs).

This function is a shortcut to masked_where, with condition = ~np.isfinite(a)). Any pre-existing mask is conserved. Only applies to arrays with a dtype where NaNs or infs make sense (i.e. floating point types), but accepts any array_like object.

See also:

masked_where
Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(5, dtype=np.float)
>>> a[2] = np.NaN
>>> a[3] = np.PINF
>>> a
array([ 0., 1., NaN, Inf, 4.])
>>> ma.masked_invalid(a)
masked_array(data = [0.0 1.0 -- -- 4.0],
              mask = [False False True True False],
              fill_value=1e+20)
```

numpy.ma.masked_less(x, value, copy=True)
Mask an array where less than a given value.

This function is a shortcut to masked_where, with condition = (x < value).
See also:

masked_where
Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_less(a, 2)
masked_array(data = [-- -- 2 3],
             mask = [ True True False False],
             fill_value=999999)
```

numpy.ma.masked_less_equal (x, value, copy=True)
Mask an array where less than or equal to a given value.
This function is a shortcut to masked_where, with condition = (x <= value).

See also:

masked_where
Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_less_equal(a, 2)
masked_array(data = [-- -- -- 3],
             mask = [ True True True False],
             fill_value=999999)
```

numpy.ma.masked_not_equal (x, value, copy=True)
Mask an array where not equal to a given value.
This function is a shortcut to masked_where, with condition = (x != value).

See also:

masked_where
Mask where a condition is met.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_not_equal(a, 2)
masked_array(data = [-- -- 2 --],
             mask = [ True True False True],
             fill_value=999999)
```
numpy.ma.masked_object(x, value=, copy=True, shrink=True)

Mask the array x where the data are exactly equal to value.

This function is similar to masked_values, but only suitable for object arrays: for floating point, use masked_values instead.

Parameters
- x : array_like
  Array to mask
- value : object
  Comparison value
- copy : {True, False}, optional
  Whether to return a copy of x.
- shrink : {True, False}, optional
  Whether to collapse a mask full of False to nomask

Returns
- result : MaskedArray
  The result of masking x where equal to value.

See also:
- masked_where
  Mask where a condition is met.
- masked_equal
  Mask where equal to a given value (integers).
- masked_values
  Mask using floating point equality.

Examples
>>> import numpy.ma as ma
>>> food = np.array(['green_eggs', 'ham'], dtype=object)
>>> # don't eat spoiled food
>>> eat = ma.masked_object(food, 'green_eggs')
>>> print eat
[-- ham]
>>> # plain ol' ham is boring
>>> fresh_food = np.array(['cheese', 'ham', 'pineapple'], dtype=object)
>>> eat = ma.masked_object(fresh_food, 'green_eggs')
>>> print eat
[cheese ham pineapple]

Note that mask is set to nomask if possible.

>>> eat
masked_array(data = [cheese ham pineapple],
              mask = False,
              fill_value=?)

numpy.ma.masked_outside(x, vl, v2=, copy=True)

Mask an array outside a given interval.
Shortcut to `masked_where`, where condition is True for \(x\) outside the interval \([v1,v2]\) \((x < v1)(x > v2)\). The boundaries \(v1\) and \(v2\) can be given in either order.

See also:

`masked_where`
Mask where a condition is met.

Notes
The array \(x\) is prefilled with its filling value.

Examples
```python
gt = (x < 1.2) & (x > -0.3)
ma.masked_where(gt, x)
```

The order of \(v1\) and \(v2\) doesn’t matter.

```python
gt = (x > 1.2) & (x < -0.3)
ma.masked_where(gt, x)
```

numpy.ma`masked_values` \((x, value, rtol=1e-05, atol=1e-08, copy=True, shrink=True)\)
Mask using floating point equality.

Return a MaskedArray, masked where the data in array \(x\) are approximately equal to \(value\), i.e. where the following condition is True

\[(\text{abs}(x - \text{value}) \leq \text{atol} + \text{rtol} \times \text{abs(value)})\]

The fill_value is set to \(value\) and the mask is set to nomask if possible. For integers, consider using `masked_equal`.

Parameters
- \(x\) : array_like
  Array to mask.
- \(value\) : float
  Masking value.
- \(rtol\) : float, optional
  Tolerance parameter.
- \(atol\) : float, optional
  Tolerance parameter (1e-8).
- \(copy\) : bool, optional
  Whether to return a copy of \(x\).
- \(shrink\) : bool, optional
  Whether to collapse a mask full of False to nomask.
Returns

result : MaskedArray

The result of masking x where approximately equal to value.

See also:

masked_where
Mask where a condition is met.

masked_equal
Mask where equal to a given value (integers).

Examples

```python
>>> import numpy.ma as ma
>>> x = np.array([1, 1.1, 2, 1.1, 3])
>>> ma.masked_values(x, 1.1)
masked_array(data = [1.0 -- 2.0 -- 3.0],
              mask = [False True False True False],
              fill_value=1.1)
```

Note that mask is set to_nomask if possible.

```python
>>> ma.masked_values(x, 1.5)
mced_array(data = [ 1. 1.1 2. 1.1 3. ],
              mask = False,
              fill_value=1.5)
```

For integers, the fill value will be different in general to the result of masked_equal.

```python
>>> x = np.arange(5)
>>> x
array([0, 1, 2, 3, 4])
>>> ma.masked_values(x, 2)
mced_array(data = [0 1 -- 3 4],
              mask = [False False True False False],
              fill_value=2)
>>> ma.masked_equal(x, 2)
mced_array(data = [0 1 -- 3 4],
              mask = [False False True False False],
              fill_value=999999)
```

numpy.ma.masked_where(condition, a, copy=True)

Mask an array where a condition is met.

Return a as an array masked where condition is True. Any masked values of a or condition are also masked in the output.

Parameters

- condition : array_like
  Masking condition. When condition tests floating point values for equality, consider using masked_values instead.

- a : array_like
  Array to mask.

- copy : bool
If True (default) make a copy of \( a \) in the result. If False modify \( a \) in place and return a view.

**Returns**
- **result**: MaskedArray
  The result of masking \( a \) where condition is True.

**See also:**
- **masked_values**: Mask using floating point equality.
- **masked_equal**: Mask where equal to a given value.
- **masked_not_equal**: Mask where *not* equal to a given value.
- **masked_less_equal**: Mask where less than or equal to a given value.
- **masked_greater_equal**: Mask where greater than or equal to a given value.
- **masked_less**: Mask where less than a given value.
- **masked_greater**: Mask where greater than a given value.
- **masked_inside**: Mask inside a given interval.
- **masked_outside**: Mask outside a given interval.
- **masked_invalid**: Mask invalid values (NaNs or infs).

**Examples**

```python
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_where(a <= 2, a)
masked_array(data = [-- -- -- 3],
             mask = [ True True True False],
             fill_value=999999)
```

Mask array \( b \) conditional on \( a \).

```python
>>> b = ['a', 'b', 'c', 'd']
>>> ma.masked_where(a == 2, b)
masked_array(data = [a b -- d],
             mask = [False False True False],
             fill_value=N/A)
```

Effect of the **copy** argument.
```python
>>> c = ma.masked_where(a <= 2, a)
>>> c
masked_array(data = [-- -- -- 3],
             mask = [ True  True  True False],
             fill_value=999999)
>>> c[0] = 99
>>> c
masked_array(data = [99 -- -- 3],
             mask = [False  True  True False],
             fill_value=999999)

```a```
array([0, 1, 2, 3])
```c = ma.masked_where(a <= 2, a, copy=False)
>>> c
masked_array(data = [99 -- -- 3],
             mask = [False  True  True False],
             fill_value=999999)
```a```
array([99, 1, 2, 3])

When `condition` or `a` contain masked values.

```a = np.arange(4)
>>> a = ma.masked_where(a == 2, a)
>>> a
masked_array(data = [0 1 -- 3],
             mask = [False False  True False],
             fill_value=999999)
```b``` = np.arange(4)
```b = ma.masked_where(b == 0, b)
>>> b
masked_array(data = [-- 1 2 3],
             mask = [ True False  True False],
             fill_value=999999)
>>> ma.masked_where(a == 3, b)
masked_array(data = [-- 1 -- --],
             mask = [ True False  True  True],
             fill_value=999999)

> to a ndarray

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<td>Return a copy of self, with masked values filled with a given value.</td>
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`numpy.ma.compress_cols(a)`

Suppress whole columns of a 2-D array that contain masked values.

This is equivalent to `np.maextras.compress_rowcols(a, 1)`, see `extras.compress_rowcols` for details.
See also:

extras.compress_rowcols

numpy.ma.compress_rowcols(x, axis=None)

Suppress the rows and/or columns of a 2-D array that contain masked values.

The suppression behavior is selected with the axis parameter.

• If axis is None, both rows and columns are suppressed.
• If axis is 0, only rows are suppressed.
• If axis is 1 or -1, only columns are suppressed.

Parameters

axis : int, optional

Axis along which to perform the operation. Default is None.

Returns

compressed_array : ndarray

The compressed array.

Examples

>>> x = np.ma.array(np.arange(9).reshape(3, 3), mask=[[1, 0, 0],
... [1, 0, 0],
... [0, 0, 0]])

>>> x
masked_array(data =
[[- -- 1 2]
[-- 4 5]
[6 7 8]],
mask =
[ [ True False False]
[ True False False]
[False False False]],
fill_value = 999999)

>>> np.maextras.compress_rowcols(x)
array([[7, 8]])

>>> np.maextras.compress_rowcols(x, 0)
array([[6, 7, 8]])

>>> np.maextras.compress_rowcols(x, 1)
array([[1, 2],
[4, 5],
[7, 8]])

numpy.ma.compress_rows(a)

Suppress whole rows of a 2-D array that contain masked values.

This is equivalent to np.maextras.compress_rowcols(a, 0). see extras.compress_rowcols for details.

See also:

extras.compress_rowcols

numpy.ma.compressed(x)

Return all the non-masked data as a 1-D array.
This function is equivalent to calling the “compressed” method of a `MaskedArray`, see `MaskedArray.compressed` for details.

See also:

```
MaskedArray.compressed
```
Equivalent method.

```
numpy.ma.filled(a, fill_value=None)
```
Return input as an array with masked data replaced by a fill value.

If `a` is not a `MaskedArray`, `a` itself is returned. If `a` is a `MaskedArray` and `fill_value` is None, `fill_value` is set to `a.fill_value`.

Parameters

- `a` : MaskedArray or array_like
  An input object.

- `fill_value` : scalar, optional
  Filling value. Default is None.

Returns

- `a` : ndarray
  The filled array.

See also:

```
compressed
```
Examples

```python
>>> x = np.ma.array(np.arange(9).reshape(3, 3), mask=[[1, 0, 0],
... [1, 0, 0],
... [0, 0, 0]])
```
```python
>>> x.filled()
array([[999999,  1,  2],
       [999999,  4,  5],
       [ 6,  7,  8]])
```

```
MaskedArray.compressed()
```
Return all the non-masked data as a 1-D array.

Returns

- `data` : ndarray
  A new `ndarray` holding the non-masked data is returned.

Notes

The result is not a `MaskedArray`!

Examples

```python
>>> x = np.ma.array(np.arange(5), mask=[0]*2 + [1]*3)
>>> x.compressed()
array([0, 1])
>>> type(x.compressed())
<type 'numpy.ndarray'>
```
MaskedArray.\texttt{filled}(\texttt{fill_value}=\texttt{None})

Return a copy of self, with masked values filled with a given value.

\begin{itemize}
  \item \textbf{Parameters}
    \begin{itemize}
      \item \texttt{fill_value} : scalar, optional
        
        The value to use for invalid entries (None by default). If None, the \texttt{fill_value}
        attribute of the array is used instead.
    \end{itemize}
  \end{itemize}

\begin{itemize}
  \item \textbf{Returns}
    \begin{itemize}
      \item \texttt{filled\_array} : ndarray
        
        A copy of \texttt{self} with invalid entries replaced by \texttt{fill\_value} (be it the function argument
        or the attribute of \texttt{self}).
    \end{itemize}
  \end{itemize}

\begin{itemize}
  \item \textbf{Notes}
    
    The result is not a MaskedArray!
  \end{itemize}

\begin{itemize}
  \item \textbf{Examples}
    
    >>> x = np.ma.array([1, 2, 3, 4, 5], mask=[0, 0, 1, 0, 1], fill_value=-999)
    >>> x.filled()
    array([1, 2, -999, 4, -999])
    >>> type(x.filled())
    <type 'numpy.ndarray'>

    Subclassing is preserved. This means that if the data part of the masked array is a matrix, \texttt{filled} returns a
    matrix:
    
    >>> x = np.ma.array(np.matrix([[1, 2], [3, 4]]), mask=[[0, 1], [1, 0]])
    >>> x.filled()
    matrix([[1, 999999],
            [999999, 4]])

  \end{itemize}

\begin{itemize}
  \item \texttt{ma.MaskedArray.tofile}(\texttt{fid}, \texttt{sep=\texttt{''}}, \texttt{format=\texttt{%s}})
    \hspace{1cm} Save a masked array to a file in binary format.
  \item \texttt{ma.MaskedArray.tolist}([\texttt{fill\_value}])
    \hspace{1cm} Return the data portion of the masked array as a hierarchical Python list.
  \item \texttt{ma.MaskedArray.torecords}()
    \hspace{1cm} Transforms a masked array into a flexible-type array.
  \item \texttt{ma.MaskedArray.tobytes}([\texttt{fill\_value}, \texttt{order}])
    \hspace{1cm} Return the array data as a string containing the raw bytes in the array.
\end{itemize}

\begin{itemize}
  \item MaskedArray.\texttt{tofile}(\texttt{fid}, \texttt{sep=\texttt{''}}, \texttt{format=\texttt{%s}})
    \hspace{1cm} Save a masked array to a file in binary format.

    \begin{tabular}{l}
      \textbf{Warning}: This function is not implemented yet.
    \end{tabular}

  \item \textbf{Raises}
    \begin{itemize}
      \item \texttt{NotImplementedError}
        \hspace{1cm} When \texttt{tofile} is called.
    \end{itemize}

\end{itemize}

MaskedArray.\texttt{tolist}(\texttt{fill\_value}=\texttt{None})

Return the data portion of the masked array as a hierarchical Python list.

Data items are converted to the nearest compatible Python type. Masked values are converted to \texttt{fill\_value}. If \texttt{fill\_value} is None, the corresponding entries in the output list will be None.
Parameters

fill_value : scalar, optional

The value to use for invalid entries. Default is None.

Returns

result : list

The Python list representation of the masked array.

Examples

>>> x = np.ma.array([[1,2,3], [4,5,6], [7,8,9]], mask=[0] + [1,0]*3)

>>> x.tolist()
[[1, None, 3], [None, 5, None], [7, None, 9]]

>>> x.tolist(-999)
[[1, -999, 3], [-999, 5, -999], [7, -999, 9]]

MaskedArray.torecords()

Transforms a masked array into a flexible-type array.

The flexible type array that is returned will have two fields:

• the _data field stores the _data part of the array.
• the _mask field stores the _mask part of the array.

Parameters

None

Returns

record : ndarray

A new flexible-type ndarray with two fields: the first element containing a value, the second element containing the corresponding mask boolean. The returned record shape matches self.shape.

Notes

A side-effect of transforming a masked array into a flexible ndarray is that meta information (fill_value, ...) will be lost.

Examples

>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*3)

>>> print x
[[1 -- 3]
[-- 5 --]
[7 -- 9]]

>>> print x.toflex()
[[[1, False) (2, True) (3, False)]
[[4, True) (5, False) (6, True)]
[[7, False) (8, True) (9, False)]

MaskedArray.tobytes(fill_value=None, order='C')

Return the array data as a string containing the raw bytes in the array.

The array is filled with a fill value before the string conversion.

New in version 1.9.0.
Parameters

fill_value : scalar, optional

Value used to fill in the masked values. Default is None, in which case
MaskedArray.fill_value is used.

order : {'C', 'F', 'A'}, optional

Order of the data item in the copy. Default is 'C'.

- 'C' – C order (row major).
- 'F' – Fortran order (column major).
- 'A' – Any, current order of array.
- None – Same as 'A'.

See also:

ndarray.tobytes, tolist, tofile

Notes

As for ndarray.tobytes, information about the shape, dtype, etc., but also about fill_value, will be lost.

Examples

>>> x = np.ma.array(np.array([[1, 2], [3, 4]]), mask=[[0, 1], [1, 0]])
>>> x.tobytes()
'\x01\x00\x00\x00?B\x0f\x00?B\x0f\x00\x04\x00\x00\x00'

Pickling and unpickling

ma.dump(a, F) Pickle a masked array to a file.
ma.dumps(a) Return a string corresponding to the pickling of a masked array.
ma.load(F) Wrapper around cPickle.load which accepts either a file-like object or a filename.
ma.loads(str) Load a pickle from the current string.

numpy.ma.dump(a, F)

Pickle a masked array to a file.

This is a wrapper around cPickle.dump.

Parameters

a : MaskedArray

The array to be pickled.

F : str or file-like object

The file to pickle a to. If a string, the full path to the file.

numpy.ma.dumps(a)

Return a string corresponding to the pickling of a masked array.

This is a wrapper around cPickle.dumps.

Parameters

a : MaskedArray

The array for which the string representation of the pickle is returned.
numpy.ma.load($F$)

Wrapper around cPickle.load which accepts either a file-like object or a filename.

**Parameters**

$F$ : str or file

The file or file name to load.

**See also:**

dump

Pickle an array.

**Notes**

This is different from numpy.load, which does not use cPickle but loads the NumPy binary .npy format.

numpy.ma.loads($strg$)

Load a pickle from the current string.

The result of cPickle.loads($strg$) is returned.

**Parameters**

$strg$ : str

The string to load.

**See also:**

dumps

Return a string corresponding to the pickling of a masked array.

**Filling a masked array**

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<td>Return the common filling value of two masked arrays, if any.</td>
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<td>ma.default_fill_value(obj)</td>
<td>Return the default fill value for the argument object.</td>
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<td>Filling value.</td>
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</table>

numpy.ma.common_fill_value(a, b)

Return the common filling value of two masked arrays, if any.

If $a.fill_value == b.fill_value$, return the fill value, otherwise return None.

**Parameters**

$a$, $b$ : MaskedArray

The masked arrays for which to compare fill values.

**Returns**

$fill_value$ : scalar or None

The common fill value, or None.
Examples

```python
>>> x = np.ma.array([0, 1., fill_value=3)
>>> y = np.ma.array([0, 1., fill_value=3)
>>> np.ma.common_fill_value(x, y)
3.0
```

`numpy.ma.default_fill_value(obj)`

Return the default fill value for the argument object.

The default filling value depends on the datatype of the input array or the type of the input scalar:

<table>
<thead>
<tr>
<th>datatype</th>
<th>default</th>
</tr>
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<tbody>
<tr>
<td>bool</td>
<td>True</td>
</tr>
<tr>
<td>int</td>
<td>999999</td>
</tr>
<tr>
<td>float</td>
<td>1e20</td>
</tr>
<tr>
<td>complex</td>
<td>1e20+0j</td>
</tr>
<tr>
<td>object</td>
<td>‘?’</td>
</tr>
<tr>
<td>string</td>
<td>‘N/A’</td>
</tr>
</tbody>
</table>

**Parameters**

- **obj**: ndarray, dtype or scalar

  The array data-type or scalar for which the default fill value is returned.

**Returns**

- **fill_value**: scalar

  The default fill value.

Examples

```python
>>> np.ma.default_fill_value(1)
999999
>>> np.ma.default_fill_value(np.array([1.1, 2., np.pi]))
1e+20
>>> np.ma.default_fill_value(np.dtype(complex))
(1e+20+0j)
```

`numpy.ma.maximum_fill_value(obj)`

Return the minimum value that can be represented by the dtype of an object.

This function is useful for calculating a fill value suitable for taking the maximum of an array with a given dtype.

**Parameters**

- **obj**: ndarray, dtype

  An object that can be queried for it’s numeric type.

**Returns**

- **val**: scalar

  The minimum representable value.

**Raises**

- **TypeError**

  If `obj` isn’t a suitable numeric type.

See also:
**minimum_fill_value**

The inverse function.

**set_fill_value**

Set the filling value of a masked array.

**MaskedArray.fill_value**

Return current fill value.

### Examples

```python
gt>> import numpy.ma as ma
gt>> a = np.int8()
gt>> ma.maximum_fill_value(a)
   -128
gt>> a = np.int32()
gt>> ma.maximum_fill_value(a)
   -2147483648
```

An array of numeric data can also be passed.

```python
gt>> a = np.array([1, 2, 3], dtype=np.int8)
gt>> ma.maximum_fill_value(a)
   -128
gt>> a = np.array([1, 2, 3], dtype=np.float32)
gt>> ma.maximum_fill_value(a)
   -inf
```

```python
numpy.ma.maximum_fill_value(obj)
```

Return the minimum value that can be represented by the dtype of an object.

This function is useful for calculating a fill value suitable for taking the maximum of an array with a given dtype.

**Parameters**

- `obj` : {ndarray, dtype}
  
  An object that can be queried for it’s numeric type.

**Returns**

- `val` : scalar
  
  The minimum representable value.

**Raises**

- `TypeError`
  
  If `obj` isn’t a suitable numeric type.

**See also**

- `minimum_fill_value`
  
  The inverse function.

- `set_fill_value`
  
  Set the filling value of a masked array.

- `MaskedArray.fill_value`
  
  Return current fill value.
Examples

```python
>>> import numpy.ma as ma
>>> a = np.int8()
>>> ma.maximum_fill_value(a)
-128
>>> a = np.int32()
>>> ma.maximum_fill_value(a)
-2147483648

An array of numeric data can also be passed.

```python
>>> a = np.array([1, 2, 3], dtype=np.int8)
>>> ma.maximum_fill_value(a)
-128
>>> a = np.array([1, 2, 3], dtype=np.float32)
>>> ma.maximum_fill_value(a)
-inf
``` 

```
numpy.ma.set_fill_value(a, fill_value)
```

Set the filling value of a, if a is a masked array.

This function changes the fill value of the masked array a in place. If a is not a masked array, the function returns silently, without doing anything.

Parameters

- **a**: array_like
  Input array.

- **fill_value**: dtype
  Filling value. A consistency test is performed to make sure the value is compatible with the dtype of a.

Returns

- None
  Nothing returned by this function.

See also:

- `maximum_fill_value`
  Return the default fill value for a dtype.

- `MaskedArray.fill_value`
  Return current fill value.

- `MaskedArray.set_fill_value`
  Equivalent method.

Examples

```python
>>> import numpy.ma as ma
>>> a = np.arange(5)
>>> a
array([0, 1, 2, 3, 4])
>>> a = ma.masked_where(a < 3, a)
>>> a
masked_array(data = [--- -- -- 3 4],
             mask = [ True True True False False],
             fill_value=999999)
```
>>> ma.set_fill_value(a, -999)
>>> a
masked_array(data = [-- -- -- 3 4],
    mask = [ True  True  True False False],
    fill_value=-999)

Nothing happens if `a` is not a masked array.

>>> a = range(5)
>>> a
[0, 1, 2, 3, 4]
>>> ma.set_fill_value(a, 100)
>>> a
[0, 1, 2, 3, 4]

MaskedArray.get_fill_value()
    Return the filling value of the masked array.

    Returns
        fill_value : scalar
            The filling value.

Examples

>>> for dt in [np.int32, np.int64, np.float64, np.complex128]:
...    np.ma.array([0, 1], dtype=dt).get_fill_value()
...
999999
999999
1e+20
(1e+20+0j)

>>> x = np.ma.array([0, 1.], fill_value=-np.inf)
>>> x.get_fill_value()
-inf

MaskedArray.set_fill_value(value=None)
    Set the filling value of the masked array.

    Parameters
        value : scalar, optional
            The new filling value. Default is None, in which case a default based on the data type is used.

    See also:

    ma.set_fill_value
        Equivalent function.
Examples

```python
>>> x = np.ma.array([0, 1.], fill_value=-np.inf)
>>> x.fill_value
-inf
>>> x.set_fill_value(np.pi)
>>> x.fill_value
3.1415926535897931

Reset to default:

```python
>>> x.set_fill_value()
>>> x.fill_value
1e+20
```

MaskedArray.fill_value
Filling value.

3.19.7 Masked arrays arithmetics

Arithmetics

```python
ma.anom(self[, axis, dtype])
ma.anomalies(self[, axis, dtype])
ma.average(a[, axis, weights, returned])
ma.conjugate(x[, out])
ma.corrcoef(x[, y, rowvar, bias, ...])
ma.cov(x[, y, rowvar, bias, allow_masked, ddof])
ma.cumprod(self[, axis, dtype, out])
ma.cumsum(self[, axis, dtype, out])
ma.median(a[, axis, out, overwrite_input])
ma.power(a, b[, third])
ma.prod(self[, axis, dtype, out])
ma.std(self[, axis, dtype, out, ddof])
ma.sum(self[, axis, dtype, out])
ma.var(self[, axis, dtype, out, ddof])
ma.MaskedArray.anom([axis, dtype])
ma.MaskedArray.cumprod([axis, dtype, out])
ma.MaskedArray.cumsum([axis, dtype, out])
ma.MaskedArray.mean([axis, dtype, out])
ma.MaskedArray.prod([axis, dtype, out])
ma.MaskedArray.std([axis, dtype, out, ddof])
ma.MaskedArray.sum([axis, dtype, out])
ma.MaskedArray.var([axis, dtype, out, ddof])
```

Compute the anomalies (deviations from the arithmetic mean) along the given axis.

Returns an array of anomalies, with the same shape as the input and where the arithmetic mean is computed along the given axis.
Parameters

axis : int, optional

Axis over which the anomalies are taken. The default is to use the mean of the flattened array as reference.

dtype : dtype, optional

Type to use in computing the variance. For arrays of integer type
the default is float32; for arrays of float types it is the same as the array type.

See also:

mean
Compute the mean of the array.

Examples

>>> a = np.ma.array([1, 2, 3])
>>> a.anom()
masked_array(data = [-1. 0. 1.],
               mask = False,
               fill_value = 1e+20)

numpy.ma.anomalies(self, axis=None, dtype=None)

Compute the anomalies (deviations from the arithmetic mean) along the given axis.

Returns an array of anomalies, with the same shape as the input and where the arithmetic mean is computed along the given axis.

Parameters

axis : int, optional

Axis over which the anomalies are taken. The default is to use the mean of the flattened array as reference.

dtype : dtype, optional

Type to use in computing the variance. For arrays of integer type
the default is float32; for arrays of float types it is the same as the array type.

See also:

mean
Compute the mean of the array.

Examples

>>> a = np.ma.array([1, 2, 3])
>>> a.anom()
masked_array(data = [-1. 0. 1.],
               mask = False,
               fill_value = 1e+20)

numpy.ma.average(a, axis=None, weights=None, returned=False)

Return the weighted average of array over the given axis.

Parameters

a : array_like

Data to be averaged. Masked entries are not taken into account in the computation.
axis : int, optional

Axis along which the average is computed. The default is to compute the average of the flattened array.

weights : array_like, optional

The importance that each element has in the computation of the average. The weights array can either be 1-D (in which case its length must be the size of `a` along the given axis) or of the same shape as `a`. If `weights=None`, then all data in `a` are assumed to have a weight equal to one. If `weights` is complex, the imaginary parts are ignored.

returned : bool, optional

Flag indicating whether a tuple (result, sum of weights) should be returned as output (True), or just the result (False). Default is False.

Returns
average, [sum_of_weights] : (tuple of) scalar or MaskedArray

The average along the specified axis. When returned is True, return a tuple with the average as the first element and the sum of the weights as the second element. The return type is np.float64 if `a` is of integer type, otherwise it is of the same type as `a`. If returned, `sum_of_weights` is of the same type as `average`.

Examples

```python
>>> a = np.ma.array([1., 2., 3., 4.], mask=[False, False, True, True])
>>> np.ma.average(a, weights=[3, 1, 0, 0])
1.25

>>> x = np.ma.arange(6.).reshape(3, 2)
>>> print x
[[ 0.  1.]
 [ 2.  3.]
 [ 4.  5.]]
>>> avg, sumweights = np.ma.average(x, axis=0, weights=[1, 2, 3],
... returned=True)
>>> print avg
[2.66666666667 3.66666666667]
```

numpy.ma.conjugate(x[, out]) = <numpy.ma.core._MaskedUnaryOperation instance at 0x42430acc>

Return the complex conjugate, element-wise.

The complex conjugate of a complex number is obtained by changing the sign of its imaginary part.

Parameters
x : array_like

Input value.

Returns
y : ndarray

The complex conjugate of x, with same dtype as y.

Examples

```python
>>> np.conjugate(1+2j)
(1-2j)
```
```python
>>> x = np.eye(2) + 1j * np.eye(2)
>>> np.conjugate(x)
array([[ 1.-1.j, 0.-0.j],
       [ 0.-0.j, 1.-1.j]])
```

`numpy.ma.corrcoef(x, y=None, rowvar=True, bias=False, allow_masked=True, ddof=None)`

Return correlation coefficients of the input array.

Except for the handling of missing data this function does the same as `numpy.corrcoef`. For more details and examples, see `numpy.corrcoef`.

**Parameters**

- **x**: array_like
  A 1-D or 2-D array containing multiple variables and observations. Each row of x represents a variable, and each column a single observation of all those variables. Also see `rowvar` below.

- **y**: array_like, optional
  An additional set of variables and observations. y has the same shape as x.

- **rowvar**: bool, optional
  If `rowvar` is True (default), then each row represents a variable, with observations in the columns. Otherwise, the relationship is transposed: each column represents a variable, while the rows contain observations.

- **bias**: bool, optional
  Default normalization (False) is by \(N-1\), where \(N\) is the number of observations given (unbiased estimate). If `bias` is 1, then normalization is by \(N\). This keyword can be overridden by the keyword `ddof` in numpy versions >= 1.5.

- **allow_masked**: bool, optional
  If True, masked values are propagated pair-wise: if a value is masked in x, the corresponding value is masked in y. If False, raises an exception.

- **ddof**: {None, int}, optional
  New in version 1.5.

  If not `None` normalization is by \(N - ddof\), where \(N\) is the number of observations; this overrides the value implied by `bias`. The default value is `None`.

**See also:**

- `numpy.corrcoef`
  Equivalent function in top-level NumPy module.

- `cov`
  Estimate the covariance matrix.

`numpy.ma.cov(x, y=None, rowvar=True, bias=False, allow_masked=True, ddof=None)`

Estimate the covariance matrix.

Except for the handling of missing data this function does the same as `numpy.cov`. For more details and examples, see `numpy.cov`.

By default, masked values are recognized as such. If x and y have the same shape, a common mask is allocated: if \(x[i, j]\) is masked, then \(y[i, j]\) will also be masked. Setting `allow_masked` to False will raise an exception if values are missing in either of the input arrays.
Parameters

\textbf{x} : array_like

A 1-D or 2-D array containing multiple variables and observations. Each row of \textit{x} represents a variable, and each column a single observation of all those variables. Also see \textit{rowvar} below.

\textbf{y} : array_like, optional

An additional set of variables and observations. \textit{y} has the same form as \textit{x}.

\textbf{rowvar} : bool, optional

If \textit{rowvar} is True (default), then each row represents a variable, with observations in the columns. Otherwise, the relationship is transposed: each column represents a variable, while the rows contain observations.

\textbf{bias} : bool, optional

Default normalization (False) is by \((N-1)\), where \(N\) is the number of observations given (unbiased estimate). If \textit{bias} is True, then normalization is by \(N\). This keyword can be overridden by the keyword \textit{ddof} in numpy versions \(\geq 1.5\).

\textbf{allow_masked} : bool, optional

If True, masked values are propagated pair-wise: if a value is masked in \textit{x}, the corresponding value is masked in \textit{y}. If False, raises a \texttt{ValueError} exception when some values are missing.

\textbf{ddof} : {None, int}, optional

New in version 1.5.

If not \texttt{None} normalization is by \((N - \textit{ddof})\), where \(N\) is the number of observations; this overrides the value implied by \textit{bias}. The default value is \texttt{None}.

Raises

\texttt{ValueError}

Raised if some values are missing and \textit{allow_masked} is False.

See also:

\texttt{numpy.cov}

\texttt{numpy.ma.cumsum} (self, axis=None, dtype=None, out=None) = \texttt{<numpy.ma.core._frommethod instance>}

Return the cumulative sum of the elements along the given axis. The cumulative sum is calculated over the flattened array by default, otherwise over the specified axis.

Masked values are set to 0 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

Parameters

\textbf{axis} : {None, -1, int}, optional

Axis along which the sum is computed. The default (\textit{axis} = \texttt{None}) is to compute over the flattened array. \textit{axis} may be negative, in which case it counts from the last to the first axis.

\textbf{dtype} : {None, dtype}, optional

Type of the returned array and of the accumulator in which the elements are summed. If \textit{dtype} is not specified, it defaults to the dtype of \(a\), unless \(a\) has an integer dtype with a
precision less than that of the default platform integer. In that case, the default platform integer is used.

**out**: ndarray, optional

Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

**Returns**

``cumsum`` : ndarray.

A new array holding the result is returned unless ``out`` is specified, in which case a reference to ``out`` is returned.

**Notes**

The mask is lost if ``out`` is not a valid `MaskedArray`!

Arithmetic is modular when using integer types, and no error is raised on overflow.

**Examples**

```python
def main():
    marr = np.ma.array(np.arange(10), mask=[0,0,0,1,1,1,0,0,0,0])
    print marr.cumsum()
```

```
[0 1 3 -- -- -- 9 16 24 33]
```

``numpy.ma.cumprod(self, axis=None, dtype=None, out=None) = <numpy.ma.core._frommethod instance at 0x4243f46c>
```

Return the cumulative product of the elements along the given axis. The cumulative product is taken over the flattened array by default, otherwise over the specified axis.

Masked values are set to 1 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

**Parameters**

``axis`` : {None, -1, int}, optional

Axis along which the product is computed. The default (``axis = None``) is to compute over the flattened array.

``dtype`` : {None, dtype}, optional

Determines the type of the returned array and of the accumulator where the elements are multiplied. If ``dtype`` has the value None and the type of ``a`` is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of ``a``.

``out`` : ndarray, optional

Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

**Returns**

``cumprod`` : ndarray

A new array holding the result is returned unless ``out`` is specified, in which case a reference to ``out`` is returned.

**Notes**

The mask is lost if ``out`` is not a valid `MaskedArray`!

Arithmetic is modular when using integer types, and no error is raised on overflow.
numpy.ma.mean(self, axis=None, dtype=None, out=None) = <numpy.ma.core._frommethod instance at 0x4243f58c>

Returns the average of the array elements.

Masked entries are ignored. The average is taken over the flattened array by default, otherwise over the specified axis. Refer to numpy.mean for the full documentation.

Parameters

a : array_like
   Array containing numbers whose mean is desired. If a is not an array, a conversion is attempted.

axis : int, optional
   Axis along which the means are computed. The default is to compute the mean of the flattened array.

dtype : dtype, optional
   Type to use in computing the mean. For integer inputs, the default is float64; for floating point, inputs it is the same as the input dtype.

out : ndarray, optional
   Alternative output array in which to place the result. It must have the same shape as the expected output but the type will be cast if necessary.

Returns

mean : ndarray, see dtype parameter above
   If out=None, returns a new array containing the mean values, otherwise a reference to the output array is returned.

See also:

numpy.ma.mean
   Equivalent function.

numpy.mean
   Equivalent function on non-masked arrays.

numpy.ma.average
   Weighted average.

Examples

>>> a = np.ma.array([1,2,3], mask=[False, False, True])

Calculate the mean:

>>> a
masked_array(data = [1 2 --],
             mask = [False False True],
       fill_value = 999999)

>>> a.mean()
1.5

numpy.ma.median(a, axis=None, out=None, overwrite_input=False)

Compute the median along the specified axis.

Returns the median of the array elements.

Parameters

a : array_like
   Input array or object that can be converted to an array.
axis : int, optional
    Axis along which the medians are computed. The default (None) is to compute the
    median along a flattened version of the array.

out : ndarray, optional
    Alternative output array in which to place the result. It must have the same shape and
    buffer length as the expected output but the type will be cast if necessary.

overwrite_input : bool, optional
    If True, then allow use of memory of input array (a) for calculations. The input array
    will be modified by the call to median. This will save memory when you do not need to
    preserve the contents of the input array. Treat the input as undefined, but it will probably
    be fully or partially sorted. Default is False. Note that, if overwrite_input is True, and
    the input is not already an ndarray, an error will be raised.

Returns
    median : ndarray
    A new array holding the result is returned unless out is specified, in which case a refer-
    ence to out is returned. Return data-type is float64 for integers and floats smaller than
    float64, or the input data-type, otherwise.

See also:
    mean

Notes
    Given a vector V with N non masked values, the median of V is the middle value of a sorted copy of V (Vs) - i.e. V[(N-1)/2], when N is odd, or {V[N/2 - 1] + V[N/2]}/2 when N is even.

Examples
    >>> x = np.ma.array(np.arange(8), mask=[0]*4 + [1]*4)
    >>> np.ma.extras.median(x)
    1.5

    >>> x = np.ma.array(np.arange(10).reshape(2, 5), mask=[0]*6 + [1]*4)
    >>> np.ma.extras.median(x)
    2.5
    >>> np.ma.extras.median(x, axis=-1, overwrite_input=True)
    masked_array(data = [2. 5.],
                 mask = False,
                 fill_value = 1e+20)

numpy.ma.power (a, b, third=None)
    Returns element-wise base array raised to power from second array.

    This is the masked array version of numpy.power. For details see numpy.power.

    See also:
    numpy.power

Notes
    The out argument to numpy.power is not supported, third has to be None.
numpy.ma.prod(self, axis=None, dtype=None, out=None) = <numpy.ma.core._frommethod instance at 0x4243f5ec>

Return the product of the array elements over the given axis. Masked elements are set to 1 internally for computation.

Parameters

axis : {None, int}, optional
    Axis over which the product is taken. If None is used, then the product is over all the array elements.

dtype : {None, dtype}, optional
    Determines the type of the returned array and of the accumulator where the elements are multiplied. If dtype has the value None and the type of a is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of a.

out : {None, array}, optional
    Alternative output array in which to place the result. It must have the same shape as the expected output but the type will be cast if necessary.

Returns

product_along_axis : {array, scalar}, see dtype parameter above.
    Returns an array whose shape is the same as a with the specified axis removed. Returns a 0d array when a is 1d or axis=None. Returns a reference to the specified output array if specified.

See also:

prod
    equivalent function

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

>>> np.prod([1.,2.])
2.0
>>> np.prod([1.,2.], dtype=np.int32)
2
>>> np.prod([[1.,2.],[3.,4.]])
24.0
>>> np.prod([[1.,2.],[3.,4.]], axis=1)
array([2., 12.])

numpy.ma.std(self, axis=None, dtype=None, out=None, ddof=0) = <numpy.ma.core._frommethod instance at 0x4243f7ac>

Compute the standard deviation along the specified axis.

Returns the standard deviation, a measure of the spread of a distribution, of the array elements. The standard deviation is computed for the flattened array by default, otherwise over the specified axis.

Parameters

a : array_like
    Calculate the standard deviation of these values.

axis : int, optional
Axis along which the standard deviation is computed. The default is to compute the standard deviation of the flattened array.

dtype : dtype, optional
Type to use in computing the standard deviation. For arrays of integer type the default is float64, for arrays of float types it is the same as the array type.

out : ndarray, optional
Alternative output array in which to place the result. It must have the same shape as the expected output but the type (of the calculated values) will be cast if necessary.

ddof : int, optional
Means Delta Degrees of Freedom. The divisor used in calculations is \( N - ddof \), where \( N \) represents the number of elements. By default \( ddof \) is zero.

keepdims : bool, optional
If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original \( arr \).

Returns

standard deviation : ndarray, see dtype parameter above.

If \( out \) is None, return a new array containing the standard deviation, otherwise return a reference to the output array.

See also:

var, mean, nanmean, nanstd, nanvar

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Notes

The standard deviation is the square root of the average of the squared deviations from the mean, i.e., \( std = \sqrt{\text{mean}(\text{abs}(x - x.\text{mean}())**2)} \).

The average squared deviation is normally calculated as \( x.\text{sum()} / N \), where \( N = \text{len}(x) \). If, however, \( ddof \) is specified, the divisor \( N - ddof \) is used instead. In standard statistical practice, \( ddof=1 \) provides an unbiased estimator of the variance of the infinite population. \( ddof=0 \) provides a maximum likelihood estimate of the variance for normally distributed variables. The standard deviation computed in this function is the square root of the estimated variance, so even with \( ddof=1 \), it will not be an unbiased estimate of the standard deviation per se.

Note that, for complex numbers, \( std \) takes the absolute value before squaring, so that the result is always real and nonnegative.

For floating-point input, the \( std \) is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the \( dtype \) keyword can alleviate this issue.

Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> np.std(a)
1.1180339887498949
>>> np.std(a, axis=0)
array([ 1.,  1.])
```
```python
>>> np.std(a, axis=1)
array([ 0.5,  0.5])

In single precision, std() can be inaccurate:

```python
>>> a = np.zeros((2, 512*512), dtype=np.float32)
>>> a[0, :] = 1.0
>>> a[1, :] = 0.1
>>> np.std(a)
0.45172946707416706
```

Computing the standard deviation in float64 is more accurate:

```python
>>> np.std(a, dtype=np.float64)
0.44999999925552653
```

```
numpy.ma.sum(self, axis=None, dtype=None, out=None) = <numpy.ma.core._frommethod instance at 0x4243f86c>
```

Return the sum of the array elements over the given axis. Masked elements are set to 0 internally.

**Parameters**

- **axis**: [{None, -1, int}, optional]
  - Axis along which the sum is computed. The default (axis = None) is to compute over the flattened array.

- **dtype**: [{None, dtype}, optional]
  - Determines the type of the returned array and of the accumulator where the elements are summed. If dtype has the value None and the type of a is an integer type of precision less than the default platform integer, then the default platform integer integer precision is used. Otherwise, the dtype is the same as that of a.

- **out**: [{None, ndarray}, optional]
  - Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

**Returns**

- **sum_along_axis**: MaskedArray or scalar
  - An array with the same shape as self, with the specified axis removed. If self is a 0-d array, or if axis is None, a scalar is returned. If an output array is specified, a reference to out is returned.

**Examples**

```python
>>> x = np.ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]], mask=[0] + [1, 0]*4)
>>> print x
[[-- 2 3]
 [5 -- --]
 [7 -- 9]]
>>> print x.sum()
25
>>> print x.sum(axis=1)
[4 5 16]
>>> print x.sum(axis=0)
[8 5 12]
>>> print type(x.sum(axis=0, dtype=np.int64)[0])
<type 'numpy.int64'>
```
Compute the variance along the specified axis.

Returns the variance of the array elements, a measure of the spread of a distribution. The variance is computed for the flattened array by default, otherwise over the specified axis.

**Parameters**

- **a**: array_like
  Array containing numbers whose variance is desired. If `a` is not an array, a conversion is attempted.

- **axis**: int, optional
  Axis along which the variance is computed. The default is to compute the variance of the flattened array.

- **dtype**: data-type, optional
  Type to use in computing the variance. For arrays of integer type the default is `float32`; for arrays of float types it is the same as the array type.

- **out**: ndarray, optional
  Alternate output array in which to place the result. It must have the same shape as the expected output, but the type is cast if necessary.

- **ddof**: int, optional
  “Delta Degrees of Freedom”: the divisor used in the calculation is \( N - ddof \), where \( N \) represents the number of elements. By default \( ddof \) is zero.

- **keepdims**: bool, optional
  If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original \( arr \).

**Returns**

- **variance**: ndarray, see dtype parameter above
  If `out=None`, returns a new array containing the variance; otherwise, a reference to the output array is returned.

**See also:**

- `std`,
- `mean`,
- `nanmean`,
- `nanstd`,
- `nanvar`

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**Notes**

The variance is the average of the squared deviations from the mean, i.e., \( \text{var} = \text{mean}((x - x.\text{mean})^2) \).

The mean is normally calculated as \( x.\text{sum}() / N \), where \( N = \text{len}(x) \). If, however, \( ddof \) is specified, the divisor \( N - ddof \) is used instead. In standard statistical practice, \( ddof=1 \) provides an unbiased estimator of the variance of a hypothetical infinite population. \( ddof=0 \) provides a maximum likelihood estimate of the variance for normally distributed variables.

Note that for complex numbers, the absolute value is taken before squaring, so that the result is always real and nonnegative.
For floating-point input, the variance is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the dtype keyword can alleviate this issue.

**Examples**

```python
gnp.array([[1, 2], [3, 4]])
gnp.var(a)
1.25
gnp.var(a, axis=0)
array([ 1.,  1.])
gnp.var(a, axis=1)
array([ 0.25,  0.25])
```

In single precision, var() can be inaccurate:

```python
gnp.zeros((2, 512*512), dtype=np.float32)
gnp.var(a, axis=0)
```

Computing the variance in float64 is more accurate:

```python
gnp.var(a, dtype=np.float64)
```

MaskedArray. `anom(axis=None, dtype=None)`

Compute the anomalies (deviations from the arithmetic mean) along the given axis.

Returns an array of anomalies, with the same shape as the input and where the arithmetic mean is computed along the given axis.

**Parameters**

- axis : int, optional
  - Axis over which the anomalies are taken. The default is to use the mean of the flattened array as reference.

- dtype : dtype, optional
  - Type to use in computing the variance. For arrays of integer type the default is float32; for arrays of float types it is the same as the array type.

**See also:**

- mean
  - Compute the mean of the array.

**Examples**

```python
gnp.ma.array([1, 2, 3])
gnp.anom()
```

3.19. Masked array operations
MaskedArray.cumprod(axis=None, dtype=None, out=None)

Return the cumulative product of the elements along the given axis. The cumulative product is taken over the flattened array by default, otherwise over the specified axis.

Masked values are set to 1 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

Parameters
- **axis**: {None, -1, int}, optional
  Axis along which the product is computed. The default (axis = None) is to compute over the flattened array.

- **dtype**: {None, dtype}, optional
  Determines the type of the returned array and of the accumulator where the elements are multiplied. If dtype has the value None and the type of a is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of a.

- **out**: ndarray, optional
  Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

Returns
- **cumprod**: ndarray
  A new array holding the result is returned unless out is specified, in which case a reference to out is returned.

Notes
The mask is lost if out is not a valid MaskedArray!

Arithmetic is modular when using integer types, and no error is raised on overflow.

MaskedArray.cumsum(axis=None, dtype=None, out=None)

Return the cumulative sum of the elements along the given axis. The cumulative sum is calculated over the flattened array by default, otherwise over the specified axis.

Masked values are set to 0 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

Parameters
- **axis**: {None, -1, int}, optional
  Axis along which the sum is computed. The default (axis = None) is to compute over the flattened array. axis may be negative, in which case it counts from the last to the first axis.

- **dtype**: {None, dtype}, optional
  Type of the returned array and of the accumulator in which the elements are summed. If dtype is not specified, it defaults to the dtype of a, unless a has an integer dtype with a precision less than that of the default platform integer. In that case, the default platform integer is used.

- **out**: ndarray, optional
  Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.
Returns

cumsum : ndarray.

A new array holding the result is returned unless out is specified, in which case a reference to out is returned.

Notes

The mask is lost if out is not a valid MaskedArray!

Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

```python
>>> marr = np.ma.array(np.arange(10), mask=[0,0,0,1,1,1,0,0,0,0])
>>> print marr.cumsum()
[0 1 3 -- -- -- 9 16 24 33]
```

MaskedArray.mean(axis=None, dtype=None, out=None)

Returns the average of the array elements.

Masked entries are ignored. The average is taken over the flattened array by default, otherwise over the specified axis. Refer to numpy.mean for the full documentation.

Parameters

- a: array_like
  Array containing numbers whose mean is desired. If a is not an array, a conversion is attempted.

- axis: int, optional
  Axis along which the means are computed. The default is to compute the mean of the flattened array.

- dtype: dtype, optional
  Type to use in computing the mean. For integer inputs, the default is float64; for floating point, inputs it is the same as the input dtype.

- out: ndarray, optional
  Alternative output array in which to place the result. It must have the same shape as the expected output but the type will be cast if necessary.

Returns

mean : ndarray, see dtype parameter above

If out=None, returns a new array containing the mean values, otherwise a reference to the output array is returned.

See also:

- numpy.ma.mean
  Equivalent function.

- numpy.mean
  Equivalent function on non-masked arrays.

- numpy.ma.average
  Weighted average.
Examples

```python
>>> a = np.ma.array([1, 2, 3], mask=[False, False, True])
>>> a
masked_array(data = [1 2 --],
             mask = [False False True],
             fill_value = 999999)
>>> a.mean()
1.5
```

MaskedArray.prod(axis=None, dtype=None, out=None)

Return the product of the array elements over the given axis. Masked elements are set to 1 internally for computation.

**Parameters**

- **axis**: [None, int], optional
  
  Axis over which the product is taken. If None is used, then the product is over all the array elements.

- **dtype**: [None, dtype], optional
  
  Determines the type of the returned array and of the accumulator where the elements are multiplied. If dtype has the value None and the type of a is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of a.

- **out**: [None, array], optional
  
  Alternative output array in which to place the result. It must have the same shape as the expected output but the type will be cast if necessary.

**Returns**

- **product_along_axis**: [array, scalar], see dtype parameter above.
  
  Returns an array whose shape is the same as a with the specified axis removed. Returns a 0d array when a is 1d or axis=None. Returns a reference to the specified output array if specified.

**See also:**

- **prod**
  
  equivalent function

**Notes**

Arithmetic is modular when using integer types, and no error is raised on overflow.

**Examples**

```python
>>> np.prod([1., 2.])
2.0
>>> np.prod([1., 2.], dtype=np.int32)
2
>>> np.prod([[1., 2.], [3., 4.]])
24.0
>>> np.prod([[1., 2.], [3., 4.]], axis=1)
array([ 2., 12.])
```

MaskedArray.std(axis=None, dtype=None, out=None, ddof=0)

Compute the standard deviation along the specified axis.
Returns the standard deviation, a measure of the spread of a distribution, of the array elements. The standard deviation is computed for the flattened array by default, otherwise over the specified axis.

**Parameters**

- **a**: array_like
  
  Calculate the standard deviation of these values.

- **axis**: int, optional
  
  Axis along which the standard deviation is computed. The default is to compute the standard deviation of the flattened array.

- **dtype**: dtype, optional
  
  Type to use in computing the standard deviation. For arrays of integer type the default is float64, for arrays of float types it is the same as the array type.

- **out**: ndarray, optional
  
  Alternative output array in which to place the result. It must have the same shape as the expected output but the type (of the calculated values) will be cast if necessary.

- **ddof**: int, optional
  
  Means Delta Degrees of Freedom. The divisor used in calculations is \( N - \text{ddof} \), where \( N \) represents the number of elements. By default \( \text{ddof} = 0 \).

- **keepdims**: bool, optional
  
  If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original `arr`.

**Returns**

- **standard_deviation**: ndarray, see dtype parameter above.
  
  If `out` is None, return a new array containing the standard deviation, otherwise return a reference to the output array.

**See also:**

- `var`, `mean`, `nanmean`, `nanstd`, `nanvar`

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**Notes**

The standard deviation is the square root of the average of the squared deviations from the mean, i.e., \( \text{std} = \sqrt{\text{mean}((x - \text{mean}(x))^2)} \).

The average squared deviation is normally calculated as \( x.\text{sum()}/N \), where \( N = \text{len}(x) \). If, however, `ddof` is specified, the divisor \( N - \text{ddof} \) is used instead. In standard statistical practice, `ddof=1` provides an unbiased estimator of the variance of the infinite population. `ddof=0` provides a maximum likelihood estimate of the variance for normally distributed variables. The standard deviation computed in this function is the square root of the estimated variance, so even with `ddof=1`, it will not be an unbiased estimate of the standard deviation per se.

Note that, for complex numbers, `std` takes the absolute value before squaring, so that the result is always real and nonnegative.

For floating-point input, the `std` is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the `dtype` keyword can alleviate this issue.
Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> np.std(a)
1.1180339887498949
>>> np.std(a, axis=0)
array([ 1., 1.])
>>> np.std(a, axis=1)
array([ 0.5, 0.5])
```

In single precision, std() can be inaccurate:

```python
>>> a = np.zeros((2,512*512), dtype=np.float32)
>>> a[0, :] = 1.0
>>> a[1, :] = 0.1
>>> np.std(a)
0.45172946707416706
```

Computing the standard deviation in float64 is more accurate:

```python
>>> np.std(a, dtype=np.float64)
0.44999999925552653
```

MaskedArray.sum(axis=None, dtype=None, out=None)

Return the sum of the array elements over the given axis. Masked elements are set to 0 internally.

Parameters

axis : {None, -1, int}, optional

Axis along which the sum is computed. The default (axis = None) is to compute over the flattened array.

dtype : {None, dtype}, optional

Determines the type of the returned array and of the accumulator where the elements are summed. If dtype has the value None and the type of a is an integer type of precision less than the default platform integer, then the default platform integer precision is used. Otherwise, the dtype is the same as that of a.

out : {None, ndarray}, optional

Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

Returns

sum_along_axis : MaskedArray or scalar

An array with the same shape as self, with the specified axis removed. If self is a 0-d array, or if axis is None, a scalar is returned. If an output array is specified, a reference to out is returned.

Examples

```python
>>> x = np.ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]], mask=[0] + [1,0]*4)
>>> print x
[[1 -- 3]
 [-- 5 --]
[7 -- 9]]
>>> print x.sum()
25
>>> print x.sum(axis=1)
[4 5 16]
```
```python
>>> print x.sum(axis=0)
[8 5 12]
>>> print type(x.sum(axis=0, dtype=np.int64)[0])
<type 'numpy.int64'>
```

MaskedArray.var (axis=None, dtype=None, out=None, ddof=0)

Compute the variance along the specified axis.

Returns the variance of the array elements, a measure of the spread of a distribution. The variance is computed for the flattened array by default, otherwise over the specified axis.

**Parameters**

- **a**: array_like
  Array containing numbers whose variance is desired. If `a` is not an array, a conversion is attempted.

- **axis**: int, optional
  Axis along which the variance is computed. The default is to compute the variance of the flattened array.

- **dtype**: data-type, optional
  Type to use in computing the variance. For arrays of integer type the default is float32; for arrays of float types it is the same as the array type.

- **out**: ndarray, optional
  Alternate output array in which to place the result. It must have the same shape as the expected output, but the type is cast if necessary.

- **ddof**: int, optional
  “Delta Degrees of Freedom”: the divisor used in the calculation is \( N - ddof \), where \( N \) represents the number of elements. By default \( ddof = 0 \) is zero.

- **keepdims**: bool, optional
  If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original `arr`.

**Returns**

- **variance**: ndarray, see dtype parameter above
  If `out=None`, returns a new array containing the variance; otherwise, a reference to the output array is returned.

**Notes**

The variance is the average of the squared deviations from the mean, i.e.,

\[
\text{var} = \text{mean}(\text{abs}(x - x.\text{mean()})*2).
\]

The mean is normally calculated as \( x.\text{sum()} / N \), where \( N = \text{len}(x) \). If, however, \( ddof \) is specified, the divisor \( N - ddof \) is used instead. In standard statistical practice, \( ddof=1 \) provides an unbiased estimator of the variance of a hypothetical infinite population. \( ddof=0 \) provides a maximum likelihood estimate of the variance for normally distributed variables.
Note that for complex numbers, the absolute value is taken before squaring, so that the result is always real and nonnegative.

For floating-point input, the variance is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the dtype keyword can alleviate this issue.

**Examples**

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> np.var(a)
1.25
>>> np.var(a, axis=0)
array([1., 1.])
>>> np.var(a, axis=1)
array([0.25, 0.25])
```

In single precision, var() can be inaccurate:

```python
>>> a = np.zeros((2, 512*512), dtype=np.float32)
>>> a[0, :] = 1.0
>>> a[1, :] = 0.1
>>> np.var(a)
0.20405951142311096
```

Computing the variance in float64 is more accurate:

```python
>>> np.var(a, dtype=np.float64)
0.20249999932997387
```

```python
>>> (1-0.55)**2 + (0.1-0.55)**2)/2
0.20250000000000001
```

**Minimum/maximum**

- `ma.argmax(a[, axis, fill_value])` Returns array of indices of the maximum values along the given axis.
- `ma.argmin(a[, axis, fill_value])` Returns array of indices to the minimum values along the given axis.
- `ma.max(obj[, axis, out, fill_value])` Return the maximum along a given axis.
- `ma.min(obj[, axis, out, fill_value])` Return the minimum along a given axis.
- `ma.ptp(obj[, axis, out, fill_value])` Return (maximum - minimum) along the the given dimension (i.e.
- `ma.MaskedArray.argmax([axis, fill_value, out])` Returns array of indices of the maximum values along the given axis.
- `ma.MaskedArray.argmin([axis, fill_value, out])` Return array of indices to the minimum values along the given axis.
- `ma.MaskedArray.max([axis, fill_value])` Return the maximum along a given axis.
- `ma.MaskedArray.min([axis, fill_value])` Return the minimum along a given axis.
- `ma.MaskedArray.ptp([axis, fill_value])` Return (maximum - minimum) along the the given dimension (i.e.

```python
numpy.ma.argmax(a, axis=None, fill_value=None)
```

Returns array of indices of the maximum values along the given axis. Masked values are treated as if they had the value fill_value.

**Parameters**

- axis : {None, integer}
  
  If None, the index is into the flattened array, otherwise along the specified axis

- fill_value : {var}, optional
  
  Value used to fill in the masked values. If None, the output of maxi-
mum_fill_value(self._data) is used instead.

**out**: {None, array}, optional

Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**Returns**

- **index_array**: {integer_array}

**Examples**

```python
>>> a = np.arange(6).reshape(2,3)
>>> a.argmax()
5
>>> a.argmax(0)
array([1, 1, 1])
>>> a.argmax(1)
array([2, 2])
```

`numpy.ma.argmin(a, axis=None, fill_value=None)`

Return array of indices to the minimum values along the given axis.

**Parameters**

- **axis**: {None, integer}
  
  If None, the index is into the flattened array, otherwise along the specified axis

- **fill_value**: {var}, optional

  Value used to fill in the masked values. If None, the output of minimum_fill_value(self._data) is used instead.

- **out**: {None, array}, optional

  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**Returns**

- **ndarray, scalar**

  If multi-dimension input, returns a new ndarray of indices to the minimum values along the given axis. Otherwise, returns a scalar of index to the minimum values along the given axis.

**Examples**

```python
>>> x = np.ma.array(arange(4), mask=[1,1,0,0])
>>> x.shape = (2,2)
>>> print x
[-- --]
[2 3]
>>> print x.argmin(axis=0, fill_value=-1)
[0 0]
>>> print x.argmin(axis=0, fill_value=9)
[1 1]
```

`numpy.ma.max(obj, axis=None, out=None, fill_value=None)`

Return the maximum along a given axis.

**Parameters**

- **axis**: {None, int}, optional
Axis along which to operate. By default, `axis` is None and the flattened input is used.

```
out : array_like, optional
```

Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output.

```
fill_value : {var}, optional
```

Value used to fill in the masked values. If None, use the output of `maximum_fill_value`.

**Returns**

```
amax : array_like
```

New array holding the result. If `out` was specified, `out` is returned.

**See also:**

```
maximum_fill_value
```

Returns the maximum filling value for a given datatype.

```
numpy.ma.min (obj, axis=None, out=None, fill_value=None)
```

Return the minimum along a given axis.

**Parameters**

```
axis : {None, int}, optional
```

Axis along which to operate. By default, `axis` is None and the flattened input is used.

```
out : array_like, optional
```

Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output.

```
fill_value : {var}, optional
```

Value used to fill in the masked values. If None, use the output of `minimum_fill_value`.

**Returns**

```
amin : array_like
```

New array holding the result. If `out` was specified, `out` is returned.

**See also:**

```
minimum_fill_value
```

Returns the minimum filling value for a given datatype.

```
numpy.ma.ptp (obj, axis=None, out=None, fill_value=None)
```

Return (maximum - minimum) along the the given dimension (i.e. peak-to-peak value).

**Parameters**

```
axis : {None, int}, optional
```

Axis along which to find the peaks. If None (default) the flattened array is used.

```
out : {None, array_like}, optional
```

Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

```
fill_value : {var}, optional
```


Value used to fill in the masked values.

**Returns**

- `ptp`: ndarray.
  
  A new array holding the result, unless `out` was specified, in which case a reference to `out` is returned.

**MaskedArray**. `argmax` *(axis=None, fill_value=None, out=None)*

Returns array of indices of the maximum values along the given axis. Masked values are treated as if they had the value `fill_value`.

**Parameters**

- `axis`: {None, integer}
  
  If None, the index is into the flattened array, otherwise along the specified axis.

- `fill_value`: {var}, optional
  
  Value used to fill in the masked values. If None, the output of `maximum_fill_value(self._data)` is used instead.

- `out`: {None, array}, optional
  
  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**Returns**

- `index_array`: {integer_array}

**Examples**

```python
>>> a = np.arange(6).reshape(2,3)
>>> a.argmax()
5
>>> a.argmax(0)
array([1, 1, 1])
>>> a.argmax(1)
array([2, 2])
```

**MaskedArray**. `argmin` *(axis=None, fill_value=None, out=None)*

Return array of indices to the minimum values along the given axis.

**Parameters**

- `axis`: {None, integer}
  
  If None, the index is into the flattened array, otherwise along the specified axis.

- `fill_value`: {var}, optional
  
  Value used to fill in the masked values. If None, the output of `minimum_fill_value(self._data)` is used instead.

- `out`: {None, array}, optional
  
  Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

**Returns**

- {ndarray, scalar}
  
  If multi-dimension input, returns a new ndarray of indices to the minimum values along the given axis. Otherwise, returns a scalar of index to the minimum values along the given axis.
Examples

```python
>>> x = np.ma.array(arange(4), mask=[1,1,0,0])
>>> x.shape = (2,2)
>>> print x
[[- --]
 [2  3]]
>>> print x.argmin(axis=0, fill_value=-1)
[0 0]
>>> print x.argmin(axis=0, fill_value=9)
[1 1]
```

MaskedArray.max (axis=None, out=None, fill_value=None)

Return the maximum along a given axis.

Parameters

- **axis**: {None, int}, optional
  Axis along which to operate. By default, axis is None and the flattened input is used.

- **out**: array_like, optional
  Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output.

- **fill_value**: {var}, optional
  Value used to fill in the masked values. If None, use the output of maximum_fill_value().

Returns

- **amax**: array_like
  New array holding the result. If out was specified, out is returned.

See also:

- maximum_fill_value
  Returns the maximum filling value for a given datatype.

MaskedArray.min (axis=None, out=None, fill_value=None)

Return the minimum along a given axis.

Parameters

- **axis**: {None, int}, optional
  Axis along which to operate. By default, axis is None and the flattened input is used.

- **out**: array_like, optional
  Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output.

- **fill_value**: {var}, optional
  Value used to fill in the masked values. If None, use the output of minimum_fill_value().

Returns

- **amin**: array_like
  New array holding the result. If out was specified, out is returned.

See also:
**minimum_fill_value**

Returns the minimum filling value for a given datatype.

**MaskedArray.ptp**(axis=None, out=None, fill_value=None)

Return (maximum - minimum) along the the given dimension (i.e. peak-to-peak value).

**Parameters**

- **axis**: {None, int}, optional  
  Axis along which to find the peaks. If None (default) the flattened array is used.
- **out**: {None, array_like}, optional  
  Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.
- **fill_value**: {var}, optional  
  Value used to fill in the masked values.

**Returns**

- **ptp**: ndarray  
  A new array holding the result, unless `out` was specified, in which case a reference to `out` is returned.

**Sorting**

- **ma.argsort**(a[, axis, kind, order, fill_value])  
  Return an ndarray of indices that sort the array along the specified axis. Masked values are filled beforehand to `fill_value`.

  **Parameters**

  - **axis**: int, optional  
    Axis along which to sort. The default is -1 (last axis). If None, the flattened array is used.
  - **fill_value**: var, optional  
    Value used to fill the array before sorting. The default is the `fill_value` attribute of the input array.
  - **kind**: {‘quicksort’, ‘mergesort’, ‘heapsort’}, optional  
    Sorting algorithm.
  - **order**: list, optional  
    When `a` is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

  **Returns**

  - **index_array**: ndarray, int  

**numpy.ma.argsort**(a, axis=None, kind='quicksort', order=None, fill_value=None)

Return an ndarray of indices that sort the array along the specified axis. Masked values are filled beforehand to `fill_value`.

  **Parameters**

  - **axis**: int, optional  
    Axis along which to sort. The default is -1 (last axis). If None, the flattened array is used.
  - **fill_value**: var, optional  
    Value used to fill the array before sorting. The default is the `fill_value` attribute of the input array.
  - **kind**: {‘quicksort’, ‘mergesort’, ‘heapsort’}, optional  
    Sorting algorithm.
  - **order**: list, optional  
    When `a` is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

  **Returns**

  - **index_array**: ndarray, int
Array of indices that sort \(a\) along the specified axis. In other words, \(a[index\_array]\) yields a sorted \(a\).

See also:

- **sort**
  Describes sorting algorithms used.

- **lexsort**
  Indirect stable sort with multiple keys.

- **ndarray.sort**
  Inplace sort.

Notes

See sort for notes on the different sorting algorithms.

Examples

```python
>>> a = np.ma.array([3,2,1], mask=[False, False, True])
>>> a
masked_array(data = [3 2 --],
             mask = [False False True],
             fill_value = 999999)
>>> a.argsort()
array([1, 0, 2])
```

```
numpy.ma.sort (a, axis=-1, kind='quicksort', order=None, endwith=True, fill_value=None)
Sort the array, in-place
```

Parameters

- **a** : array_like
  Array to be sorted.

- **axis** : int, optional
  Axis along which to sort. If None, the array is flattened before sorting. The default is -1, which sorts along the last axis.

- **kind** : {'quicksort', 'mergesort', 'heapsort'}, optional
  Sorting algorithm. Default is 'quicksort'.

- **order** : list, optional
  When \(a\) is a structured array, this argument specifies which fields to compare first, second, and so on. This list does not need to include all of the fields.

- **endwith** : {True, False}, optional
  Whether missing values (if any) should be forced in the upper indices (at the end of the array) (True) or lower indices (at the beginning). When the array contains unmasked values of the largest (or smallest if False) representable value of the datatype the ordering of these values and the masked values is undefined. To enforce the masked values are at the end (beginning) in this case one must sort the mask.

- **fill_value** : {var}, optional
  Value used internally for the masked values. If fill_value is not None, it supersedes endwith.
Returns

```
sorted_array : ndarray

Array of the same type and shape as a.
```

See also:

```
ndarray.sort
    Method to sort an array in-place.
argsort
    Indirect sort.
lexsort
    Indirect stable sort on multiple keys.
searchsorted
    Find elements in a sorted array.
```

Notes

See sort for notes on the different sorting algorithms.

Examples

```
>>> a = ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # Default
>>> a.sort()
>>> print a
[1 3 5 -- --]

>>> a = ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # Put missing values in the front
>>> a.sort((endwith=False)
>>> print a
[-- -- 1 3 5]

>>> a = ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # fill_value takes over endwith
>>> a.sort((endwith=False, fill_value=3)
>>> print a
[1 -- -- 3 5]
```

MaskedArray.argsort (axis=None, kind='quicksort', order=None, fill_value=None)

Return an ndarray of indices that sort the array along the specified axis. Masked values are filled beforehand to fill_value.

Parameters

```
axis     : int, optional
            Axis along which to sort. The default is -1 (last axis). If None, the flattened array is used.
fill_value     : var, optional
            Value used to fill the array before sorting. The default is the fill_value attribute of the input array.
kind : {'quicksort', 'mergesort', 'heapsort'}, optional
            Sorting algorithm.
```

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order : list, optional

When a is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

Returns

index_array : ndarray, int

Array of indices that sort a along the specified axis. In other words, a[index_array] yields a sorted a.

See also:

sort
Describes sorting algorithms used.

lexsort
Indirect stable sort with multiple keys.

ndarray.sort
Inplace sort.

Notes

See sort for notes on the different sorting algorithms.

Examples

>>> a = np.ma.array([3,2,1], mask=[False, False, True])
>>> a
masked_array(data = [3 2 --],
             mask = [False False True],
             fill_value = 999999)
>>> a.argsort()
array([1, 0, 2])

MaskedArray.sort (axis=-1, kind='quicksort', order=None, endwith=True, fill_value=None)
Sort the array, in-place

Parameters

a : array_like
Array to be sorted.

axis : int, optional
Axis along which to sort. If None, the array is flattened before sorting. The default is -1, which sorts along the last axis.

kind : {'quicksort', 'mergesort', 'heapsort'}, optional
Sorting algorithm. Default is 'quicksort'.

order : list, optional
When a is a structured array, this argument specifies which fields to compare first, second, and so on. This list does not need to include all of the fields.

endwith : {True, False}, optional
Whether missing values (if any) should be forced in the upper indices (at the end of the array) (True) or lower indices (at the beginning). When the array contains unmasked
values of the largest (or smallest if False) representable value of the datatype the ordering of these values and the masked values is undefined. To enforce the masked values are at the end (beginning) in this case one must sort the mask.

**fill_value**: {var}, optional

Value used internally for the masked values. If `fill_value` is not None, it supersedes `endwith`.

**Returns**

- **sorted_array**: ndarray

  Array of the same type and shape as `a`.

**See also:**

- **ndarray.sort**
  Method to sort an array in-place.

- **argsort**
  Indirect sort.

- **lexsort**
  Indirect stable sort on multiple keys.

- **searchsorted**
  Find elements in a sorted array.

**Notes**

See `sort` for notes on the different sorting algorithms.

**Examples**

```python
>>> a = ma.array([1, 2, 5, 4, 3], mask=[0, 1, 0, 1, 0])
>>> # Default
>>> a.sort()
>>> print a
[1 3 5 -- --]

>>> a = ma.array([1, 2, 5, 4, 3], mask=[0, 1, 0, 1, 0])
>>> # Put missing values in the front
>>> a.sort(endwith=False)
>>> print a
[-- -- 1 3 5]

>>> a = ma.array([1, 2, 5, 4, 3], mask=[0, 1, 0, 1, 0])
>>> # fill_value takes over endwith
>>> a.sort(endwith=False, fill_value=3)
>>> print a
[1 -- -- 3 5]
```

**Algebra**

- **ma.diag(v[, k])**
  Extract a diagonal or construct a diagonal array.

- **ma.dot(a, b[, strict])**
  Return the dot product of two arrays.

- **ma.identity(n[, dtype])**
  Return the identity array.

- **ma.inner(a, b)**
  Inner product of two arrays.

---

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```python
numpy.ma.diag(v, k=0)
```

Extract a diagonal or construct a diagonal array.

This function is the equivalent of `numpy.diag` that takes masked values into account, see `numpy.diag` for details.

**See also:**

- `numpy.diag`  
  Equivalent function for ndarrays.

```python
numpy.ma.dot(a, b, strict=False)
```

Return the dot product of two arrays.

**Note:** Works only with 2-D arrays at the moment.

This function is the equivalent of `numpy.dot` that takes masked values into account, see `numpy.dot` for details.

**Parameters**

- `a, b` : ndarray  
  Inputs arrays.

- `strict` : bool, optional
  Whether masked data are propagated (True) or set to 0 (False) for the computation. Default is False. Propagating the mask means that if a masked value appears in a row or column, the whole row or column is considered masked.

**See also:**

- `numpy.dot`  
  Equivalent function for ndarrays.

**Examples**

```python
>>> a = ma.array([[1, 2, 3], [4, 5, 6]], mask=[[1, 0, 0], [0, 0, 0]])
>>> b = ma.array([[1, 2], [3, 4], [5, 6]], mask=[[1, 0], [0, 0], [0, 0]])
>>> np.ma.dot(a, b)
masked_array(data =
[[21 26]
 [45 64]],
   mask =
[[False False]
[False False]],
   fill_value = 999999)
>>> np.ma.dot(a, b, strict=True)
masked_array(data =
```
numpy.ma.identity(n, dtype=None) = <numpy.ma.core._convert2ma instance at 0x4243fbac>

Return the identity array.

The identity array is a square array with ones on the main diagonal.

Parameters

n : int
    Number of rows (and columns) in n x n output.

dtype : data-type, optional
    Data-type of the output. Defaults to float.

Returns

out : ndarray
    n x n array with its main diagonal set to one, and all other elements 0.

Examples

>>> np.identity(3)
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])

numpy.ma.inner(a, b)

Inner product of two arrays.

Ordinary inner product of vectors for 1-D arrays (without complex conjugation), in higher dimensions a sum product over the last axes.

Parameters

a, b : array_like
    If a and b are nonscalar, their last dimensions of must match.

Returns

out : ndarray
    out.shape = a.shape[:-1] + b.shape[:-1]

Raises

ValueError
    If the last dimension of a and b has different size.

See also:

tensordot
    Sum products over arbitrary axes.
dot
    Generalised matrix product, using second last dimension of b.
einsum
    Einstein summation convention.
Notes

Masked values are replaced by 0.

Examples

Ordinary inner product for vectors:

```python
>>> a = np.array([1, 2, 3])
>>> b = np.array([0, 1, 0])
>>> np.inner(a, b)
2
```

A multidimensional example:

```python
>>> a = np.arange(24).reshape((2, 3, 4))
>>> b = np.arange(4)
>>> np.inner(a, b)
array([[ 14,  38,  62],
       [135, 110, 134]])
```

An example where `b` is a scalar:

```python
>>> np.inner(np.eye(2), 7)
array([[ 7.,  0.],
       [ 0.,  7.]]
```

`numpy.ma.innerproduct(a, b)`

Inner product of two arrays.

Ordinary inner product of vectors for 1-D arrays (without complex conjugation), in higher dimensions a sum product over the last axes.

Parameters

- `a, b`: array_like
  
  If `a` and `b` are nonscalar, their last dimensions of must match.

Returns

- `out`: ndarray
  
  \(\text{out.shape} = a.shape[:-1] + b.shape[:-1]\)

Raises

- ValueError
  
  If the last dimension of `a` and `b` has different size.

See also:

- `tensordot`
  
  Sum products over arbitrary axes.

- `dot`
  
  Generalised matrix product, using second last dimension of `b`.

- `einsum`
  
  Einstein summation convention.

Notes

Masked values are replaced by 0.
Examples

Ordinary inner product for vectors:

```python
g = np.array([1,2,3])
g2 = np.array([0,1,0])
np.inner(a, b)
2
```

A multidimensional example:

```python
g = np.arange(24).reshape((2,3,4))
g2 = np.arange(4)
np.inner(a, b)
array([[ 14,  38,  62],
       [ 86, 110, 134]])
```

An example where $\mathbf{b}$ is a scalar:

```python
np.inner(np.eye(2), 7)
array([[ 7.,  0.],
       [ 0.,  7.]])
```

numpy.ma.outer($a$, $b$)
Compute the outer product of two vectors.

Given two vectors, $a = [a_0, a_1, \ldots, a_M]$ and $b = [b_0, b_1, \ldots, b_N]$, the outer product [R50] is:

```
[[a_0*b_0 a_0*b_1 \ldots a_0*b_N]
 [a_1*b_0 \ldots]
 [\ldots]
 [a_M*b_0 \ldots a_M*b_N]]
```

Parameters

- **a** : (M,) array_like
  First input vector. Input is flattened if not already 1-dimensional.

- **b** : (N,) array_like
  Second input vector. Input is flattened if not already 1-dimensional.

- **out** : (M, N) ndarray, optional
  A location where the result is stored

  New in version 1.9.0.

Returns

- **out** : (M, N) ndarray
  
  \[out[i, j] = a[i] \times b[j]\]

See also:

inner, einsum

Notes

Masked values are replaced by 0.

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Examples

Make a (very coarse) grid for computing a Mandelbrot set:

```python
>>> r1 = np.outer(np.ones((5,)), np.linspace(-2, 2, 5))
>>> r1
array([[-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.]]

>>> im = np.outer(1j*np.linspace(2, -2, 5), np.ones((5,)))
>>> im
array([[ 0.+2.j,  0.+2.j,  0.+2.j,  0.+2.j,  0.+2.j],
       [ 0.+1.j,  0.+1.j,  0.+1.j,  0.+1.j,  0.+1.j],
       [ 0.+0.j,  0.+0.j,  0.+0.j,  0.+0.j,  0.+0.j],
       [ 0.-1.j,  0.-1.j,  0.-1.j,  0.-1.j,  0.-1.j],
       [ 0.-2.j,  0.-2.j,  0.-2.j,  0.-2.j,  0.-2.j]])

>>> grid = r1 + im
>>> grid
array([[-2.+2.j, -1.+2.j,  0.+2.j,  1.+2.j,  2.+2.j],
       [-2.+1.j, -1.+1.j,  0.+1.j,  1.+1.j,  2.+1.j],
       [-2.+0.j, -1.+0.j,  0.+0.j,  1.+0.j,  2.+0.j],
       [-2.-1.j, -1.-1.j,  0.-1.j,  1.-1.j,  2.-1.j],
       [-2.-2.j, -1.-2.j,  0.-2.j,  1.-2.j,  2.-2.j]])
```

An example using a “vector” of letters:

```python
>>> x = np.array(['a', 'b', 'c'], dtype=object)
>>> np.outer(x, [1, 2, 3])
array([['a', 'aa', 'aaa'],
       ['b', 'bb', 'bbb'],
       ['c', 'cc', 'ccc']], dtype=object)
```

```
numpy.ma.outerproduct (a, b)
Compute the outer product of two vectors.

Given two vectors, a = [a0, a1, ..., aM] and b = [b0, b1, ..., bN], the outer product [R51]
is:

[[a0*b0 a0*b1 ... a0*bN ]
 [a1*b0 ...
  [ ... .
 [aM*b0 aM*bN ]

Parameters
a : (M,) array_like
    First input vector. Input is flattened if not already 1-dimensional.

b : (N,) array_like
    Second input vector. Input is flattened if not already 1-dimensional.

out : (M, N) ndarray, optional
    A location where the result is stored
```
New in version 1.9.0.

Returns

out : (M, N) ndarray

out[i, j] = a[i] * b[j]

See also:

inner, einsum

Notes

Masked values are replaced by 0.

References

[R51]

Examples

Make a (very coarse) grid for computing a Mandelbrot set:

```python
>>> r1 = np.outer(np.ones((5,)), np.linspace(-2, 2, 5))
>>> r1
array([[-2., -1., 0., 1., 2.],
       [-2., -1., 0., 1., 2.],
       [-2., -1., 0., 1., 2.],
       [-2., -1., 0., 1., 2.],
       [-2., -1., 0., 1., 2.])
```

```python
>>> im = np.outer(1j*np.linspace(2, -2, 5), np.ones((5,)))
>>> im
array([[ 0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j],
       [ 0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j],
       [ 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j],
       [ 0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j],
       [ 0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j]])
```

```python
>>> grid = rl + im
>>> grid
array([[-2.+2.j, -1.+2.j, 0.+2.j, 1.+2.j, 2.+2.j],
       [-2.+1.j, -1.+1.j, 0.+1.j, 1.+1.j, 2.+1.j],
       [-2.+0.j, -1.+0.j, 0.+0.j, 1.+0.j, 2.+0.j],
       [-2.-1.j, -1.-1.j, 0.-1.j, 1.-1.j, 2.-1.j],
       [-2.-2.j, -1.-2.j, 0.-2.j, 1.-2.j, 2.-2.j]])
```

An example using a “vector” of letters:

```python
>>> x = np.array(["a", "b", "c"], dtype=object)
>>> np.outer(x, [1, 2, 3])
array([['a', 'a', 'a'],
       ['b', 'bb', 'bbb'],
       ['c', 'cc', 'ccc']], dtype=object)
```

```
numpy.ma.trace(self, offset=0, axis1=0, axis2=1, dtype=None, out=None) a.trace(offset=0, axis1=0, axis2=1, dtype=None, out=None) = <numpy.ma.core._frommethod instance at 0x4243f84c>
```

Return the sum along diagonals of the array.

Refer to numpy.trace for full documentation.

See also:
**numpy.trace**

Equivalent function

```
numpy.ma.transpose(a, axes=None)
```

Permute the dimensions of an array.

This function is exactly equivalent to `numpy.transpose`.

See also:

**numpy.transpose**

Equivalent function in top-level NumPy module.

**Examples**

```python
>>> import numpy.ma as ma
>>> x = ma.arange(4).reshape((2,2))
>>> x[1, 1] = ma.masked
>>> x
masked_array(data =
    [[0 1]
     [2 --]],
   mask =
    [[False False]
     [False  True]],
   fill_value = 999999)
>>> ma.transpose(x)
masked_array(data =
    [[0 2]
     [1 --]],
   mask =
    [[False False]
     [False  True]],
   fill_value = 999999)
```

**MaskedArray.trace**

Return the sum along diagonals of the array.

Refer to `numpy.trace` for full documentation.

See also:

**numpy.trace**

Equivalent function

```
MaskedArray.transpose(*axes)
```

Returns a view of the array with axes transposed.

For a 1-D array, this has no effect. (To change between column and row vectors, first cast the 1-D array into a matrix object.) For a 2-D array, this is the usual matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided and `a.shape = (i[0], i[1], ... i[n-2], i[n-1])`, then `a.transpose().shape = (i[n-1], i[n-2], ... i[1], i[0]).`

**Parameters**

- **axes**: None, tuple of ints, or `n` ints
  - None or no argument: reverses the order of the axes.
• tuple of ints: \( i \) in the \( j \)-th place in the tuple means \( a \)'s \( i \)-th axis becomes \( a\text{.transpose()} \)'s \( j \)-th axis.

• \( n \) ints: same as an \( n \)-tuple of the same ints (this form is intended simply as a “convenience” alternative to the tuple form)

**Returns**

\[ \text{out : ndarray} \]

View of \( a \), with axes suitably permuted.

**See also:**

\[ \text{ndarray.T} \]

Array property returning the array transposed.

**Examples**

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])
```

**Polynomial fit**

\[
\text{ma.vander}(x[, n]) \quad \text{Generate a Vandermonde matrix.}
\]

\[
\text{ma.polyfit}(x, y, deg[, rcond, full, w, cov]) \quad \text{Least squares polynomial fit.}
\]

\[
\text{numpy.ma.vander} \ (x, n=\text{None}) \quad \text{Generate a Vandermonde matrix.}
\]

The columns of the output matrix are powers of the input vector. The order of the powers is determined by the \textit{increasing} boolean argument. Specifically, when \textit{increasing} is False, the \( i \)-th output column is the input vector raised element-wise to the power of \( N - i - 1 \). Such a matrix with a geometric progression in each row is named for Alexandre-Theophile Vandermonde.

**Parameters**

\[
x : \text{array_like} \quad 1 \text{-D input array.}
\]

\[
N : \text{int, optional} \quad \text{Number of columns in the output. If } N \text{ is not specified, a square array is returned (} N = \text{len}(x)\text{).}
\]

\[
\text{increasing} : \text{bool, optional} \quad \text{Order of the powers of the columns. If True, the powers increase from left to right, if False (the default) they are reversed.}
\]
New in version 1.9.0.

Returns

```
out : ndarray

Vandermonde matrix. If `increasing` is False, the first column is \(x^{(N-1)}\), the second \(x^{(N-2)}\) and so forth. If `increasing` is True, the columns are \(x^0, x^1, \ldots, x^{(N-1)}\).
```

See also:

`polynomial.polynomial.polyvander`

Notes

Masked values in the input array result in rows of zeros.

Examples

```python
>>> x = np.array([1, 2, 3, 5])
>>> N = 3
>>> np.vander(x, N)
array([[ 1,  1,  1],
[ 4,  2,  1],
[ 9,  3,  1],
[25,  5,  1]])

>>> np.column_stack([x**(N-1-i) for i in range(N)])
array([[ 1,  1,  1],
[ 4,  2,  1],
[ 9,  3,  1],
[25,  5,  1]])

>>> x = np.array([1, 2, 3, 5])
>>> np.vander(x)
array([[ 1,  1,  1,  1],
[ 8,  4,  2,  1],
[27,  9,  3,  1],
[125, 25,  5,  1]])

>>> np.vander(x, increasing=True)
array([[ 1,  1,  1,  1],
[ 1,  2,  4,  8],
[ 1,  3,  9, 27],
[ 1,  5, 25, 125]])
```

The determinant of a square Vandermonde matrix is the product of the differences between the values of the input vector:

```python
>>> np.linalg.det(np.vander(x))
48.000000000000043

>>> (5-3)*(5-2)*(5-1)*(3-2)*(3-1)*(2-1)
48
```

```
numpy.ma.polyfit(x, y, deg, rcond=None, full=False, w=None, cov=False)
Least squares polynomial fit.

Fit a polynomial \(p(x) = p[0] * x^\deg + \ldots + p[\deg]\) of degree \(\deg\) to points \((x, y)\). Returns a vector of coefficients \(p\) that minimises the squared error.

Parameters

- \(x\) : array_like, shape (M,)
- \(y\) : array_like, shape (M,)
- \(deg\) : int
- \(rcond\) : float
- \(full\) : bool
- \(w\) : array_like
- \(cov\) : bool

Returns

- \(p\) : array_like
  - if \(cov\) is True, \(p\) and \(cov\) are returned
```

Chapter 3. Routines
x-coordinates of the M sample points \((x[i], \ y[i])\).

\(y\) : array_like, shape (M,) or (M, K)

y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

deg : int

Degree of the fitting polynomial

rcond : float, optional

Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is \(\text{len}(x)\ast\text{eps}\), where eps is the relative precision of the float type, about \(2\ast10^{-16}\) in most cases.

full : bool, optional

Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w : array_like, shape (M,), optional

weights to apply to the y-coordinates of the sample points.

cov : bool, optional

Return the estimate and the covariance matrix of the estimate If full is True, then cov is not returned.

Returns

\(p\) : ndarray, shape (M,) or (M, K)

Polynomial coefficients, highest power first. If \(y\) was 2-D, the coefficients for \(k\)-th data set are in \(p[:,k]\).

residuals, rank, singular_values, rcond :

Present only if full = True. Residuals of the least-squares fit, the effective rank of the scaled Vandermonde coefficient matrix, its singular values, and the specified value of rcond. For more details, see \textit{linalg.lstsq}.

\(V\) : ndarray, shape (M,M) or (M,M,K)

Present only if full = False and cov = True. The covariance matrix of the polynomial coefficient estimates. The diagonal of this matrix are the variance estimates for each coefficient. If \(y\) is a 2-D array, then the covariance matrix for the \(k\)-th data set are in \(V[:,:,k]\).

Warns

\textbf{RankWarning}

The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if full = False.

The warnings can be turned off by


>>> import warnings

>>> warnings.simplefilter('ignore', np.RankWarning)

See also:
polyval
Computes polynomial values.

linalg.lstsq
Computes a least-squares fit.

scipy.interpolate.UnivariateSpline
Computes spline fits.

Notes
Any masked values in x is propagated in y, and vice-versa.

References
[R52], [R53]

Examples
```python
>>> x = np.array([0.0, 1.0, 2.0, 3.0, 4.0, 5.0])
>>> y = np.array([0.0, 0.8, 0.9, 0.1, -0.8, -1.0])
>>> z = np.polyfit(x, y, 3)
>>> z
array([ 0.08703704, -0.81349206, 1.69312169, -0.03968254])
```

It is convenient to use `poly1d` objects for dealing with polynomials:
```python
>>> p = np.poly1d(z)
>>> p(0.5)
0.6143849206349179
>>> p(3.5)
-0.34732142857143039
>>> p(10)
22.579365079365115
```

High-order polynomials may oscillate wildly:
```python
>>> p30 = np.poly1d(np.polyfit(x, y, 30))
/... RankWarning: Polyfit may be poorly conditioned...
>>> p30(4)
-0.80000000000000204
>>> p30(5)
-0.99999999999999445
>>> p30(4.5)
-0.10547061179440398
```

Illustration:
```python
>>> import matplotlib.pyplot as plt
>>> xp = np.linspace(-2, 6, 100)
>>> _ = plt.plot(x, y, '.', xp, p(xp), '-', xp, p30(xp), '--')
>>> plt.ylim(-2,2)
(-2, 2)
>>> plt.show()
```
## Clipping and rounding

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<td><code>ma.around</code></td>
<td>Round an array to the given number of decimals.</td>
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<tr>
<td><code>ma.clip(a, a_min, a_max[, out])</code></td>
<td>Clip (limit) the values in an array.</td>
</tr>
<tr>
<td><code>ma.round(a[, decimals, out])</code></td>
<td>Return a copy of a, rounded to ’decimals’ places.</td>
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<tr>
<td><code>ma.MaskedArray.clip(a_min, a_max[, out])</code></td>
<td>Return an array whose values are limited to [a_min, a_max].</td>
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<td><code>ma.MaskedArray.round([decimals, out])</code></td>
<td>Return a with each element rounded to the given number of decimals.</td>
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**NumPy.ma.around**

Round an array to the given number of decimals.

Refer to `around` for full documentation.

See also:

**around**
equivalent function

**NumPy.ma.clip**

Given an interval, values outside the interval are clipped to the interval edges. For example, if an interval of [0, 1] is specified, values smaller than 0 become 0, and values larger than 1 become 1.

**Parameters**

- `a`: array_like
  - Array containing elements to clip.

- `a_min`: scalar or array_like
  - Minimum value.

- `a_max`: scalar or array_like
  - Maximum value. If `a_min` or `a_max` are array_like, then they will be broadcasted to the shape of `a`.

---

**3.19. Masked array operations**

---
out : ndarray, optional
The results will be placed in this array. It may be the input array for in-place clipping. 
out must be of the right shape to hold the output. Its type is preserved.

Returns

clipped_array : ndarray
An array with the elements of a, but where values < a_min are replaced with a_min, and 
those > a_max with a_max.

See also:

numpy.doc.ufuncs
Section “Output arguments”

Examples

>>> a = np.arange(10)
>>> np.clip(a, 1, 8)
array([1, 1, 2, 3, 4, 5, 6, 7, 8, 8])
>>> a
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> np.clip(a, 3, 6, out=a)
array([3, 3, 3, 3, 4, 5, 6, 6, 6, 6])
>>> a = np.arange(10)
>>> a
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> np.clip(a, [3,4,1,1,1,4,4,4,4,4], 8)
array([3, 4, 2, 3, 4, 5, 6, 7, 8, 8])

numpy.ma.round(a, decimals=0, out=None)
Return a copy of a, rounded to ‘decimals’ places.

When ‘decimals’ is negative, it specifies the number of positions to the left of the decimal point. The real and imaginary parts of complex numbers are rounded separately. Nothing is done if the array is not of float type and ‘decimals’ is greater than or equal to 0.

Parameters

decimals : int
Number of decimals to round to. May be negative.

out : array_like
Existing array to use for output. If not given, returns a default copy of a.

Notes
If out is given and does not have a mask attribute, the mask of a is lost!

MaskedArray.clip(a_min, a_max, out=None)
Return an array whose values are limited to [a_min, a_max].

Refer to numpy.clip for full documentation.

See also:

numpy.clip
equivalent function
**MaskedArray**.round\((\text{decimals}=0, \text{out}=\text{None})\)

Return a with each element rounded to the given number of decimals.

Refer to `numpy.around` for full documentation.

See also:

`numpy.around`

equivalent function

### Miscellanea

<table>
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<td><code>ma.allequal(a, b[, fill_value])</code></td>
<td>Return True if all entries of a and b are equal, using fill_value as a truth value where either or both are masked.</td>
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<tr>
<td><code>ma.allclose(a, b[, masked_equal, rtol, atol])</code></td>
<td>Returns True if two arrays are element-wise equal within a tolerance.</td>
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<td><code>ma.apply_along_axis(func1d, axis, arr,...)</code></td>
<td>Apply a function to 1-D slices along the given axis.</td>
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<td><code>ma.arange([start[, stop[, step[, dtype]])]</code></td>
<td>Return evenly spaced values within a given interval.</td>
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<tr>
<td><code>ma.choose(indices, choices[, out, mode])</code></td>
<td>Compute the differences between consecutive elements of an array.</td>
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<tr>
<td><code>ma.indices(dimensions[, dtype])</code></td>
<td>Return an array representing the indices of a grid.</td>
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<td><code>ma.where(condition[, x, y])</code></td>
<td>Return a masked array with elements from x or y, depending on condition.</td>
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**numpy.ma.allequal\((a, b, fill_value=True)\)**

Return True if all entries of a and b are equal, using fill_value as a truth value where either or both are masked.

**Parameters**

- **a, b**: array_like
  
  Input arrays to compare.

- **fill_value**: bool, optional
  
  Whether masked values in a or b are considered equal (True) or not (False).

**Returns**

- **y**: bool
  
  Returns True if the two arrays are equal within the given tolerance, False otherwise. If either array contains NaN, then False is returned.

See also:

`all, any, numpy.ma.allclose`

**Examples**

```python
>>> a = ma.array([1e10, 1e-7, 42.0], mask=[0, 0, 1])
>>> a
masked_array(data = [10000000000.0 1e-07 --],
mask = [False False True],
fill_value=1e+20)

>>> b = array([1e10, 1e-7, -42.0])
>>> b
array([ 1.00000000e+10, 1.00000000e-07, -4.20000000e+01])

>>> ma.allequal(a, b, fill_value=False)
False

>>> ma.allequal(a, b)
True
```
numpy.ma.allclose(a, b, masked_equal=True, rtol=1e-05, atol=1e-08)

Returns True if two arrays are element-wise equal within a tolerance.

This function is equivalent to allclose except that masked values are treated as equal (default) or unequal, depending on the masked_equal argument.

Parameters

a, b : array_like
Input arrays to compare.

masked_equal : bool, optional
Whether masked values in a and b are considered equal (True) or not (False). They are considered equal by default.

rtol : float, optional
Relative tolerance. The relative difference is equal to rtol * b. Default is 1e-5.

atol : float, optional
Absolute tolerance. The absolute difference is equal to atol. Default is 1e-8.

Returns

y : bool
Returns True if the two arrays are equal within the given tolerance, False otherwise. If either array contains NaN, then False is returned.

See also:
all, any

numpy.allclose
the non-masked allclose.

Notes

If the following equation is element-wise True, then allclose returns True:

absolute('a' - 'b') <= ('atol' + 'rtol' * absolute('b'))

Return True if all elements of a and b are equal subject to given tolerances.

Examples

>>> a = ma.array([1e10, 1e-7, 42.0], mask=[0, 0, 1])
>>> a
masked_array(data = [10000000000.0 1e-07 --],
             mask = [False False True],
             fill_value = 1e+20)
>>> b = ma.array([1e10, 1e-8, -42.0], mask=[0, 0, 1])
>>> ma.allclose(a, b)
False

>>> a = ma.array([1e10, 1e-8, 42.0], mask=[0, 0, 1])
>>> b = ma.array([1.00001e10, 1e-9, -42.0], mask=[0, 0, 1])
>>> ma.allclose(a, b)
True
>>> ma.allclose(a, b, masked_equal=False)
False

Masked values are not compared directly.
>>> a = ma.array([1e10, 1e-8, 42.0], mask=[0, 0, 1])
>>> b = ma.array([1.00001e10, 1e-9, 42.0], mask=[0, 0, 1])
>>> ma.allclose(a, b)
True
>>> ma.allclose(a, b, masked_equal=False)
False

numpy.ma.apply_along_axis(func1d, axis, arr, *args, **kwargs)

Apply a function to 1-D slices along the given axis.

Execute func1d(a, *args) where func1d operates on 1-D arrays and a is a 1-D slice of arr along axis.

Parameters

func1d : function
    This function should accept 1-D arrays. It is applied to 1-D slices of arr along the specified axis.

axis : integer
    Axis along which arr is sliced.

arr : ndarray
    Input array.

args : any
    Additional arguments to func1d.

kwargs: any
    Additional named arguments to func1d.

New in version 1.9.0.

Returns

apply_along_axis : ndarray
    The output array. The shape of outarr is identical to the shape of arr, except along the axis dimension, where the length of outarr is equal to the size of the return value of func1d. If func1d returns a scalar outarr will have one fewer dimensions than arr.

See also:

apply_over_axes
    Apply a function repeatedly over multiple axes.

Examples

>>> def my_func(a):
...     """Average first and last element of a 1-D array"""
...     return (a[0] + a[-1]) / 0.5
>>> b = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])
>>> np.apply_along_axis(my_func, 0, b)
array([ 4.,  5.,  6.])
>>> np.apply_along_axis(my_func, 1, b)
array([ 2.,  5.,  8.])

For a function that doesn’t return a scalar, the number of dimensions in outarr is the same as arr.
>>> b = np.array([[8, 1, 7], [4, 3, 9], [5, 2, 6]])
>>> np.apply_along_axis(sorted, 1, b)
array([[1, 7, 8],
      [4, 3, 9],
      [2, 5, 6]])

numpy.ma.arange([start], stop[, step], dtype=None) = <numpy.ma.core._convert2ma instance at 0x4243fa4c>

Return evenly spaced values within a given interval.

Values are generated within the half-open interval [start, stop) (in other words, the interval including start but excluding stop). For integer arguments the function is equivalent to the Python built-in range function, but returns an ndarray rather than a list.

When using a non-integer step, such as 0.1, the results will often not be consistent. It is better to use linspace for these cases.

Parameters

start : number, optional
    Start of interval. The interval includes this value. The default start value is 0.

stop : number
    End of interval. The interval does not include this value, except in some cases where step is not an integer and floating point round-off affects the length of out.

step : number, optional
    Spacing between values. For any output out, this is the distance between two adjacent values, out[i+1] - out[i]. The default step size is 1. If step is specified, start must also be given.

dtype : dtype
    The type of the output array. If dtype is not given, infer the data type from the other input arguments.

Returns

arange : ndarray
    Array of evenly spaced values.

    For floating point arguments, the length of the result is ceil((stop - start)/step). Because of floating point overflow, this rule may result in the last element of out being greater than stop.

See also:

linspace
    Evenly spaced numbers with careful handling of endpoints.

ogrid
    Arrays of evenly spaced numbers in N-dimensions.

mgrid
    Grid-shaped arrays of evenly spaced numbers in N-dimensions.

Examples

>>> np.arange(3)
array([0, 1, 2])

>>> np.arange(3.0)
array([ 0.,  1.,  2.])
>>> np.arange(3,7)
array([3, 4, 5, 6])
>>> np.arange(3,7,2)
array([3, 5])

numpy.ma.choose (indices, choices, out=None, mode='raise')

Use an index array to construct a new array from a set of choices.

Given an array of integers and a set of n choice arrays, this method will create a new array that merges each of the choice arrays. Where a value in a is i, the new array will have the value that choices[i] contains in the same place.

Parameters
   a : ndarray of ints
       This array must contain integers in [0, n-1], where n is the number of choices.
   choices : sequence of arrays
       Choice arrays. The index array and all of the choices should be broadcastable to the same shape.
   out : array, optional
       If provided, the result will be inserted into this array. It should be of the appropriate shape and dtype.
   mode : {'raise', 'wrap', 'clip'}, optional
       Specifies how out-of-bounds indices will behave.
       • 'raise': raise an error
       • 'wrap': wrap around
       • 'clip': clip to the range

Returns
   merged_array : array

See also:

choose
equivalent function

Examples
   >>> choice = np.array([[1,1,1], [2,2,2], [3,3,3]])
   >>> a = np.array([2, 1, 0])
   >>> np.ma.choose(a, choice)
mixed_array(data = [3 2 1],
           mask = False,
           fill_value=999999)

numpy.ma.ediff1d (arr, to_end=None, to_begin=None)

Compute the differences between consecutive elements of an array.

This function is the equivalent of numpy.ediff1d that takes masked values into account, see numpy.ediff1d for details.

See also:
**numpy.ediff1d**

Equivalent function for ndarrays.

**numpy.ma.indices** *(dimensions, dtype=<type 'int'>)*

Return an array representing the indices of a grid.

Compute an array where the subarrays contain index values 0,1,... varying only along the corresponding axis.

**Parameters**

- **dimensions** : sequence of ints
  - The shape of the grid.
- **dtype** : dtype, optional
  - Data type of the result.

**Returns**

- **grid** : ndarray
  - The array of grid indices, `grid.shape = (len(dimensions),) + tuple(dimensions)`.

**See also:**

mgrid, meshgrid

**Notes**

The output shape is obtained by prepending the number of dimensions in front of the tuple of dimensions, i.e. if `dimensions` is a tuple `(r0, ..., rN-1)` of length N, the output shape is `(N, r0, ..., rN-1)`.

The subarrays `grid[k]` contains the N-D array of indices along the k-th axis. Explicitly:

```python
grid[k,i0,i1,...,iN-1] = ik
```

**Examples**

```python
>>> grid = np.indices((2, 3))
>>> grid.shape
(2, 2, 3)
>>> grid[0]  # row indices
array([[0, 0, 0],
       [1, 1, 1]])
>>> grid[1]  # column indices
array([[0, 1, 2],
       [0, 1, 2]])
```

The indices can be used as an index into an array.

```python
>>> x = np.arange(20).reshape(5, 4)
>>> row, col = np.indices((2, 3))
>>> x[row, col]
array([[0, 1, 2],
       [4, 5, 6]])
```

Note that it would be more straightforward in the above example to extract the required elements directly with `x[:,2:3]`.

**numpy.ma.where** *(condition, x=None, y=None)*

Return a masked array with elements from x or y, depending on condition.
Returns a masked array, shaped like condition, where the elements are from x when condition is True, and from y otherwise. If neither x nor y are given, the function returns a tuple of indices where condition is True (the result of condition.nonzero()).

Parameters
condition : array_like, bool
    The condition to meet. For each True element, yield the corresponding element from x, otherwise from y.

x, y : array_like, optional
    Values from which to choose. x and y need to have the same shape as condition, or be broadcast-able to that shape.

Returns
out : MaskedArray or tuple of ndarrays
    The resulting masked array if x and y were given, otherwise the result of condition.nonzero().

See also:

numpy.where
    Equivalent function in the top-level NumPy module.

Examples

>>> x = np.ma.array(np.arange(9.).reshape(3, 3), mask=[[0, 1, 0],
...                                                  [1, 0, 1],
...                                                  [0, 1, 0]])
>>> print x
[[0.0 -- 2.0]
 [-- 4.0 --]
[6.0 -- 8.0]]
>>> np.ma.where(x > 5)    # return the indices where x > 5
(array([2, 2]), array([0, 2]))

>>> print np.ma.where(x > 5, x, -3.1416)
[[[-3.1416 -- -3.1416]
  [-- -3.1416 --]
[6.0 -- 8.0]]

3.20 Mathematical functions

3.20.1 Trigonometric functions

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| degrees(x[, out])  | Convert angles from radians to degrees. |
| radians(x[, out])  | Convert angles from degrees to radians. |
| unwrap(p[, discont, axis]) | Unwrap by changing deltas between values to 2*pi complement. |
| deg2rad(x[, out])  | Convert angles from degrees to radians. |
| rad2deg(x[, out])  | Convert angles from radians to degrees. |

```python
numpy.sin(x[, out]) = <ufunc 'sin'>
```

Trigonometric sine, element-wise.

**Parameters**

- `x`: array_like
  Angle, in radians (2π rad equals 360 degrees).

**Returns**

- `y`: array_like
  The sine of each element of x.

**See also:**

arcsin, sinh, cos

**Notes**

The sine is one of the fundamental functions of trigonometry (the mathematical study of triangles). Consider a circle of radius 1 centered on the origin. A ray comes in from the +x axis, makes an angle at the origin (measured counter-clockwise from that axis), and departs from the origin. The y coordinate of the outgoing ray’s intersection with the unit circle is the sine of that angle. It ranges from -1 for \( x = \frac{3\pi}{2} \) to +1 for \( \frac{\pi}{2} \). The function has zeroes where the angle is a multiple of \( \pi \). Sines of angles between \( \pi \) and \( 2\pi \) are negative. The numerous properties of the sine and related functions are included in any standard trigonometry text.

**Examples**

Print sine of one angle:

```python
>>> np.sin(np.pi/2.)
1.0
```

Print sines of an array of angles given in degrees:

```python
>>> np.sin(np.array((0., 30., 45., 60., 90.)) * np.pi / 180.)
array([ 0.        , 0.5        , 0.70710678, 0.8660254 , 1.        ])
```

Plot the sine function:

```python
>>> import matplotlib.pyplot as plt
>>> x = np.linspace(-np.pi, np.pi, 201)
>>> plt.plot(x, np.sin(x))
>>> plt.xlabel('Angle [rad]')
>>> plt.ylabel('sin(x)')
>>> plt.axis('tight')
>>> plt.show()
```
numpy.cos(x[, out]) = <ufunc 'cos'>
Cosine element-wise.

**Parameters**
- **x**: array_like
  Input array in radians.
- **out**: ndarray, optional
  Output array of same shape as x.

**Returns**
- **y**: ndarray
  The corresponding cosine values.

**Raises**
- **ValueError**: invalid return array shape
  if out is provided and out.shape != x.shape (See Examples)

**Notes**
If out is provided, the function writes the result into it, and returns a reference to out. (See Examples)

**References**

**Examples**

```python
gnp.cos(np.array([0, np.pi/2, np.pi])) array([ 1.00000000e+00, 6.12303177e-17, -1.00000000e+00])
```

```python
# Example of providing the optional output parameter
gnp.cos([0.1], out1) out2 is out1 True
gnp.cos([0.1], out1)
```

```python
# Example of ValueError due to provision of shape mis-matched 'out'
```
```python
>>> np.cos(np.zeros((3,3)),np.zeros((2,2)))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: invalid return array shape
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: invalid return array shape
```

```python
numpy.tan(x[, out]) = <ufunc 'tan'>
Compute tangent element-wise.

Equivalent to np.sin(x)/np.cos(x) element-wise.

Parameters

x : array_like
   Input array.

out : ndarray, optional
   Output array of same shape as x.

Returns

y : ndarray
   The corresponding tangent values.

Raises

ValueError: invalid return array shape
   if out is provided and out.shape != x.shape (See Examples)
```

Notes

If out is provided, the function writes the result into it, and returns a reference to out. (See Examples)

References


Examples

```python
>>> from math import pi
>>> np.tan(np.array([-pi,pi/2,pi]))
array([-1.22460635e-16, 1.63317787e+16, -1.22460635e-16])
```

```python
>>> # Example of providing the optional output parameter illustrating
>>> # that what is returned is a reference to said parameter
>>> out2 = np.cos([0.1], out1)
>>> out2 is out1
True
```

```python
>>> # Example of ValueError due to provision of shape mis-matched `out`
>>> np.cos(np.zeros((3,3)),np.zeros((2,2)))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: invalid return array shape
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: invalid return array shape
```
```python
numpy.arcsin(x[, out]) = <ufunc 'arcsin'>
Inverse sine, element-wise.

Parameters
  x : array_like
      y-coordinate on the unit circle.
  out : ndarray, optional
      Array of the same shape as x, in which to store the results. See doc.ufuncs
      (Section “Output arguments”) for more details.

Returns
  angle : ndarray
      The inverse sine of each element in x, in radians and in the closed interval
      [-pi/2, pi/2]. If x is a scalar, a scalar is returned, otherwise an array.

See also:
  sin, cos, arccos, tan, arctan, arctan2, emath.arcsin

Notes
  arcsin is a multivalued function: for each x there are infinitely many numbers
  z such that sin(z) = x. The convention is to return the angle z whose real part
  lies in [-pi/2, pi/2]. For real-valued input data types, arcsin always returns
  real output. For each value that cannot be expressed as a real number or infinity,
  it yields nan and sets the invalid floating point error flag.
  For complex-valued input, arcsin is a complex analytic function that has, by
  convention, the branch cuts [-inf, -1] and [1, inf] and is continuous from above
  on the former and from below on the latter.
  The inverse sine is also known as asin or sin^[-1].

References
  Abramowitz, M. and Stegun, I. A., Handbook of Mathematical Functions, 10th

Examples
  >>> np.arcsin(1)     # pi/2
  1.5707963267948966
  >>> np.arcsin(-1)    # -pi/2
  -1.5707963267948966
  >>> np.arcsin(0)     # 0
  0.0
```

numpy.arccos(x[, out]) = <ufunc 'arccos'>
Trigonometric inverse cosine, element-wise.

The inverse of cos so that, if y = cos(x), then x = arccos(y).

Parameters
  x : array_like
      x-coordinate on the unit circle. For real arguments, the domain is [-1, 1].
  out : ndarray, optional
      Array of the same shape as x, to store results in. See doc.ufuncs (Section
      “Output arguments”) for more details.
Returns

angle : ndarray

The angle of the ray intersecting the unit circle at the given x-coordinate in radians [0, pi]. If x is a scalar then a scalar is returned, otherwise an array of the same shape as x is returned.

See also:

cos, arctan, arcsin, emath.arccos

Notes

arccos is a multivalued function: for each x there are infinitely many numbers z such that cos(z) = x. The convention is to return the angle z whose real part lies in [0, pi].

For real-valued input data types, arccos always returns real output. For each value that cannot be expressed as a real number or infinity, it yields nan and sets the invalid floating point error flag.

For complex-valued input, arccos is a complex analytic function that has branch cuts [-inf, -1] and [1, inf] and is continuous from above on the former and from below on the latter.

The inverse cos is also known as acos or cos^-1.

References


Examples

We expect the arccos of 1 to be 0, and of -1 to be pi:

```python
>>> np.arccos([1, -1])
array([ 0. , 3.14159265])
```

Plot arccos:

```python
>>> import matplotlib.pyplot as plt
>>> x = np.linspace(-1, 1, num=100)
>>> plt.plot(x, np.arccos(x))
>>> plt.axis('tight')
>>> plt.show()
```
numpy.arctan(x[, out]) = <ufunc ‘arctan’>
Trigonometric inverse tangent, element-wise.
The inverse of tan, so that if y = tan(x) then x = arctan(y).

Parameters
   x : array_like
      Input values. arctan is applied to each element of x.

Returns
   out : ndarray
      Out has the same shape as x. Its real part is in [-pi/2, pi/2] (arctan(+/-inf) returns +/-pi/2). It is a scalar if x is a scalar.

See also:
   arctan2
      The “four quadrant” arctan of the angle formed by (x, y) and the positive x-axis.
   angle
      Argument of complex values.

Notes
   arctan is a multi-valued function: for each x there are infinitely many numbers z such that tan(z) = x. The convention is to return the angle z whose real part lies in [-pi/2, pi/2].

   For real-valued input data types, arctan always returns real output. For each value that cannot be expressed as a real number or infinity, it yields nan and sets the invalid floating point error flag.

   For complex-valued input, arctan is a complex analytic function that has [1j, infj] and [-1j, -infj] as branch cuts, and is continuous from the left on the former and from the right on the latter.

   The inverse tangent is also known as atan or tan^{-1}.

References
Examples

We expect the arctan of 0 to be 0, and of 1 to be $\pi/4$:

```python
>>> np.arctan([0, 1])
array([ 0. , 0.78539816])
```

```python
>>> np.pi/4
0.78539816339744828
```

Plot arctan:

```python
>>> import matplotlib.pyplot as plt

>>> x = np.linspace(-10, 10)

>>> plt.plot(x, np.arctan(x))

>>> plt.axis('tight')

>>> plt.show()
```

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```
Examples

```python
>>> np.hypot(3*np.ones((3, 3)), 4*np.ones((3, 3)))
array([[ 5.,  5.,  5.],
       [ 5.,  5.,  5.],
       [ 5.,  5.,  5.]])
```

Example showing broadcast of scalar_like argument:

```python
>>> np.hypot(3*np.ones((3, 3)), [4])
array([[ 5.,  5.,  5.],
       [ 5.,  5.,  5.],
       [ 5.,  5.,  5.]])
```

numpy.arctan2(x1, x2[, out]) = <ufunc 'arctan2'>

Element-wise arc tangent of \(x1/x2\) choosing the quadrant correctly.

The quadrant (i.e., branch) is chosen so that \(\arctan2(x1, x2)\) is the signed angle in radians between the ray ending at the origin and passing through the point \((1,0)\), and the ray ending at the origin and passing through the point \((x2, x1)\). (Note the role reversal: the “y-coordinate” is the first function parameter, the “x-coordinate” is the second.) By IEEE convention, this function is defined for \(x2 = \pm 0\) and for either or both of \(x1\) and \(x2 = \pm \infty\) (see Notes for specific values).

This function is not defined for complex-valued arguments; for the so-called argument of complex values, use \(\text{angle}\).

Parameters

- \(x1\) : array_like, real-valued
  y-coordinates.
- \(x2\) : array_like, real-valued
  x-coordinates. \(x2\) must be broadcastable to match the shape of \(x1\) or vice versa.

Returns

- \(angle\) : ndarray
  Array of angles in radians, in the range \([-\pi, \pi]\).

See also:

\(\text{arctan, tan, angle}\)

Notes

\(\arctan2\) is identical to the \(atan2\) function of the underlying C library. The following special values are defined in the C standard: [R6]

<table>
<thead>
<tr>
<th>(x1)</th>
<th>(x2)</th>
<th>(\arctan2(x1, x2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 0</td>
<td>+0</td>
<td>+/- 0</td>
</tr>
<tr>
<td>+/- 0</td>
<td>-0</td>
<td>+/- (\pi)</td>
</tr>
<tr>
<td>&gt; 0</td>
<td>+/- (\infty)</td>
<td>+0 / +(\pi)</td>
</tr>
<tr>
<td>&lt; 0</td>
<td>+/- (\infty)</td>
<td>-0 / -(\pi)</td>
</tr>
<tr>
<td>+/- (\infty)</td>
<td>+inf</td>
<td>+/- ((\pi/4))</td>
</tr>
<tr>
<td>+/- (\infty)</td>
<td>-inf</td>
<td>+/- (-3*(\pi/4))</td>
</tr>
</tbody>
</table>

Note that +0 and -0 are distinct floating point numbers, as are +\(\infty\) and -\(\infty\).

References

[R6]
Examples

Consider four points in different quadrants:

```python
>>> x = np.array([-1, +1, +1, -1])
>>> y = np.array([-1, -1, +1, +1])
>>> np.arctan2(y, x) * 180 / np.pi
array([-135., -45., 45., 135.])
```

Note the order of the parameters. `arctan2` is defined also when \( x_2 = 0 \) and at several other special points, obtaining values in the range \([-\pi, \pi]\):

```python
>>> np.arctan2([1., -1.], [0., 0.])
array([ 1.57079633, -1.57079633])
>>> np.arctan2([0., 0., np.inf], [+0., -0., np.inf])
array([ 0. , 3.14159265, 0.78539816])
```

```
numpy. degrees (x[, out]) = <ufunc 'degrees'>

Convert angles from radians to degrees.

Parameters

x : array_like
    Input array in radians.

out : ndarray, optional
    Output array of same shape as x.

Returns

y : ndarray of floats
    The corresponding degree values; if out was supplied this is a reference to it.

See also:

rad2deg
    equivalent function
```

Examples

Convert a radian array to degrees

```python
>>> rad = np.arange(12.)*np.pi/6
>>> np.degrees(rad)
array([ 0., 30., 60., 90., 120., 150., 180., 210., 240.,
       270., 300., 330.])
```

```python
>>> out = np.zeros((rad.shape))
>>> r = degrees(rad, out)
>>> np.all(r == out)
True
```

```
numpy. radians (x[, out]) = <ufunc 'radians'>

Convert angles from degrees to radians.

Parameters

x : array_like
    Input array in degrees.

out : ndarray, optional
    Output array of same shape as x.
```
Output array of same shape as $x$.

Returns

$y$: ndarray

The corresponding radian values.

See also:

deg2rad

equivalent function

Examples
Convert a degree array to radians

```python
>>> deg = np.arange(12.) * 30.
>>> np.radians(deg)
array([ 0.      , 0.52359878, 1.04719755, 1.57079633, 2.0943951 ,
       2.61799388, 3.14159265, 3.66519143, 4.1887902 , 4.71238898,
       5.23598776, 5.75958653])
```

```python
>>> out = np.zeros((deg.shape))
>>> ret = np.radians(deg, out)
>>> ret is out
True
```

numpy.unwrap ($p$, $discont=3.141592653589793$, $axis=-1$)

Unwrap by changing deltas between values to 2*pi complement.

Unwrap radian phase $p$ by changing absolute jumps greater than $discont$ to their 2*pi complement along the given axis.

Parameters

$p$: array_like

Input array.

discont: float, optional

Maximum discontinuity between values, default is $\pi$.

axis: int, optional

Axis along which unwrap will operate, default is the last axis.

Returns

$out$: ndarray

Output array.

See also:

rad2deg, deg2rad

Notes

If the discontinuity in $p$ is smaller than $\pi$, but larger than $discont$, no unwrapping is done because taking the 2*pi complement would only make the discontinuity larger.

Examples
```python
>>> phase = np.linspace(0, np.pi, num=5)
>>> phase[3:] += np.pi
>>> phase
array([ 0. , 0.78539816, 1.57079633, 5.49778714, 6.28318531])
>>> np.unwrap(phase)
array([ 0. , 0.78539816, 1.57079633, -0.78539816, 0. ])
```

### numpy.deg2rad(x[, out]) = <ufunc ‘deg2rad’>

Convert angles from degrees to radians.

**Parameters**

- `x : array_like`
  
  Angles in degrees.

**Returns**

- `y : ndarray`
  
  The corresponding angle in radians.

**See also:**

- `rad2deg`
  
  Convert angles from radians to degrees.

- `unwrap`
  
  Remove large jumps in angle by wrapping.

### Notes

New in version 1.3.0.

`deg2rad(x)` is `x * pi / 180`.

### Examples

```python
>>> np.deg2rad(180)
3.1415926535897931
```

### numpy.rad2deg(x[, out]) = <ufunc ‘rad2deg’>

Convert angles from radians to degrees.

**Parameters**

- `x : array_like`
  
  Angle in radians.

- `out : ndarray, optional`
  
  Array into which the output is placed. Its type is preserved and it must be of the right shape to hold the output. See doc.ufuncs.

**Returns**

- `y : ndarray`
  
  The corresponding angle in degrees.

**See also:**

- `deg2rad`
  
  Convert angles from degrees to radians.
unwrap
    Remove large jumps in angle by wrapping.

Notes
New in version 1.3.0.
    rad2deg(x) is 180 * x / pi.

Examples
    >>> np.rad2deg(np.pi/2)
    90.0

3.20.2 Hyperbolic functions

    sinh(x[, out]) Hyperbolic sine, element-wise.
    cosh(x[, out]) Hyperbolic cosine, element-wise.
    tanh(x[, out]) Compute hyperbolic tangent element-wise.
    arcsinh(x[, out]) Inverse hyperbolic sine element-wise.
    arccosh(x[, out]) Inverse hyperbolic cosine, element-wise.
    arctanh(x[, out]) Inverse hyperbolic tangent element-wise.

numpy.sinh(x[, out]) = <ufunc 'sinh'>
    Hyperbolic sine, element-wise.
    Equivalent to 1/2 * (np.exp(x) - np.exp(-x)) or -1j * np.sin(1j*x).

Parameters
    x : array_like
        Input array.
    out : ndarray, optional
        Output array of same shape as x.

Returns
    y : ndarray
        The corresponding hyperbolic sine values.

Raises
    ValueError: invalid return array shape
        if out is provided and out.shape != x.shape (See Examples)

Notes
If out is provided, the function writes the result into it, and returns a reference to out. (See Examples)

References

Examples
    >>> np.sinh(0)
    0.0

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```
>>> np.sinh(np.pi*1j/2)
1j
>>> np.sinh(np.pi*1j)  # (exact value is 0)
1.2246063538223773e-016j
>>> # Discrepancy due to vagaries of floating point arithmetic.

>>> # Example of providing the optional output parameter
>>> out2 = np.sinh([0.1], out1)
>>> out2 is out1
True

>>> # Example of ValueError due to provision of shape mis-matched 'out'
>>> np.sinh(np.zeros((3,3)),np.zeros((2,2)))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
    ValueError: invalid return array shape
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
    ValueError: invalid return array shape
```

```python
cosh(x[, out]) = <ufunc 'cosh'>

Hyperbolic cosine, element-wise.

Equivalent to 1/2 * (np.exp(x) + np.exp(-x)) and np.cos(1j*x).

Parameters
x : array_like
    Input array.

Returns
out : ndarray
    Output array of same shape as x.

Examples
>>> np.cosh(0)
1.0

The hyperbolic cosine describes the shape of a hanging cable:
```
>>> import matplotlib.pyplot as plt
>>> x = np.linspace(-4, 4, 1000)
>>> plt.plot(x, np.cosh(x))
>>> plt.show()```
numpy.tanh(x [, out]) = <ufunc ‘tanh’>
Compute hyperbolic tangent element-wise.

Equivalent to np.sinh(x)/np.cosh(x) or -1j * np.tan(1j*x).

Parameters
   x : array_like
      Input array.
   out : ndarray, optional
      Output array of same shape as x.

Returns
   y : ndarray
      The corresponding hyperbolic tangent values.

Raises
   ValueError: invalid return array shape
      if out is provided and out.shape != x.shape (See Examples)

Notes
If out is provided, the function writes the result into it, and returns a reference to out. (See Examples)

References
[R248], [R249]

Examples
>>> np.tanh([0, np.pi*1j, np.pi*1j/2])
array([ 0. +0.00000000e+00j, 0. -1.22460635e-16j, 0. +1.63317787e+16j])

>>> # Example of providing the optional output parameter illustrating
>>> # that what is returned is a reference to said parameter
>>> out2 = np.tanh([0.1], out1)
>>> out2 is out1
True
numpy.arcsinh(x[, out]) = <ufunc ‘arcsinh’>
Inverse hyperbolic sine element-wise.

Parameters
- x : array_like
  Input array.
- out : ndarray, optional
  Array into which the output is placed. Its type is preserved and it must be of the right shape to hold the output. See doc.ufuncs.

Returns
- out : ndarray
  Array of of the same shape as x.

Notes
arcsinh is a multivalued function: for each x there are infinitely many numbers z such that sinh(z) = x. The convention is to return the z whose imaginary part lies in [-pi/2, pi/2].

For real-valued input data types, arcsinh always returns real output. For each value that cannot be expressed as a real number or infinity, it returns nan and sets the invalid floating point error flag.

For complex-valued input, arccos is a complex analytical function that has branch cuts [1j, infj] and [-1j, -infj] and is continuous from the right on the former and from the left on the latter.

The inverse hyperbolic sine is also known as asinh or sinh^-1.

References
[R4], [R5]

Examples
>>> np.arcsinh(np.array([np.e, 10.0]))
array([ 1.72538256, 2.99822295])

numpy.arccosh(x[, out]) = <ufunc ‘arccosh’>
Inverse hyperbolic cosine, element-wise.

Parameters
- x : array_like
  Input array.
- out : ndarray, optional
  Array of the same shape as x, to store results in. See doc.ufuncs (Section “Output arguments”) for details.
Returns

\texttt{arccosh} : ndarray

Array of the same shape as \texttt{x}.

See also:
\texttt{cosh, arcsinh, sinh, arctanh, tanh}

Notes

\texttt{arccosh} is a multivalued function: for each \texttt{x} there are infinitely many numbers \texttt{z} such that \texttt{cosh(z) = x}. The convention is to return the \texttt{z} whose imaginary part lies in \([-\pi, \pi]\) and the real part in \([0, \infty]\).

For real-valued input data types, \texttt{arccosh} always returns real output. For each value that cannot be expressed as a real number or infinity, it yields \texttt{nan} and sets the \texttt{invalid} floating point error flag.

For complex-valued input, \texttt{arccosh} is a complex analytical function that has a branch cut \([-\infty, 1]\) and is continuous from above on it.

References

[R2], [R3]

Examples

```python
>>> np.arccosh([np.e, 10.0])
array([ 1.65745445, 2.99322285])
```

```
>>> np.arccosh(1)
0.0
```

\texttt{numpy.arctanh} \(x[, \text{ out}]) = <ufunc \text{\texttt{arctanh}}>

Inverse hyperbolic tangent element-wise.

Parameters

\texttt{x} : array_like

Input array.

Returns

\texttt{out} : ndarray

Array of the same shape as \texttt{x}.

See also:
\texttt{emath.arctanh}

Notes

\texttt{arctanh} is a multivalued function: for each \texttt{x} there are infinitely many numbers \texttt{z} such that \texttt{tanh(z) = x}. The convention is to return the \texttt{z} whose imaginary part lies in \([-\pi/2, \pi/2]\).

For real-valued input data types, \texttt{arctanh} always returns real output. For each value that cannot be expressed as a real number or infinity, it yields \texttt{nan} and sets the \texttt{invalid} floating point error flag.

For complex-valued input, \texttt{arctanh} is a complex analytical function that has branch cuts \([-1, -\infty]\) and \([1, \infty]\) and is continuous from above on the former and from below on the latter.

The inverse hyperbolic tangent is also known as \texttt{atanh} or \texttt{tanh^-1}.

References

[R7], [R8]
Examples

```python
>>> np.arctanh([0, -0.5])
array([ 0. , -0.54930614])
```

### 3.20.3 Rounding

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<td><code>trunc(x[, out])</code></td>
<td>Return the truncated value of the input, element-wise.</td>
</tr>
</tbody>
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**Parameters**

- `a` : array_like
  
  Input data.

- `decimals` : int, optional

  Number of decimal places to round to (default: 0). If decimals is negative, it specifies the number of positions to the left of the decimal point.

- `out` : ndarray, optional

  Alternative output array in which to place the result. It must have the same shape as the expected output, but the type of the output values will be cast if necessary. See `doc.ufuncs` (Section “Output arguments”) for details.

**Returns**

- `rounded_array` : ndarray

  An array of the same type as `a`, containing the rounded values. Unless `out` was specified, a new array is created. A reference to the result is returned.

  The real and imaginary parts of complex numbers are rounded separately. The result of rounding a float is a float.

**See also:**

- `ndarray.round`
  
  equivalent method

- `ceil, fix, floor, rint, trunc`

**Notes**

For values exactly halfway between rounded decimal values, Numpy rounds to the nearest even value. Thus 1.5 and 2.5 round to 2.0, -0.5 and 0.5 round to 0.0, etc. Results may also be surprising due to the inexact representation of decimal fractions in the IEEE floating point standard [R9] and errors introduced when scaling by powers of ten.
References

[R9], [R10]

Examples

```python
>>> np.around([0.37, 1.64])
array([ 0., 2.])
>>> np.around([0.37, 1.64], decimals=1)
array([ 0.4, 1.6])
>>> np.around([0.5, 1.5, 2.5, 3.5, 4.5])  # rounds to nearest even value
array([ 0., 2., 2., 4., 4.])
>>> np.around([1,2,3,11], decimals=-1)  # ndarray of ints is returned
array([ 0, 0, 0, 10])
```

```
numpy.round_(a, decimals=0, out=None)

Round an array to the given number of decimals.

Refer to around for full documentation.

See also:

around
equivalent function
```

```
numpy.rint(x, out) = <ufunc 'rint'>

Round elements of the array to the nearest integer.

Parameters

x : array_like

Input array.

Returns

out : {ndarray, scalar}

Output array is same shape and type as x.

See also:

ceil, floor, trunc
```

```
numpy.fix(x, y=None)

Round to nearest integer towards zero.

Round an array of floats element-wise to nearest integer towards zero. The rounded values are returned as floats.

Parameters

x : array_like

An array of floats to be rounded

y : ndarray, optional

Output array
```

3.20. Mathematical functions
Returns

out : ndarray of floats

The array of rounded numbers

See also:

trunc, floor, ceil

around

Round to given number of decimals

Examples

>>> np.fix(3.14)
3.0
>>> np.fix(3)
3.0
>>> np.fix([2.1, 2.9, -2.1, -2.9])
array([ 2.,  2., -2., -2.])

numpy.floor(x[, out]) = <ufunc ‘floor’>

Return the floor of the input, element-wise.

The floor of the scalar $x$ is the largest integer $i$, such that $i \leq x$. It is often denoted as $\lfloor x \rfloor$.

Parameters

x : array_like

Input data.

Returns

y : {ndarray, scalar}

The floor of each element in x.

See also:

ceil, trunc, rint

Notes

Some spreadsheet programs calculate the “floor-towards-zero”, in other words $\text{floor}(-2.5) == -2$. NumPy instead uses the definition of floor where $\text{floor}(-2.5) == -3$.

Examples

>>> a = np.array([-1.7, -1.5, -0.2, 0.2, 1.5, 1.7, 2.0])
>>> np.floor(a)
array([-2., -2., -1.,  0.,  1.,  1.,  2.])

numpy.ceil(x[, out]) = <ufunc ‘ceil’>

Return the ceiling of the input, element-wise.

The ceiling of the scalar $x$ is the smallest integer $i$, such that $i \geq x$. It is often denoted as $\lceil x \rceil$.

Parameters

x : array_like

Input data.

Returns

y : {ndarray, scalar}

The ceiling of each element in x, with float dtype.
See also:

`floor`, `trunc`, `rint`

**Examples**

```python
>>> a = np.array([-1.7, -1.5, -0.2, 0.2, 1.5, 1.7, 2.0])
>>> np.ceil(a)
array([-1., -1., -0., 1., 2., 2., 2.])
```

```python
numpy.trunc(x[, out]) = <ufunc 'trunc'>
```

Return the truncated value of the input, element-wise.

The truncated value of the scalar `x` is the nearest integer `i` which is closer to zero than `x` is. In short, the fractional part of the signed number `x` is discarded.

**Parameters**

- `x`: array_like
  
  Input data.

**Returns**

- `y`: {ndarray, scalar}
  
  The truncated value of each element in `x`.

See also:

`ceil`, `floor`, `rint`

**Notes**

New in version 1.3.0.

**Examples**

```python
>>> a = np.array([-1.7, -1.5, -0.2, 0.2, 1.5, 1.7, 2.0])
>>> np.trunc(a)
array([-1., -1., -0., 0., 1., 1., 2.])
```

### 3.20.4 Sums, products, differences

- `prod(a[, axis, dtype, out, keepdims])`  
  Return the product of array elements over a given axis.

- `sum(a[, axis, dtype, out, keepdims])`  
  Sum of array elements over a given axis.

- `nansum(a[, axis, dtype, out, keepdims])`  
  Return the sum of array elements over a given axis treating Not a Numbers (NaNs) as zero.

- `cumprod(a[, axis, dtype, out])`  
  Return the cumulative product of elements along a given axis.

- `cumsum(a[, axis, dtype, out])`  
  Return the cumulative sum of the elements along a given axis.

- `diff(a[, n, axis])`  
  Calculate the n-th order discrete difference along given axis.

- `ediff1d(ary[, to_end, to_begin])`  
  The differences between consecutive elements of an array.

- `gradient(f, *varargs, **kwargs)`  
  Return the gradient of an N-dimensional array.

- `cross(a, b[, axisa, axisb, axisc, axis])`  
  Return the cross product of two (arrays of) vectors.

- `trapz(y[, x, dx, axis])`  
  Integrate along the given axis using the composite trapezoidal rule.

```python
numpy.prod(a, axis=None, dtype=None, out=None, keepdims=False)
```

Return the product of array elements over a given axis.

**Parameters**

- `a`: array_like
Input data.

**axis**: None or int or tuple of ints, optional

Axis or axes along which a product is performed. The default ($axis = None$) is perform a product over all the dimensions of the input array. $axis$ may be negative, in which case it counts from the last to the first axis.

New in version 1.7.0.

If this is a tuple of ints, a product is performed on multiple axes, instead of a single axis or all the axes as before.

**dtype**: data-type, optional

The data-type of the returned array, as well as of the accumulator in which the elements are multiplied. By default, if $a$ is of integer type, $dtype$ is the default platform integer. (Note: if the type of $a$ is unsigned, then so is $dtype$.) Otherwise, the $dtype$ is the same as that of $a$.

**out**: ndarray, optional

Alternative output array in which to place the result. It must have the same shape as the expected output, but the type of the output values will be cast if necessary.

**keepdims**: bool, optional

If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original $arr$.

Returns

**product_along_axis**: ndarray, see $dtype$ parameter above.

An array shaped as $a$ but with the specified axis removed. Returns a reference to $out$ if specified.

See also:

- `ndarray.prod`
  equivalent method
- `numpy.doc.ufuncs`
  Section “Output arguments”

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow. That means that, on a 32-bit platform:

```python
>>> x = np.array([536870910, 536870910, 536870910, 536870910])
>>> np.prod(x)  #random
16
```

Examples

By default, calculate the product of all elements:

```python
>>> np.prod([1., 2.])
2.0
```

Even when the input array is two-dimensional:
>>> np.prod([[1.,2.],[3.,4.]])
24.0

But we can also specify the axis over which to multiply:

>>> np.prod([[1.,2.],[3.,4.]], axis=1)
array([ 2., 12.])

If the type of x is unsigned, then the output type is the unsigned platform integer:

>>> x = np.array([1, 2, 3], dtype=np.uint8)
>>> np.prod(x).dtype == np.uint
True

If x is of a signed integer type, then the output type is the default platform integer:

>>> x = np.array([1, 2, 3], dtype=np.int8)
>>> np.prod(x).dtype == np.int
True

*numpy.sum*(a, axis=None, dtype=None, out=None, keepdims=False)

Sum of array elements over a given axis.

Parameters

- **a**: array_like
  - Elements to sum.

- **axis**: None or int or tuple of ints, optional
  - Axis or axes along which a sum is performed. The default (*axis = None*) is perform a sum over all the dimensions of the input array. *axis* may be negative, in which case it counts from the last to the first axis.

  New in version 1.7.0.

  If this is a tuple of ints, a sum is performed on multiple axes, instead of a single axis or all the axes as before.

- **dtype**: dtype, optional
  - The type of the returned array and of the accumulator in which the elements are summed. By default, the dtype of *a* is used. An exception is when *a* has an integer type with less precision than the default platform integer. In that case, the default platform integer is used instead.

- **out**: ndarray, optional
  - Array into which the output is placed. By default, a new array is created. If *out* is given, it must be of the appropriate shape (the shape of *a* with *axis* removed, i.e., `numpy.delete(a.shape, axis)`). Its type is preserved. See doc.ufuncs (Section “Output arguments”) for more details.

- **keepdims**: bool, optional
  - If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *a*.

Returns

- **sum_along_axis**: ndarray
  - An array with the same shape as *a*, with the specified axis removed. If *a* is a 0-d array, or if *axis* is None, a scalar is returned. If an output array is specified, a reference to *out* is returned.
See also:

- `ndarray.sum`
  Equivalent method.
- `cumsum`
  Cumulative sum of array elements.
- `trapz`
  Integration of array values using the composite trapezoidal rule.
- `mean`, `average`

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

```python
>>> np.sum([0.5, 1.5])
2.0
>>> np.sum([0.5, 0.7, 0.2, 1.5], dtype=np.int32)
1
>>> np.sum([[0, 1], [0, 5]])
6
>>> np.sum([[0, 1], [0, 5]], axis=0)
array([0, 6])
>>> np.sum([[0, 1], [0, 5]], axis=1)
array([1, 5])
```

If the accumulator is too small, overflow occurs:

```python
>>> np.ones(128, dtype=np.int8).sum(dtype=np.int8)
-128
```

`numpy.nansum(a, axis=None, dtype=None, out=None, keepdims=0)`

Return the sum of array elements over a given axis treating Not a Numbers (NaNs) as zero.

In Numpy versions <= 1.8 NaN is returned for slices that are all-NaN or empty. In later versions zero is returned.

Parameters

- `a`: array_like
  Array containing numbers whose sum is desired. If `a` is not an array, a conversion is attempted.
- `axis`: int, optional
  Axis along which the sum is computed. The default is to compute the sum of the flattened array.
- `dtype`: data-type, optional
  The type of the returned array and of the accumulator in which the elements are summed. By default, the dtype of `a` is used. An exception is when `a` has an integer type with less precision than the platform (u)intp. In that case, the default will be either (u)int32 or (u)int64 depending on whether the platform is 32 or 64 bits. For inexact inputs, dtype must be inexact.

  New in version 1.8.0.
- `out`: ndarray, optional
Alternate output array in which to place the result. The default is None. If provided, it must have the same shape as the expected output, but the type will be cast if necessary. See doc.ufuncs for details. The casting of NaN to integer can yield unexpected results.

New in version 1.8.0.

keepdims : bool, optional
If True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original arr.

New in version 1.8.0.

Returns
y : ndarray or numpy scalar

See also:
numpy.sum
Sum across array propagating NaNs.

isnan
Show which elements are NaN.

isfinite
Show which elements are not NaN or +/-inf.

Notes
If both positive and negative infinity are present, the sum will be Not A Number (NaN).
Numpy integer arithmetic is modular. If the size of a sum exceeds the size of an integer accumulator, its value will wrap around and the result will be incorrect. Specifying dtype=double can alleviate that problem.

Examples
>>> np.nansum(1)
1
>>> np.nansum([1])
1
>>> np.nansum([1, np.nan])
1.0
>>> a = np.array([[[1], [1]], [1, np.nan]])
>>> np.nansum(a)
3.0
>>> np.nansum(a, axis=0)
array([ 2.,  1.])
>>> np.nansum([1, np.nan, np.inf])
inf
>>> np.nansum([1, np.nan, np.NINF])
-inf
>>> np.nansum([1, np.nan, np.inf, -np.inf]) # both +/- infinity present
nan

numpy.cumprod(a, axis=None, dtype=None, out=None)
Return the cumulative product of elements along a given axis.

Parameters
a : array_like
Input array.
axis : int, optional
    Axis along which the cumulative product is computed. By default the input is flattened.

dtype : dtype, optional
    Type of the returned array, as well as of the accumulator in which the elements are multiplied. If dtype is not specified, it defaults to the dtype of a, unless a has an integer dtype with a precision less than that of the default platform integer. In that case, the default platform integer is used instead.

out : ndarray, optional
    Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type of the resulting values will be cast if necessary.

Returns
    cumprod : ndarray
        A new array holding the result is returned unless out is specified, in which case a reference to out is returned.

See also:
    numpy.doc.ufuncs
        Section “Output arguments”

Notes
    Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples
    >>> a = np.array([1,2,3])
    >>> np.cumprod(a) # intermediate results 1, 1*2
    array([1, 2, 6])
    # total product 1*2*3 = 6

    >>> a = np.array([[1, 2, 3], [4, 5, 6]])
    >>> np.cumprod(a, dtype=float) # specify type of output
    array([[ 1.,  2.,  6.],
           [ 4., 20., 120.]])

    The cumulative product for each column (i.e., over the rows) of a:
    >>> np.cumprod(a, axis=0)
    array([[ 1,  2,  6],
           [ 4, 20, 120]])

    The cumulative product for each row (i.e. over the columns) of a:
    >>> np.cumprod(a,axis=1)
    array([[ 1,  2,  6],
           [ 4, 20, 120]])

    numpy.cumsum(a, axis=None, dtype=None, out=None)
    Return the cumulative sum of the elements along a given axis.

    Parameters
        a : array_like
            Input array.
        axis : int, optional
Axis along which the cumulative sum is computed. The default (None) is to compute the cumsum over the flattened array.

dtype : dtype, optional
    Type of the returned array and of the accumulator in which the elements are summed. If
dtype is not specified, it defaults to the dtype of a, unless a has an integer dtype with a
precision less than that of the default platform integer. In that case, the default platform
integer is used.

out : ndarray, optional
    Alternative output array in which to place the result. It must have the same shape
and buffer length as the expected output but the type will be cast if necessary. See
doc.ufuncs (Section “Output arguments”) for more details.

Returns
cumsum_along_axis : ndarray.
    A new array holding the result is returned unless out is specified, in which case a refer-
cence to out is returned. The result has the same size as a, and the same shape as a if
axis is not None or a is a 1-d array.

See also:

sum
    Sum array elements.

trapz
    Integration of array values using the composite trapezoidal rule.

diff
    Calculate the n-th order discrete difference along given axis.

Notes
Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

>>> a = np.array([[1, 2, 3], [4, 5, 6]])
>>> a
array([[1, 2, 3],
       [4, 5, 6]])
>>> np.cumsum(a)
array([ 1, 3, 6, 10, 15, 21])
>>> np.cumsum(a, dtype=float)  # specifies type of output value(s)
array([ 1., 3., 6., 10., 15., 21.])

>>> np.cumsum(a, axis=0)  # sum over rows for each of the 3 columns
array([[ 1,  3,  6, 10, 15, 21]])

>>> np.cumsum(a, axis=1)  # sum over columns for each of the 2 rows
array([[ 1,  3,  6],
       [ 4,  9, 15]])

numpy.diff(a, n=1, axis=-1)
    Calculate the n-th order discrete difference along given axis.

    The first order difference is given by out[n] = a[n+1] - a[n] along the given axis, higher order differ-
ences are calculated by using diff recursively.
Parameters
   a : array_like
       Input array
   n : int, optional
       The number of times values are differenced.
   axis : int, optional
       The axis along which the difference is taken, default is the last axis.

Returns
   diff : ndarray
       The n order differences. The shape of the output is the same as a except along axis where the dimension is smaller by n.

See also:
   gradient, ediff1d, cumsum

Examples
   >>> x = np.array([1, 2, 4, 7, 0])
   >>> np.diff(x)
   array([ 1, 2, 3, -7])
   >>> np.diff(x, n=2)
   array([ 1, 1, -10])
   >>> x = np.array([[1, 3, 6, 10], [0, 5, 6, 8]])
   >>> np.diff(x)
   array([[2, 3, 4],
          [5, 1, 2]])
   >>> np.diff(x, axis=0)
   array([[1, 2, 0, -2]])

numpy.ediff1d(ary, to_end=None, to_begin=None)
The differences between consecutive elements of an array.

Parameters
   ary : array_like
       If necessary, will be flattened before the differences are taken.
   to_end : array_like, optional
       Number(s) to append at the end of the returned differences.
   to_begin : array_like, optional
       Number(s) to prepend at the beginning of the returned differences.

Returns
   ediff1d : ndarray
       The differences. Loosely, this is ary.flat[1:] - ary.flat[:-1].

See also:
   diff, gradient
Notes
When applied to masked arrays, this function drops the mask information if the to_begin and/or to_end parameters are used.

Examples
>>> x = np.array([1, 2, 4, 7, 0])
>>> np.ediff1d(x)
array([ 1, 2, 3, -7])

The returned array is always 1D.

numpy.gradient(f, *varargs, **kwargs)
Return the gradient of an N-dimensional array.

The gradient is computed using second order accurate central differences in the interior and either first differences or second order accurate one-sides (forward or backwards) differences at the boundaries. The returned gradient hence has the same shape as the input array.

Parameters
f : array_like
An N-dimensional array containing samples of a scalar function.

varargs : list of scalar, optional
N scalars specifying the sample distances for each dimension, i.e. dx, dy, dz, ... Default distance: 1.

edge_order : {1, 2}, optional
Gradient is calculated using Nth order accurate differences at the boundaries. Default: 1.

New in version 1.9.1.

Returns
gradient : ndarray
N arrays of the same shape as f giving the derivative of f with respect to each dimension.

Examples
>>> x = np.array([1, 2, 4, 7, 11, 16], dtype=np.float)
>>> np.gradient(x)
array([ 1., 1.5, 2.5, 3.5, 4.5, 5. ])
>>> np.gradient(x, 2)
array([ 0.5 , 0.75, 1.25, 1.75, 2.25, 2.5 ])
```python
>>> x = np.array([0, 1, 2, 3, 4])
>>> dx = np.gradient(x)
>>> y = x**2
>>> np.gradient(y, dx, edge_order=2)
array([-0., 2., 4., 6., 8.])
```

```
numpy.cross(a, b, axisa=-1, axisb=-1, axisc=-1, axis=None)

Return the cross product of two (arrays of) vectors.

The cross product of \(a\) and \(b\) in \(\mathbb{R}^3\) is a vector perpendicular to both \(a\) and \(b\). If \(a\) and \(b\) are arrays of vectors, the vectors are defined by the last axis of \(a\) and \(b\) by default, and these axes can have dimensions 2 or 3. Where the dimension of either \(a\) or \(b\) is 2, the third component of the input vector is assumed to be zero and the cross product calculated accordingly. In cases where both input vectors have dimension 2, the \(z\)-component of the cross product is returned.

Parameters

- **a**: array_like
  Components of the first vector(s).
- **b**: array_like
  Components of the second vector(s).
- **axisa**: int, optional
  Axis of \(a\) that defines the vector(s). By default, the last axis.
- **axisb**: int, optional
  Axis of \(b\) that defines the vector(s). By default, the last axis.
- **axisc**: int, optional
  Axis of \(c\) containing the cross product vector(s). By default, the last axis.
- **axis**: int, optional
  If defined, the axis of \(a\), \(b\) and \(c\) that defines the vector(s) and cross product(s). Overrides \(axisa\), \(axisb\) and \(axisc\).

Returns

- **c**: ndarray
  Vector cross product(s).

Raises

- **ValueError**
  When the dimension of the vector(s) in \(a\) and/or \(b\) does not equal 2 or 3.

See also:

- **inner**
  Inner product
- **outer**
  Outer product.
- **ix_**
  Construct index arrays.
```
Notes

New in version 1.9.0.

Supports full broadcasting of the inputs.

Examples

Vector cross-product.

```python
>>> x = [1, 2, 3]
>>> y = [4, 5, 6]
>>> np.cross(x, y)
array([-3,  6, -3])
```

One vector with dimension 2.

```python
>>> x = [1, 2]
>>> y = [4, 5, 6]
>>> np.cross(x, y)
array([12, -6, -3])
```

Equivalently:

```python
>>> x = [1, 2, 0]
>>> y = [4, 5, 6]
>>> np.cross(x, y)
array([12, -6, -3])
```

Both vectors with dimension 2.

```python
>>> x = [1,2]
>>> y = [4,5]
>>> np.cross(x, y)
-3
```

Multiple vector cross-products. Note that the direction of the cross product vector is defined by the right-hand rule.

```python
>>> x = np.array([[1,2,3], [4,5,6]])
>>> y = np.array([[4,5,6], [1,2,3]])
>>> np.cross(x, y)
array([[-3,  6, -3],
       [ 3, -6,  3]])
```

The orientation of $c$ can be changed using the `axisc` keyword.

```python
>>> np.cross(x, y, axisc=0)
array([[-3,  3],
       [ 6, -6],
       [-3,  3]])
```

Change the vector definition of $x$ and $y$ using `axisa` and `axisb`.

```python
>>> x = np.array([[1,2,3], [4,5,6], [7, 8, 9]])
>>> y = np.array([[7, 8, 9], [4,5,6], [1,2,3]])
>>> np.cross(x, y)
array([[-6, 12, -6],
       [ 0,  0,  0],
       [ 6, -12,  6]])
>>> np.cross(x, y, axisa=0, axisb=0)
array([[-24,  48, -24],
       [ 32, -64,  32],
       [-24,  48, -24]])
```
**numpy.trapz**

Integrate along the given axis using the composite trapezoidal rule.

Integrate \( y(x) \) along given axis.

**Parameters**

- **y**: array_like
  - Input array to integrate.

- **x**: array_like, optional
  - If \( x \) is None, then spacing between all \( y \) elements is \( dx \).

- **dx**: scalar, optional
  - If \( x \) is None, spacing given by \( dx \) is assumed. Default is 1.

- **axis**: int, optional
  - Specify the axis.

**Returns**

- **trapz**: float
  - Definite integral as approximated by trapezoidal rule.

**See also:**

*sum, cumsum*

**Notes**

Image [R251] illustrates trapezoidal rule – \( y \)-axis locations of points will be taken from \( y \) array, by default \( x \)-axis distances between points will be 1.0, alternatively they can be provided with \( x \) array or with \( dx \) scalar. Return value will be equal to combined area under the red lines.

**References**

[R250], [R251]

**Examples**

```python
g>>> np.trapz([1,2,3])
4.0
g>>> np.trapz([1,2,3], x=[4,6,8])
8.0
g>>> np.trapz([1,2,3], dx=2)
8.0
g>>> a = np.arange(6).reshape(2, 3)
g>>> a
array([[0, 1, 2],
       [3, 4, 5]])
g>>> np.trapz(a, axis=0)
array([ 1.5, 2.5, 3.5])
g>>> np.trapz(a, axis=1)
array([ 2.,  8.])
```
3.20.5 Exponents and logarithms

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<td>Calculate the exponential of all elements in the input array.</td>
</tr>
<tr>
<td><code>expm1(x[, out])</code></td>
<td>Calculate ( \exp(x) - 1 ) for all elements in the array.</td>
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<tr>
<td><code>exp2(x[, out])</code></td>
<td>Calculate ( 2^x ) for all elements in the array.</td>
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<td><code>log(x[, out])</code></td>
<td>Natural logarithm, element-wise.</td>
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<td><code>log10(x[, out])</code></td>
<td>Return the base 10 logarithm of the input array, element-wise.</td>
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</tr>
<tr>
<td><code>logaddexp(x1, x2[, out])</code></td>
<td>Logarithm of the sum of exponentiations of the inputs.</td>
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<td>Logarithm of the sum of exponentiations of the inputs in base-2.</td>
</tr>
</tbody>
</table>

```
numpy.exp(x[, out]) = <ufunc 'exp'>
```

Calculate the exponential of all elements in the input array.

Parameters

\( x \) : array_like

Input values.

Returns

\( out \) : ndarray

Output array, element-wise exponential of \( x \).

See also:

- `expm1`
  - Calculate \( \exp(x) - 1 \) for all elements in the array.

- `exp2`
  - Calculate \( 2^x \) for all elements in the array.

Notes

The irrational number \( e \) is also known as Euler’s number. It is approximately 2.718281, and is the base of the natural logarithm, \( \ln \) (this means that, if \( x = \ln y = \log_e y \), then \( e^x = y \). For real input, \( \exp(x) \) is always positive.

For complex arguments, \( x = a + ib \), we can write \( e^x = e^a e^{ib} \). The first term, \( e^a \), is already known (it is the real argument, described above). The second term, \( e^{ib} \), is \( \cos b + i \sin b \), a function with magnitude 1 and a periodic phase.

References

[R18], [R19]

Examples

Plot the magnitude and phase of \( \exp(x) \) in the complex plane:

```python
>>> import matplotlib.pyplot as plt

>>> x = np.linspace(-2*np.pi, 2*np.pi, 100)
>>> xx = x + 1j * x[:, np.newaxis]  # a + ib over complex plane
>>> out = np.exp(xx)
```
```python
>>> plt.subplot(121)
>>> plt.imshow(np.abs(out),
... extent=[-2*np.pi, 2*np.pi, -2*np.pi, 2*np.pi])
>>> plt.title('Magnitude of exp(x)')

>>> plt.subplot(122)
>>> plt.imshow(np.angle(out),
... extent=[-2*np.pi, 2*np.pi, -2*np.pi, 2*np.pi])
>>> plt.title('Phase (angle) of exp(x)')
>>> plt.show()
```

```
import numpy as np

numpy.exp(x[, out]) = <ufunc 'expm1'>
Calculate \( \exp(x) - 1 \) for all elements in the array.

Parameters

- x : array_like
  Input values.

Returns

- out : ndarray
  Element-wise exponential minus one: \( \text{out} = \exp(x) - 1 \).

See also:

- log1p
  \( \log(1 + x) \), the inverse of expm1.

Notes

This function provides greater precision than \( \exp(x) - 1 \) for small values of \( x \).

Examples

The true value of \( \exp(1e-10) - 1 \) is \( 1.00000000005e-10 \) to about 32 significant digits. This example shows the superiority of expm1 in this case.
```
>>> np.expm1(1e-10)
1.00000000005e-10
>>> np.exp(1e-10) - 1
1.000000082740371e-10

\texttt{numpy.exp2}(x[, out]) = <ufunc ‘exp2’>
Calculate \(2^{p}\) for all \(p\) in the input array.

**Parameters**
- \(x\) : array_like
  Input values.
- \(out\) : ndarray, optional
  Array to insert results into.

**Returns**
- \(out\) : ndarray
  Element-wise 2 to the power \(x\).

**See also:**
- \texttt{power}

**Notes**
New in version 1.3.0.

**Examples**

```python
>>> np.exp2([2, 3])
array([4., 8.])
```

\texttt{numpy.log}(x[, out]) = <ufunc ‘log’>
Natural logarithm, element-wise.

The natural logarithm \(\log\) is the inverse of the exponential function, so that \(\log(\exp(x)) = x\). The natural logarithm is logarithm in base \(e\).

**Parameters**
- \(x\) : array_like
  Input value.

**Returns**
- \(y\) : ndarray
  The natural logarithm of \(x\), element-wise.

**See also:**
- \texttt{log10, log2, log1p, emath.log}

**Notes**
Logarithm is a multivalued function: for each \(x\) there is an infinite number of \(z\) such that \(\exp(z) = x\). The convention is to return the \(z\) whose imaginary part lies in \([-\pi, \pi]\).

For real-valued input data types, \texttt{log} always returns real output. For each value that cannot be expressed as a real number or infinity, it yields \texttt{nan} and sets the \texttt{invalid} floating point error flag.
For complex-valued input, \( \log \) is a complex analytical function that has a branch cut \([-\infty, 0]\) and is continuous from above on it. \( \log \) handles the floating-point negative zero as an infinitesimal negative number, conforming to the C99 standard.

References
[R44], [R45]

Examples

```python
>>> np.log([1, np.e, np.e**2, 0])
array([0., 1., 2., -Inf])
```

```
numpy.log(x[, out]) = <ufunc ‘log’>
```
Return the base 10 logarithm of the input array, element-wise.

Parameters
- `x`: array_like
  Input values.

Returns
- `y`: ndarray
  The logarithm to the base 10 of \( x \), element-wise. NaNs are returned where \( x \) is negative.

See also:
- `emath.log10`

Notes
Logarithm is a multivalued function: for each \( x \) there is an infinite number of \( z \) such that \( 10^z = x \). The convention is to return the \( z \) whose imaginary part lies in \([-\pi, \pi]\).

For real-valued input data types, \( \log10 \) always returns real output. For each value that cannot be expressed as a real number or infinity, it yields NaN and sets the invalid floating point error flag.

For complex-valued input, \( \log10 \) is a complex analytical function that has a branch cut \([-\infty, 0]\) and is continuous from above on it. \( \log10 \) handles the floating-point negative zero as an infinitesimal negative number, conforming to the C99 standard.

References
[R46], [R47]

Examples

```python
>>> np.log10([1e-15, -3.])
array([-15., NaN])
```

```
numpy.log10(x[, out]) = <ufunc ‘log10’>
```
Return the base 10 logarithm of \( x \), element-wise.

Parameters
- `x`: array_like
  Input values.

Returns
- `y`: ndarray
  The logarithm to the base 10 of \( x \), element-wise. NaNs are returned where \( x \) is negative.

See also:
- `emath.log10`

Notes
Logarithm is a multivalued function: for each \( x \) there is an infinite number of \( z \) such that \( 10^z = x \). The convention is to return the \( z \) whose imaginary part lies in \([-\pi, \pi]\).

For real-valued input data types, \( \log10 \) always returns real output. For each value that cannot be expressed as a real number or infinity, it yields NaN and sets the invalid floating point error flag.

For complex-valued input, \( \log10 \) is a complex analytical function that has a branch cut \([-\infty, 0]\) and is continuous from above on it. \( \log10 \) handles the floating-point negative zero as an infinitesimal negative number, conforming to the C99 standard.

References
[R46], [R47]

Examples

```python
>>> np.log10([1e-15, -3.])
array([-15., NaN])
```

```
numpy.log2(x[, out]) = <ufunc ‘log2’>
```
Base-2 logarithm of \( x \).

Parameters
- `x`: array_like
  Input values.

Returns
- `y`: ndarray
  Base-2 logarithm of \( x \).
See also:

log, log10, log1p, emath.log2

Notes

New in version 1.3.0.

Logarithm is a multivalued function: for each \( x \) there is an infinite number of \( z \) such that \( 2^z = x \). The convention is to return the \( z \) whose imaginary part lies in \([-\pi, \pi]\).

For real-valued input data types, \( \log_2 \) always returns real output. For each value that cannot be expressed as a real number or infinity, it yields \( \text{nan} \) and sets the invalid floating point error flag.

For complex-valued input, \( \log_2 \) is a complex analytical function that has a branch cut \([-\infty, 0]\) and is continuous from above on it. \( \log_2 \) handles the floating-point negative zero as an infinitesimal negative number, conforming to the C99 standard.

Examples

```python
>>> x = np.array([0, 1, 2, 2**4])
>>> np.log2(x)
array([-Inf, 0., 1., 4.])

>>> xi = np.array([0+1.j, 1, 2+0.j, 4.j])
>>> np.log2(xi)
array([ 0.+2.26618007j, 0.+0.j , 1.+0.j , 2.+2.26618007j])
```

numpy.log1p(x[, out]) = <ufunc 'log1p'>

Return the natural logarithm of one plus the input array, element-wise.

Calculates \( \log(1 + x) \).

Parameters

- x : array_like

  Input values.

Returns

- y : ndarray

  Natural logarithm of \( 1 + x \), element-wise.

See also:

expm1

\( \exp(x) - 1 \), the inverse of log1p.

Notes

For real-valued input, \( \log1p \) is accurate also for \( x \) so small that \( 1 + x == 1 \) in floating-point accuracy.

Logarithm is a multivalued function: for each \( x \) there is an infinite number of \( z \) such that \( \exp(z) = 1 + x \). The convention is to return the \( z \) whose imaginary part lies in \([-\pi, \pi]\).

For real-valued input data types, \( \log1p \) always returns real output. For each value that cannot be expressed as a real number or infinity, it yields \( \text{nan} \) and sets the invalid floating point error flag.

For complex-valued input, \( \log1p \) is a complex analytical function that has a branch cut \([-\infty, -1]\) and is continuous from above on it. \( \log1p \) handles the floating-point negative zero as an infinitesimal negative number, conforming to the C99 standard.
References
[R48], [R49]

Examples
>>> np.log1p(1e-99)
1e-99
>>> np.log(1 + 1e-99)
0.0

numpy.logaddexp(x1, x2[, out]) = <ufunc ‘logaddexp’>
Logarithm of the sum of exponentiations of the inputs.
Calculates log(exp(x1) + exp(x2)). This function is useful in statistics where the calculated probabilities of events may be so small as to exceed the range of normal floating point numbers. In such cases the logarithm of the calculated probability is stored. This function allows adding probabilities stored in such a fashion.

Parameters
x1, x2 : array_like
   Input values.

Returns
result : ndarray
   Logarithm of exp(x1) + exp(x2).

See also:
logaddexp2
Logarithm of the sum of exponentiations of inputs in base 2.

Notes
New in version 1.3.0.

Examples
>>> prob1 = np.log(1e-50)
>>> prob2 = np.log(2.5e-50)
>>> prob12 = np.logaddexp(prob1, prob2)
>>> prob12
-113.87649168120691
>>> np.exp(prob12)
3.5000000000000057e-50

numpy.logaddexp2(x1, x2[, out]) = <ufunc ‘logaddexp2’>
Logarithm of the sum of exponentiations of the inputs in base-2.
Calculates log2(2**x1 + 2**x2). This function is useful in machine learning when the calculated probabilities of events may be so small as to exceed the range of normal floating point numbers. In such cases the base-2 logarithm of the calculated probability can be used instead. This function allows adding probabilities stored in such a fashion.

Parameters
x1, x2 : array_like
   Input values.

out : ndarray, optional
Array to store results in.

**Returns**

- **result**: ndarray

  Base-2 logarithm of \(2^{x_1} + 2^{x_2}\).

**See also:**

- **logaddexp**: Logarithm of the sum of exponentiations of the inputs.

**Notes**

New in version 1.3.0.

**Examples**

```python
>>> prob1 = np.log2(1e-50)
>>> prob2 = np.log2(2.5e-50)
>>> prob12 = np.logaddexp2(prob1, prob2)
>>> prob1, prob2, prob12
(-166.09640474436813, -164.77447664948076, -164.28904982231052)
>>> 2**prob12
3.4999999999999914e-50
```

### 3.20.6 Other special functions

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<td>(i_0(x))</td>
<td>Modified Bessel function of the first kind, order 0.</td>
</tr>
<tr>
<td>(\text{sinc}(x))</td>
<td>Return the sinc function.</td>
</tr>
</tbody>
</table>

**numpy.i0(x)**

Modified Bessel function of the first kind, order 0.

Usually denoted \(I_0\). This function does broadcast, but will not “up-cast” int dtype arguments unless accompanied by at least one float or complex dtype argument (see Raises below).

**Parameters**

- **x**: array_like, dtype float or complex

  Argument of the Bessel function.

**Returns**

- **out**: ndarray, shape = x.shape, dtype = x.dtype

  The modified Bessel function evaluated at each of the elements of \(x\).

**Raises**

- **TypeError**: array cannot be safely cast to required type

  If argument consists exclusively of int dtypes.

**See also:**

- scipy.special.iv, scipy.special.ive

**Notes**

We use the algorithm published by Clenshaw \[R29\] and referenced by Abramowitz and Stegun \[R30\], for which the function domain is partitioned into the two intervals \([0,8]\) and \((8,\infty)\), and Chebyshev polynomial expansions...
are employed in each interval. Relative error on the domain [0,30] using IEEE arithmetic is documented [R31] as having a peak of 5.8e-16 with an rms of 1.4e-16 (n = 30000).

References
[R29], [R30], [R31]

Examples

```python
>>> np.i0([0.])
array(1.0)
>>> np.i0([0., 1. + 2j])
array([ 1.00000000+0.j , 0.18785373+0.64616944j])
```

`numpy.sinc(x)`

Return the sinc function.

The sinc function is \( \frac{\sin(\pi x)}{\pi x} \).

Parameters

- **x**: ndarray

  Array (possibly multi-dimensional) of values for which to calculate \( \text{sinc}(x) \).

Returns

- **out**: ndarray

  \( \text{sinc}(x) \), which has the same shape as the input.

Notes

\( \text{sinc}(0) \) is the limit value 1.

The name sinc is short for “sine cardinal” or “sinus cardinalis”.

The sinc function is used in various signal processing applications, including in anti-aliasing, in the construction of a Lanczos resampling filter, and in interpolation.

For bandlimited interpolation of discrete-time signals, the ideal interpolation kernel is proportional to the sinc function.

References

[R246], [R247]

Examples

```python
>>> x = np.linspace(-4, 4, 41)
>>> np.sinc(x)
array([-3.89804309e-17, -4.92362781e-02, -8.40918587e-02, -8.90384387e-02, -5.84680802e-02, 3.89804309e-17, 6.68206631e-02, 1.16434881e-01, 1.26137788e-01, 8.50444803e-02, -3.89804309e-17, -1.03943254e-01, -1.89206682e-01, -2.16236208e-01, -1.55914881e-01, 3.89804309e-17, 2.33872321e-01, 5.04551152e-01, 7.56826729e-01, 9.35489284e-01, 1.00000000e+00, 9.35489284e-01, 7.56826729e-01, 5.04551152e-01, 2.33872321e-01, 3.89804309e-17, -1.55914881e-01, -2.16236208e-01, -1.89206682e-01, -3.89804309e-17, 8.50444803e-02, 1.26137788e-01, 6.68206631e-02, 3.89804309e-17])
```
-5.84680802e-02, -8.90384387e-02, -8.40918587e-02, -4.92362781e-02, -3.89804309e-17

```python
>>> plt.plot(x, np.sinc(x))
[<matplotlib.lines.Line2D object at 0x...>]

>>> plt.title("Sinc Function")
<matplotlib.text.Text object at 0x...>

>>> plt.ylabel("Amplitude")
<matplotlib.text.Text object at 0x...>

>>> plt.xlabel("X")
<matplotlib.text.Text object at 0x...>

>>> plt.show()

It works in 2-D as well:

```python
>>> x = np.linspace(-4, 4, 401)

>>> xx = np.outer(x, x)

>>> plt.imshow(np.sinc(xx))
<matplotlib.image.AxesImage object at 0x...>
```

3.20.7 Floating point routines

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<th>Description</th>
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<td><code>signbit(x[, out])</code></td>
<td>Returns element-wise True where signbit is set (less than zero).</td>
</tr>
<tr>
<td><code>copysign(x1, x2[, out])</code></td>
<td>Change the sign of x1 to that of x2, element-wise.</td>
</tr>
<tr>
<td><code>frexp(x[, out1, out2])</code></td>
<td>Decompose the elements of x into mantissa and twos exponent.</td>
</tr>
<tr>
<td><code>ldexp(x1, x2[, out])</code></td>
<td>Returns x1 * 2**x2, element-wise.</td>
</tr>
</tbody>
</table>

**numpy.signbit(x[, out]) = <ufunc ‘signbit’>**

Returns element-wise True where signbit is set (less than zero).

**Parameters**

- x : array_like
  The input value(s).
- out : ndarray, optional
  Array into which the output is placed. Its type is preserved and it must be of the right shape to hold the output. See doc.ufuncs.

**Returns**

- result : ndarray of bool
  Output array, or reference to out if that was supplied.

**Examples**

```python
>>> np.signbit(-1.2)
True

>>> np.signbit(np.array([1, -2.3, 2.1]))
array([False,  True, False], dtype=bool)
```

**numpy.copysign(x1, x2[, out]) = <ufunc ‘copysign’>**

Change the sign of x1 to that of x2, element-wise.

If both arguments are arrays or sequences, they have to be of the same length. If x2 is a scalar, its sign will be copied to all elements of x1.
Parameters

x1 : array_like
   Values to change the sign of.

x2 : array_like
   The sign of x2 is copied to x1.

out : ndarray, optional
   Array into which the output is placed. Its type is preserved and it must be of the right
   shape to hold the output. See doc.ufuncs.

Returns

out : array_like
   The values of x1 with the sign of x2.

Examples

>>> np.copysign(1.3, -1)
-1.3
>>> 1/np.copysign(0, 1)
inf
>>> 1/np.copysign(0, -1)
-ninf

>>> np.copysign([-1, 0, 1], -1.1)
array([-1., -0., -1.])

numpy.frexp (x[, out1, out2]) = <ufunc ‘frexp’>

Decompose the elements of x into mantissa and twos exponent.

Returns (mantissa, exponent), where x = mantissa * 2**exponent’. The mantissa is lies in the open interval(-1, 1), while the twos exponent is a signed integer.

Parameters

x : array_like
   Array of numbers to be decomposed.

out1: ndarray, optional
   Output array for the mantissa. Must have the same shape as x.

out2: ndarray, optional
   Output array for the exponent. Must have the same shape as x.

Returns

(mantissa, exponent) : tuple of ndarrays, (float, int)

mantissa is a float array with values between -1 and 1. exponent is an int array which
represents the exponent of 2.

See also:

ldexp
Compute y = x1 * 2**x2, the inverse of frexp.
Notes
Complex dtypes are not supported, they will raise a TypeError.

Examples

```python
>>> x = np.arange(9)
```

```python
>>> y1, y2 = np.frexp(x)
```

```python
>>> y1
array([ 0. , 0.5 , 0.5 , 0.75 , 0.5 , 0.625, 0.75 , 0.875, 0.5 ])
```

```python
>>> y2
array([0, 1, 2, 2, 3, 3, 3, 3, 4])
```

```python
>>> y1 * 2**y2
array([ 0. , 1. , 2. , 3. , 4. , 5. , 6. , 7. , 8.])
```

```python
numpy.ldexp(x1, x2[, out]) = <ufunc ‘ldexp’>
```

Returns $x_1 \times 2^{x_2}$, element-wise.

The mantissas $x_1$ and twos exponents $x_2$ are used to construct floating point numbers $x_1 \times 2^{x_2}$.

Parameters

- **x1**: array_like
  Array of multipliers.

- **x2**: array_like, int
  Array of twos exponents.

- **out**: ndarray, optional
  Output array for the result.

Returns

- **y**: ndarray or scalar
  The result of $x_1 \times 2^{x_2}$.

See also:

- **frexp**: Return $(y1, y2)$ from $x = y1 \times 2^{y2}$, inverse to `ldexp`.

Notes
Complex dtypes are not supported, they will raise a TypeError.

`ldexp` is useful as the inverse of `frexp`, if used by itself it is more clear to simply use the expression $x_1 \times 2^{x_2}$.

Examples

```python
>>> np.ldexp(5, np.arange(4))
array([ 5., 10., 20., 40.], dtype=float32)
```

```python
>>> x = np.arange(6)
```

```python
>>> np.ldexp(*np.frexp(x))
array([ 0., 1., 2., 3., 4., 5.])
```
3.20.8 Arithmetic operations
### NumPy Reference, Release 1.9.2

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#### numpy

- **`add(x1, x2[, out])`**
  - Add arguments element-wise.

  **Parameters**
  - `x1, x2`: array_like
    - The arrays to be added. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which may be the shape of one or the other).

  **Returns**
  - `add`: ndarray or scalar
    - The sum of `x1` and `x2`, element-wise. Returns a scalar if both `x1` and `x2` are scalars.

  **Notes**
  - Equivalent to `x1 + x2` in terms of array broadcasting.

  **Examples**
  ```python
  >>> np.add(1.0, 4.0)
  5.0
  >>> x1 = np.arange(9.0).reshape((3, 3))
  >>> x2 = np.arange(3.0)
  >>> np.add(x1, x2)
  array([[ 0.,  2.,  4.],
         [ 3.,  5.,  7.],
         [ 6.,  8., 10.]])
  ```

- **`reciprocal(x[, out])`**
  - Return the reciprocal of the argument, element-wise.

  **Calculates** \(1/x\).

  **Parameters**
  - `x`: array_like
    - Input array.

  **Returns**
  - `y`: ndarray
    - Return array.
Notes

Note: This function is not designed to work with integers.

For integer arguments with absolute value larger than 1 the result is always zero because of the way Python handles integer division. For integer zero the result is an overflow.

Examples

```python
>>> np.reciprocal(2.)
0.5
>>> np.reciprocal([1, 2., 3.33])
array([ 1. , 0.5 , 0.3003003])
```

`numpy.negative(x[, out]) = <ufunc 'negative'>`
Numerical negative, element-wise.

Parameters
- `x`: array_like or scalar
  Input array.

Returns
- `y`: ndarray or scalar
  Returned array or scalar: \( y = -x \).

Examples

```python
>>> np.negative([1.,-1.])
array([-1., 1.])
```

`numpy.multiply(x1, x2[, out]) = <ufunc 'multiply'>`
Multiply arguments element-wise.

Parameters
- `x1`, `x2`: array_like
  Input arrays to be multiplied.

Returns
- `y`: ndarray
  The product of \( x1 \) and \( x2 \), element-wise. Returns a scalar if both \( x1 \) and \( x2 \) are scalars.

Notes
Equivalent to \( x1 \times x2 \) in terms of array broadcasting.

Examples

```python
>>> np.multiply(2.0, 4.0)
8.0
```

```python
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> np.multiply(x1, x2)
array([[ 0.,  1.,  4.],
       [ 0.,  4., 10.],
       [ 0.,  7., 16.]])
```
numpy.divide(x1, x2[, out]) = <ufunc ‘divide’>
Divide arguments element-wise.

Parameters
   x1 : array_like
      Dividend array.
   x2 : array_like
      Divisor array.
   out : ndarray, optional
      Array into which the output is placed. Its type is preserved and it must be of the right
      shape to hold the output. See doc.ufuncs.

Returns
   y : {ndarray, scalar}
      The quotient x1/x2, element-wise. Returns a scalar if both x1 and x2 are scalars.

See also:
   seterr
      Set whether to raise or warn on overflow, underflow and division by zero.

Notes
   Equivalent to x1 / x2 in terms of array-broadcasting.

Behavior on division by zero can be changed using seterr.

When both x1 and x2 are of an integer type, divide will return integers and throw away the fractional part.
Moreover, division by zero always yields zero in integer arithmetic.

Examples
   >>> np.divide(2.0, 4.0)
   0.5
   >>> x1 = np.arange(9.0).reshape((3, 3))
   >>> x2 = np.arange(3.0)
   >>> np.divide(x1, x2)
   array([[Inf, 1., 1.],
          [Inf, 4., 2.5],
          [Inf, 7., 4.]])

Note the behavior with integer types:
   >>> np.divide(2, 4)
   0
   >>> np.divide(2, 4.)
   0.5

Division by zero always yields zero in integer arithmetic, and does not raise an exception or a warning:
   >>> np.divide(np.array([0, 1], dtype=int), np.array([0, 0], dtype=int))
   array([[0]])

Division by zero can, however, be caught using seterr:
```python
>>> old_err_state = np.seterr(divide='raise')
>>> np.divide(1, 0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
FloatingPointError: divide by zero encountered in divide
>>> ignored_states = np.seterr(**old_err_state)
>>> np.divide(1, 0)
0
```

```
numpy.power(x1, x2[, out]) = <ufunc 'power'>

First array elements raised to powers from second array, element-wise.

Raise each base in x1 to the positionally-corresponding power in x2. x1 and x2 must be broadcastable to the same shape.

**Parameters**

- **x1**: array_like
  - The bases.
- **x2**: array_like
  - The exponents.

**Returns**

- **y**: ndarray
  - The bases in x1 raised to the exponents in x2.

**Examples**

Cube each element in a list.

```python
>>> x1 = range(6)
>>> x1
[0, 1, 2, 3, 4, 5]
>>> np.power(x1, 3)
array([ 0,  1,  8, 27, 64, 125])
```

Raise the bases to different exponents.

```python
>>> x2 = [1.0, 2.0, 3.0, 3.0, 2.0, 1.0]
>>> np.power(x1, x2)
array([ 0.,  1.,  8., 27., 16.,   5.])
```

The effect of broadcasting.

```python
>>> x2 = np.array([[1, 2, 3, 3, 2, 1], [1, 2, 3, 3, 2, 1]])
>>> x2
array([[1, 2, 3, 3, 2, 1],
       [1, 2, 3, 3, 2, 1]])
>>> np.power(x1, x2)
array([[ 0,  1,  8, 27, 16,  5],
       [ 0,  1,  8, 27, 16,  5]])
```

```
numpy.subtract(x1, x2[, out]) = <ufunc 'subtract'>

Subtract arguments, element-wise.
```
Parameters

.. code-block:: python

   x1, x2 : array_like

   The arrays to be subtracted from each other.

Returns

.. code-block:: python

   y : ndarray

   The difference of x1 and x2, element-wise. Returns a scalar if both x1 and x2 are scalars.

Notes

Equivalent to x1 - x2 in terms of array broadcasting.

Examples

>>> np.subtract(1.0, 4.0)
-3.0

>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> np.subtract(x1, x2)
array([[ 0.,  0.,  0.],
       [ 3.,  3.,  3.],
       [ 6.,  6.,  6.]])

numpy.true_divide(x1, x2[, out]) = <ufunc 'true_divide'>

Returns a true division of the inputs, element-wise.

Instead of the Python traditional ‘floor division’, this returns a true division. True division adjusts the output
type to present the best answer, regardless of input types.

Parameters

.. code-block:: python

   x1 : array_like

   Dividend array.

   x2 : array_like

   Divisor array.

Returns

.. code-block:: python

   out : ndarray

   Result is scalar if both inputs are scalar, ndarray otherwise.

Notes

The floor division operator // was added in Python 2.2 making // and / equivalent operators. The default floor
division operation of / can be replaced by true division with from __future__ import division.

In Python 3.0, // is the floor division operator and / the true division operator. The true_divide(x1, x2) function is equivalent to true division in Python.

Examples

>>> x = np.arange(5)
>>> np.true_divide(x, 4)
array([ 0. ,  0.25,  0.5 ,  0.75,   1. ])

>>> x/4
array([0, 0, 0, 0, 1])
numpy.floor_divide(x1, x2[, out]) = <ufunc 'floor_divide'>

Return the largest integer smaller or equal to the division of the inputs.

Parameters

x1 : array_like
    Numerator.

x2 : array_like
    Denominator.

Returns

y : ndarray
    y = floor(x1/x2)

See also:

divide
    Standard division.

floor
    Round a number to the nearest integer toward minus infinity.

ceil
    Round a number to the nearest integer toward infinity.

Examples

```python
g through 7
array([0, 0, 0, 1])
g through 7
array([ 0., 0.25, 0.5, 0.75, 1.])
g through 7
array([0, 0, 0, 0, 1])
```
The remainder of the division of $x_1$ by $x_2$.

See also:

**remainder**
Equivalent to the Python `%` operator.

**divide**

Notes
The result of the modulo operation for negative dividend and divisors is bound by conventions. For `fmod`, the sign of result is the sign of the dividend, while for `remainder` the sign of the result is the sign of the divisor. The `fmod` function is equivalent to the Matlab(TM) `rem` function.

Examples

```python
>>> np.fmod([-3, -2, -1, 1, 2, 3], 2)
array([-1, 0, -1, 1, 0, 1])
>>> np.remainder([-3, -2, -1, 1, 2, 3], 2)
array([1, 0, 1, 1, 0, 1])
>>> np.fmod([5, 3], [2, 2.])
array([1., 1.])
>>> a = np.arange(-3, 3).reshape(3, 2)
>>> a
array([[-3, -2],
       [-1,  0],
       [ 1,  2]])
>>> np.fmod(a, [2, 2])
array([[-1,  0],
       [-1,  0],
       [ 1,  0]])
```

**numpy.mod**(x1, x2[, out]) = <ufunc ‘remainder’>
Return element-wise remainder of division.

Computes $x_1 - \text{floor}(x_1 / x_2) \times x_2$, the result has the same sign as the divisor $x_2$. It is equivalent to the Python modulus operator $x_1 \% x_2$ and should not be confused with the Matlab(TM) `rem` function.

Parameters

- **x1**: array_like
  Dividend array.

- **x2**: array_like
  Divisor array.

- **out**: ndarray, optional
  Array into which the output is placed. Its type is preserved and it must be of the right shape to hold the output. See doc.ufuncs.

Returns

- **y**: ndarray
  The remainder of the quotient $x_1/x_2$, element-wise. Returns a scalar if both $x_1$ and $x_2$ are scalars.

See also:
fmod
   Equivalent of the Matlab(TM) rem function.

divide, floor

Notes
Returns 0 when x2 is 0 and both x1 and x2 are (arrays of) integers.

Examples
>>> np.remainder([4, 7], [2, 3])
array([0, 1])
>>> np.remainder(np.arange(7), 5)
array([0, 1, 2, 3, 4, 0, 1])

numpy.modf(x[, out1, out2]) = <ufunc 'modf'>
Return the fractional and integral parts of an array, element-wise.

The fractional and integral parts are negative if the given number is negative.

Parameters
   x : array_like
      Input array.

Returns
   y1 : ndarray
      Fractional part of x.
   y2 : ndarray
      Integral part of x.

Notes
For integer input the return values are floats.

Examples
>>> np.modf([0, 3.5])
(array([ 0. , 0.5]), array([ 0., 3.]))
>>> np.modf(-0.5)
(-0.5, -0)

numpy.remainder(x1, x2[, out]) = <ufunc 'remainder'>
Return element-wise remainder of division.

Computes x1 - floor(x1 / x2) * x2, the result has the same sign as the divisor x2. It is equivalent to
the Python modulus operator x1 % x2 and should not be confused with the Matlab(TM) rem function.

Parameters
   x1 : array_like
      Dividend array.
   x2 : array_like
      Divisor array.
   out : ndarray, optional
Array into which the output is placed. Its type is preserved and it must be of the right shape to hold the output. See doc.ufuncs.

**Returns**

- y : ndarray
  
  The remainder of the quotient \( x1/x2 \), element-wise. Returns a scalar if both \( x1 \) and \( x2 \) are scalars.

**See also:**

- **fmod**
  
  Equivalent of the Matlab(TM) \( \text{rem} \) function.

- **divide, floor**

**Notes**

Returns 0 when \( x2 \) is 0 and both \( x1 \) and \( x2 \) are (arrays of) integers.

**Examples**

```python
>>> np.remainder([4, 7], [2, 3])
array([0, 1])
```

```python
>>> np.remainder(np.arange(7), 5)
array([0, 1, 2, 3, 4, 0, 1])
```

### 3.20.9 Handling complex numbers

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<td><code>angle(z[, deg=0])</code></td>
<td>Return the angle of the complex argument.</td>
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<tr>
<td><code>real(val)</code></td>
<td>Return the real part of the elements of the array.</td>
</tr>
<tr>
<td><code>imag(val)</code></td>
<td>Return the imaginary part of the elements of the array.</td>
</tr>
<tr>
<td><code>conj(x[, out])</code></td>
<td>Return the complex conjugate, element-wise.</td>
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**numpy.angle**(z, deg=0)

Return the angle of the complex argument.

**Parameters**

- z : array_like
  
  A complex number or sequence of complex numbers.

- deg : bool, optional
  
  Return angle in degrees if True, radians if False (default).

**Returns**

- angle : {ndarray, scalar}
  
  The counterclockwise angle from the positive real axis on the complex plane, with dtype as `numpy.float64`.

**See also:**

- `arctan2`, `absolute`
Examples

```python
>>> np.angle([1.0, 1.0j, 1+1j]) # in radians
array([ 0. , 1.57079633, 0.78539816])
```

```python
>>> np.angle(1+1j, deg=True) # in degrees
45.0
```

**numpy.real (val)**

Return the real part of the elements of the array.

**Parameters**

- **val**: array_like
  Input array.

**Returns**

- **out**: ndarray
  Output array. If `val` is real, the type of `val` is used for the output. If `val` has complex elements, the returned type is float.

See also:

- `real_if_close`, `imag`, `angle`

**Examples**

```python
>>> a = np.array([1+2j, 3+4j, 5+6j])
>>> a.real
array([ 1., 3., 5.])
```

```python
>>> a.real = 9
>>> a
array([ 9.+2.j, 9.+4.j, 9.+6.j])
```

```python
>>> a.real = np.array([9, 8, 7])
>>> a
array([ 9.+2.j, 8.+4.j, 7.+6.j])
```

**numpy.imag (val)**

Return the imaginary part of the elements of the array.

**Parameters**

- **val**: array_like
  Input array.

**Returns**

- **out**: ndarray
  Output array. If `val` is real, the type of `val` is used for the output. If `val` has complex elements, the returned type is float.

See also:

- `real`, `angle`, `real_if_close`

**Examples**

```python
>>> a = np.array([1+2j, 3+4j, 5+6j])
>>> a.imag
array([ 2., 4., 6.])
```

```python
>>> a.imag = np.array([8, 10, 12])
>>> a
array([ 1. +8.j, 3.+10.j, 5.+12.j])
```
**numpy.conj**(x[, out]) = <ufunc ‘conjugate’>

Return the complex conjugate, element-wise.

The complex conjugate of a complex number is obtained by changing the sign of its imaginary part.

**Parameters**

- **x**: array_like
  - Input value.

**Returns**

- **y**: ndarray
  - The complex conjugate of x, with same dtype as y.

**Examples**

```python
c>>> np.conjugate(1+2j)
(1-2j)
c>>> x = np.eye(2) + 1j * np.eye(2)
c>>> np.conjugate(x)
array([[ 1.-1.j, 0.-0.j],
       [ 0.-0.j, 1.-1.j]])
```

### 3.20.10 Miscellaneous

**numpy.convolve**(a, v[, mode])

Returns the discrete, linear convolution of two one-dimensional sequences.

The convolution operator is often seen in signal processing, where it models the effect of a linear time-invariant system on a signal [R17]. In probability theory, the sum of two independent random variables is distributed according to the convolution of their individual distributions.

If v is longer than a, the arrays are swapped before computation.

**Parameters**

- **a**: (N,) array_like
  - First one-dimensional input array.
- **v**: (M,) array_like
  - Second one-dimensional input array.

**Returns**

- **y**: ndarray
  - Array containing the convolution.

**Notes**

- The convolution of two vectors is defined as
  \[ (a * b)[n] = \sum_{m=-\infty}^{\infty} a[m] b[n-m] \]
  for any sequences a and b.

- If a and v are both one-dimensional, the output extends from the minimum to the maximum of the indices of a and v.

- The convolution of a one-dimensional vector a with itself is called an autocorrelation.

- The convolution of a one-dimensional vector a with a reversed version of itself is called a cross-correlation.

**Examples**

```python
c>>> np.convolve([1, 2, 3], [0, 1, 0.5])
array([ 0.5, 1.0, 2.0, 1.5])
c>>> np.convolve([1, 2, 3], [0, 1, 0.5], mode='valid')
array([ 1. , 2. , 1.5])
c>>> np.convolve([1, 2, 3], [0, 1, 0.5], mode='same')
array([ 1.5, 2. , 1. , 0.5])
```
Second one-dimensional input array.

**mode**: {'full', 'valid', 'same'}, optional

- **'full'**: By default, mode is 'full'. This returns the convolution at each point of overlap, with an output shape of (N+M-1). At the end-points of the convolution, the signals do not overlap completely, and boundary effects may be seen.

- **'same'**: Mode same returns output of length \( \max(M, N) \). Boundary effects are still visible.

- **'valid'**: Mode valid returns output of length \( \max(M, N) - \min(M, N) + 1 \). The convolution product is only given for points where the signals overlap completely. Values outside the signal boundary have no effect.

**Returns**

**out**: ndarray

Discrete, linear convolution of \( a \) and \( v \).

**See also:**

- **scipy.signal.fftconvolve**: Convolve two arrays using the Fast Fourier Transform.
- **scipy.linalg.toeplitz**: Used to construct the convolution operator.
- **polymul**: Polynomial multiplication. Same output as convolve, but also accepts poly1d objects as input.

**Notes**

The discrete convolution operation is defined as

\[
(a * v)[n] = \sum_{m=-\infty}^{\infty} a[m]v[n - m]
\]

It can be shown that a convolution \( x(t) * y(t) \) in time/space is equivalent to the multiplication \( X(f)Y(f) \) in the Fourier domain, after appropriate padding (padding is necessary to prevent circular convolution). Since multiplication is more efficient (faster) than convolution, the function scipy.signal.fftconvolve exploits the FFT to calculate the convolution of large data-sets.

**References**

[R17]

**Examples**

Note how the convolution operator flips the second array before “sliding” the two across one another:

```python
>>> np.convolve([1, 2, 3], [0, 1, 0.5])
array([ 0. , 1. , 2.5, 4. , 1.5])
```

Only return the middle values of the convolution. Contains boundary effects, where zeros are taken into account:

```python
>>> np.convolve([1,2,3],[0,1,0.5], 'same')
array([ 1. , 2.5, 4. ])
```
The two arrays are of the same length, so there is only one position where they completely overlap:

```python
gnp.convolve([1,2,3],[0,1,0.5], 'valid')
array([ 2.5])
```

**numpy.clip(a, a_min, a_max, out=None)**

Clip (limit) the values in an array.

Given an interval, values outside the interval are clipped to the interval edges. For example, if an interval of $[0, 1]$ is specified, values smaller than 0 become 0, and values larger than 1 become 1.

**Parameters**

- **a**: array_like
  Array containing elements to clip.

- **a_min**: scalar or array_like
  Minimum value.

- **a_max**: scalar or array_like
  Maximum value. If `a_min` or `a_max` are array_like, then they will be broadcasted to the shape of `a`.

- **out**: ndarray, optional
  The results will be placed in this array. It may be the input array for in-place clipping. `out` must be of the right shape to hold the output. Its type is preserved.

**Returns**

- **clipped_array**: ndarray
  An array with the elements of `a`, but where values < `a_min` are replaced with `a_min`, and those > `a_max` with `a_max`.

**See also:**

- **numpy.doc.ufuncs**
  Section “Output arguments”

**Examples**

```python
>>> a = np.arange(10)
>>> np.clip(a, 1, 8)
array([1, 1, 2, 3, 4, 5, 6, 7, 8, 8])
```

```python
>>> a = np.arange(10)
>>> a
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

```python
>>> np.clip(a, [3, 4, 1, 1, 4, 4, 4, 4], 8)
array([3, 4, 2, 3, 4, 5, 6, 7, 8, 8])
```

**numpy.sqrt(x[, out]) = <ufunc 'sqrt'>**

Return the positive square-root of an array, element-wise.

**Parameters**

- **x**: array_like
  The values whose square-roots are required.
out : ndarray, optional
    Alternate array object in which to put the result; if provided, it must have the same
    shape as x

Returns
    y : ndarray
    An array of the same shape as x, containing the positive square-root of each element in
    x. If any element in x is complex, a complex array is returned (and the square-roots of
    negative reals are calculated). If all of the elements in x are real, so is y, with negative
    elements returning nan. If out was provided, y is a reference to it.

See also:

lib.scimath.sqrt
    A version which returns complex numbers when given negative reals.

Notes

sqrt has–consistent with common convention–as its branch cut the real “interval” [-inf, 0), and is continuous
from above on it. A branch cut is a curve in the complex plane across which a given complex function fails to
be continuous.

Examples

>>> np.sqrt([1, 4, 9])
array([ 1., 2., 3.])

>>> np.sqrt([4, -1, -3+4J])
array([ 2.+0.j, 0.+1.j, 1.+2.j])

>>> np.sqrt([4, -1, numpy.inf])
array([ 2., NaN, Inf])

numpy.square(x[, out]) = <ufunc 'square'>

Return the element-wise square of the input.

Parameters
    x : array_like
        Input data.

Returns
    out : ndarray
        Element-wise x*x, of the same shape and dtype as x. Returns scalar if x is a scalar.

See also:

numpy.linalg.matrix_power,sqrt,power

Examples

>>> np.square([-1j, 1])
array([-1.-0.j, 1.+0.j])

numpy.absolute(x[, out]) = <ufunc 'absolute'>

Calculate the absolute value element-wise.

Parameters
    x : array_like
Input array.

Returns

**absolute**: ndarray

An ndarray containing the absolute value of each element in \(x\). For complex input, \(a + ib\), the absolute value is \(\sqrt{a^2 + b^2}\).

**Examples**

```python
>>> x = np.array([-1.2, 1.2])
>>> np.abs(x)
array([1.2, 1.2])
```

Plot the function over \([-10, 10]\):

```python
>>> import matplotlib.pyplot as plt

>>> x = np.linspace(start=-10, stop=10, num=101)
>>> plt.plot(x, np.abs(x))
>>> plt.show()
```

Plot the function over the complex plane:

```python
>>> xx = x + 1j * x[:, np.newaxis]

>>> plt.imshow(np.abs(xx), extent=[-10, 10, -10, 10])
>>> plt.show()
```
**numpy.fabs(x[, out]) = <ufunc ‘fabs’>**

Compute the absolute values element-wise.

This function returns the absolute values (positive magnitude) of the data in `x`. Complex values are not handled, use `absolute` to find the absolute values of complex data.

**Parameters**

- `x`: array_like
  The array of numbers for which the absolute values are required. If `x` is a scalar, the result `y` will also be a scalar.

- `out`: ndarray, optional
  Array into which the output is placed. Its type is preserved and it must be of the right shape to hold the output. See doc.ufuncs.

**Returns**

- `y`: {ndarray, scalar}
  The absolute values of `x`, the returned values are always floats.

**See also:**

- `absolute`
  Absolute values including complex types.

**Examples**

```python
>>> np.fabs(-1)
1.0
>>> np.fabs([-1.2, 1.2])
array([ 1.2, 1.2])
```

**numpy.sign(x[, out]) = <ufunc ‘sign’>**

Returns an element-wise indication of the sign of a number.

The `sign` function returns $-1$ if $x < 0$, $0$ if $x = 0$, $1$ if $x > 0$.

**Parameters**

- `x`: array_like
Input values.

**Returns**

- `y`: ndarray
  The sign of `x`.

**Examples**

```python
>>> np.sign([-5., 4.5])
array([-1., 1.])
```

```python
>>> np.sign(0)
0
```

```
np.maximum(x1, x2[, out]) = <ufunc ‘maximum’>
```

Element-wise maximum of array elements.

Compare two arrays and returns a new array containing the element-wise maxima. If one of the elements being compared is a NaN, then that element is returned. If both elements are NaNs then the first is returned. The latter distinction is important for complex NaNs, which are defined as at least one of the real or imaginary parts being a NaN. The net effect is that NaNs are propagated.

**Parameters**

- `x1, x2`: array_like
  The arrays holding the elements to be compared. They must have the same shape, or shapes that can be broadcast to a single shape.

**Returns**

- `y`: {ndarray, scalar}
  The maximum of `x1` and `x2`, element-wise. Returns scalar if both `x1` and `x2` are scalars.

**See also:**

- `minimum`
  Element-wise minimum of two arrays, propagates NaNs.

- `fmax`
  Element-wise maximum of two arrays, ignores NaNs.

- `amax`
  The maximum value of an array along a given axis, propagates NaNs.

- `nanmax`
  The maximum value of an array along a given axis, ignores NaNs.

- `fmin`, `amin`, `nanmin`

**Notes**

The maximum is equivalent to `np.where(x1 >= x2, x1, x2)` when neither `x1` nor `x2` are nans, but it is faster and does proper broadcasting.

**Examples**

```python
>>> np.maximum([2, 3, 4], [1, 5, 2])
array([2, 5, 4])
```

```python
>>> np.maximum(np.eye(2), [0.5, 2]) # broadcasting
array([[ 1. , 2. ],
        [ 0.5, 2. ]])
```
```python
>>> np.maximum([np.nan, 0, np.nan], [0, np.nan, np.nan])
array([ NaN,  NaN,  NaN])
```
```python
>>> np.maximum(np.Inf, 1)
inf
```
```
```python
numpy.
m
d
```

**numpy.
m
**

**Element-wise minimum of array elements.**

Compare two arrays and returns a new array containing the element-wise minima. If one of the elements being compared is a NaN, then that element is returned. If both elements are NaNs then the first is returned. The latter distinction is important for complex NaNs, which are defined as at least one of the real or imaginary parts being a NaN. The net effect is that NaNs are propagated.

**Parameters**

- **x1, x2**: array_like
  
The arrays holding the elements to be compared. They must have the same shape, or shapes that can be broadcast to a single shape.

**Returns**

- **y**: {ndarray, scalar}
  
The minimum of x1 and x2, element-wise. Returns scalar if both x1 and x2 are scalars.

**See also:**

- **maximum**: Element-wise maximum of two arrays, propagates NaNs.
- **fmin**: Element-wise minimum of two arrays, ignores NaNs.
- **amin**: The minimum value of an array along a given axis, propagates NaNs.
- **nanmin**: The minimum value of an array along a given axis, ignores NaNs.
- **fmax, amax, nanmax**

**Notes**

The minimum is equivalent to `np.where(x1 <= x2, x1, x2)` when neither x1 nor x2 are NaNs, but it is faster and does proper broadcasting.

**Examples**

```python
>>> np.minimum([2, 3, 4], [1, 5, 2])
array([1, 3, 2])
```
```python
>>> np.minimum(np.eye(2), [0.5, 2]) # broadcasting
array([[ 0.5,  0.],
       [ 0. ,  1. ]])
```
```python
>>> np.minimum([np.nan, 0, np.nan], [0, np.nan, np.nan])
array([ Na,  NaN,  NaN])
```
```python
>>> np.minimum(-np.Inf, 1)
-inf
```
```
```python
numpy.
f
```

**Element-wise maximum of array elements.**

```python
>>> np.fmax([2, 3, 4], [1, 5, 2])
array([2, 3, 4])
```
```python
>>> np.fmax(np.eye(2), [0.5, 2]) # broadcasting
array([[ 1. ,  1. ],
       [ 0.5,  2. ]])
```
```python
>>> np.fmax([np.nan, 0, np.nan], [0, np.nan, np.nan])
array([ 1. ,  NaN,  NaN])
```
```python
>>> np.fmax(-np.Inf, 1)
inf
```
Compare two arrays and returns a new array containing the element-wise maxima. If one of the elements being compared is a NaN, then the non-nan element is returned. If both elements are NaNs then the first is returned. The latter distinction is important for complex NaNs, which are defined as at least one of the real or imaginary parts being a NaN. The net effect is that NaNs are ignored when possible.

**Parameters**

x1, x2 : array_like

The arrays holding the elements to be compared. They must have the same shape.

**Returns**

y : [ndarray, scalar]

The minimum of x1 and x2, element-wise. Returns scalar if both x1 and x2 are scalars.

**See also:**

fmin
Element-wise minimum of two arrays, ignores NaNs.

maximum
Element-wise maximum of two arrays, propagates NaNs.

amax
The maximum value of an array along a given axis, propagates NaNs.

nanmax
The maximum value of an array along a given axis, ignores NaNs.

minimum, amin, nanmin

**Notes**

New in version 1.3.0.

The fmax is equivalent to \(\text{np.where}(x1 \geq x2, x1, x2)\) when neither x1 nor x2 are NaNs, but it is faster and does proper broadcasting.

**Examples**

```python
>>> np.fmax([2, 3, 4], [1, 5, 2])
array([ 2., 5., 4.])
```

```python
>>> np.fmax(np.eye(2), [0.5, 2])
array([[ 1., 2.],
       [ 0.5, 2.]])
```

```python
>>> np.fmax([np.nan, 0, np.nan], [0, np.nan, np.nan])
array([ 0., 0., nan])
```

numpy.fmin(x1, x2[, out]) = <ufunc ‘fmin’>
Element-wise minimum of array elements.

Compare two arrays and returns a new array containing the element-wise minima. If one of the elements being compared is a NaN, then the non-nan element is returned. If both elements are NaNs then the first is returned. The latter distinction is important for complex NaNs, which are defined as at least one of the real or imaginary parts being a NaN. The net effect is that NaNs are ignored when possible.

**Parameters**

x1, x2 : array_like

The arrays holding the elements to be compared. They must have the same shape.
Returns

y : {ndarray, scalar}

The minimum of x1 and x2, element-wise. Returns scalar if both x1 and x2 are scalars.

See also:

fmax
Element-wise maximum of two arrays, ignores NaNs.

minimum
Element-wise minimum of two arrays, propagates NaNs.

amin
The minimum value of an array along a given axis, propagates NaNs.

nanmin
The minimum value of an array along a given axis, ignores NaNs.

maximum, amax, nanmax

Notes

New in version 1.3.0.

The fmin is equivalent to np.where(x1 <= x2, x1, x2) when neither x1 nor x2 are NaNs, but it is faster and does proper broadcasting.

Examples

>>> np.fmin([2, 3, 4], [1, 5, 2])
array([2, 5, 4])

>>> np.fmin(np.eye(2), [0.5, 2])
array([[1. , 2. ],
       [0.5, 2. ]])

>>> np.fmin([np.nan, 0, np.nan],[0, np.nan, np.nan])
array([0., 0., NaN])

numpy.nan_to_num(x)
Replace nan with zero and inf with finite numbers.

Returns an array or scalar replacing Not a Number (NaN) with zero, (positive) infinity with a very large number and negative infinity with a very small (or negative) number.

Parameters

x : array_like
Input data.

Returns

out : ndarray, float
Array with the same shape as x and dtype of the element in x with the greatest precision. NaN is replaced by zero, and infinity (-infinity) is replaced by the largest (smallest or most negative) floating point value that fits in the output dtype. All finite numbers are upcast to the output dtype (default float64).

See also:
**isinf**

Shows which elements are negative or negative infinity.

**isneginf**

Shows which elements are negative infinity.

**isposinf**

Shows which elements are positive infinity.

**isnan**

Shows which elements are Not a Number (NaN).

**isfinite**

Shows which elements are finite (not NaN, not infinity)

**Notes**

Numpy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity.

**Examples**

```python
>>> np.set_printoptions(precision=8)
>>> x = np.array([np.inf, -np.inf, np.nan, -128, 128])
>>> np.nan_to_num(x)
array([ 1.79769313e+308, -1.79769313e+308, 0.00000000e+000,
       -1.28000000e+002, 1.28000000e+002])
```

**numpy.real_if_close(a, tol=100)**

If complex input returns a real array if complex parts are close to zero.

“Close to zero” is defined as \( tol \times (\text{machine epsilon of the type for } a) \).

**Parameters**

- **a**: array_like
  - Input array.
- **tol**: float
  - Tolerance in machine epsilons for the complex part of the elements in the array.

**Returns**

- **out**: ndarray
  - If \( a \) is real, the type of \( a \) is used for the output. If \( a \) has complex elements, the returned type is float.

**See also:**

real, imag, angle

**Notes**

Machine epsilon varies from machine to machine and between data types but Python floats on most platforms have a machine epsilon equal to \( 2.2204460492503131 \times 10^{-16} \). You can use ‘np.finfo(np.float).eps’ to print out the machine epsilon for floats.

**Examples**

```python
>>> np.finfo(np.float).eps
2.2204460492503131e-16
```
numpy.real_if_close([2.1 + 4e-14j], tol=1000)
array([ 2.1])

numpy.real_if_close([2.1 + 4e-13j], tol=1000)
array([ 2.1 +4.00000000e-13j])

numpy.interp(x, xp, fp, left=None, right=None)

One-dimensional linear interpolation.

Returns the one-dimensional piecewise linear interpolant to a function with given values at discrete data-points.

Parameters

x : array_like
    The x-coordinates of the interpolated values.
	xp : 1-D sequence of floats
    The x-coordinates of the data points, must be increasing.

fp : 1-D sequence of floats
    The y-coordinates of the data points, same length as xp.

left : float, optional
    Value to return for \(x < xp[0]\), default is \(fp[0]\).

right : float, optional
    Value to return for \(x > xp[-1]\), default is \(fp[-1]\).

Returns

y : {float, ndarray}
    The interpolated values, same shape as x.

Raises

ValueError
    If \(xp\) and \(fp\) have different length

Notes

Does not check that the x-coordinate sequence \(xp\) is increasing. If \(xp\) is not increasing, the results are nonsense. A simple check for increasing is:

\[
\text{np.all(np.diff(xp) > 0)}
\]

Examples

\[
>>> xp = [1, 2, 3]
\]
\[
>>> fp = [3, 2, 0]
\]
\[
>>> np.interp(2.5, xp, fp)
1.0
\]
\[
>>> np.interp([0, 1, 1.5, 2.72, 3.14], xp, fp)
array([ 3. , 3. , 2.5 , 0.56, 0. ])
\]
\[
>>> UNDEF = -99.0
\]
\[
>>> np.interp(3.14, xp, fp, right=UNDEF)
-99.0
\]

Plot an interpolant to the sine function:
```python
>>> x = np.linspace(0, 2*np.pi, 10)
>>> y = np.sin(x)
>>> xvals = np.linspace(0, 2*np.pi, 50)
>>> yinterp = np.interp(xvals, x, y)
>>> import matplotlib.pyplot as plt
>>> plt.plot(x, y, 'o')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.plot(xvals, yinterp, '-x')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.show()
```

### 3.21 Matrix library (numpy.matlib)

This module contains all functions in the numpy namespace, with the following replacement functions that return matrices instead of ndarrays.

Functions that are also in the numpy namespace and return matrices

- `mat(data[, dtype])`: Interpret the input as a matrix.
- `matrix`:
  - Returns a matrix from an array-like object, or from a string of data.
- `asmatrix(data[, dtype])`: Interpret the input as a matrix.
- `bmat(obj[, ldict, gdict])`: Build a matrix object from a string, nested sequence, or array.

Replacement functions in `matlib`

- `empty(shape[, dtype, order])`: Return a new matrix of given shape and type, without initializing entries.
- `zeros(shape[, dtype, order])`: Return a matrix of given shape and type, filled with zeros.
- `ones(shape[, dtype, order])`: Matrix of ones.
- `eye(n[, M, k, dtype])`: Return a matrix with ones on the diagonal and zeros elsewhere.
- `identity(n[, dtype])`: Returns the square identity matrix of given size.
- `repmat(a, m, n)`: Repeat a 0-D to 2-D array or matrix MxN times.
- `rand(*args)`: Return a matrix of random values with given shape.
- `randn(*args)`: Return a random matrix with data from the “standard normal” distribution.
numpy.matlib.empty(shape, dtype=None, order='C')

Return a new matrix of given shape and type, without initializing entries.

Parameters
    shape : int or tuple of int
        Shape of the empty matrix.
    dtype : data-type, optional
        Desired output data-type.
    order : {'C', 'F'}, optional
        Whether to store multi-dimensional data in C (row-major) or
        Fortran (column-major) order in memory.

See also:
    empty_like, zeros

Notes

empty, unlike zeros, does not set the matrix values to zero, and may therefore be marginally faster. On the
other hand, it requires the user to manually set all the values in the array, and should be used with caution.

Examples

>>> import numpy.matlib
>>> np.matlib.empty((2, 2))  # filled with random data
matrix([[ 6.76425276e-320, 9.79033856e-307],
        [ 7.39337286e-309, 3.22135945e-309]])  #random

>>> np.matlib.empty((2, 2), dtype=int)
matrix([[ 6600475, 0],
        [ 6586976, 22740995]])  #random

numpy.matlib.zeros(shape, dtype=None, order='C')

Return a matrix of given shape and type, filled with zeros.

Parameters
    shape : int or sequence of ints
        Shape of the matrix
    dtype : data-type, optional
        The desired data-type for the matrix, default is float.
    order : {'C', 'F'}, optional
        Whether to store the result in C- or Fortran-contiguous order, default is ‘C’.

Returns
    out : matrix
        Zero matrix of given shape, dtype, and order.

See also:

numpy.zeros
    Equivalent array function.

matlib.ones
    Return a matrix of ones.
Notes

If `shape` has length one i.e. `(N,)`, or is a scalar `N`, `out` becomes a single row matrix of shape `(1, N)`.

Examples

```python
def import numpy.matlib
>>> np.matlib.zeros((2, 3))
matrix([[ 0., 0., 0.],
        [ 0., 0., 0.]])

>>> np.matlib.zeros(2)
matrix([[ 0., 0.]])
```

`numpy.matlib.ones(shape, dtype=None, order='C')`

Matrix of ones.

Return a matrix of given shape and type, filled with ones.

Parameters

- `shape`: {sequence of ints, int}
  
  Shape of the matrix

- `dtype`: data-type, optional
  
  The desired data-type for the matrix, default is np.float64.

- `order`: {'C', 'F'}, optional
  
  Whether to store matrix in C- or Fortran-contiguous order, default is ‘C’.

Returns

- `out`: matrix
  
  Matrix of ones of given shape, dtype, and order.

See also:

- `ones`
  
  Array of ones.

- `matlib.zeros`
  
  Zero matrix.

Notes

If `shape` has length one i.e. `(N,)`, or is a scalar `N`, `out` becomes a single row matrix of shape `(1, N)`.

Examples

```python
def np.matlib.ones((2,3))
matrix([[ 1., 1., 1.],
        [ 1., 1., 1.]])

>>> np.matlib.ones(2)
matrix([[ 1., 1.]])
```

`numpy.matlib.eye(n, M=None, k=0, dtype=<type 'float'>)`

Return a matrix with ones on the diagonal and zeros elsewhere.

Parameters

- `n`: int
Number of rows in the output.

M : int, optional
   Number of columns in the output, defaults to n.

k : int, optional
   Index of the diagonal: 0 refers to the main diagonal, a positive value refers to an upper
diagonal, and a negative value to a lower diagonal.

dtype : dtype, optional
   Data-type of the returned matrix.

Returns
I : matrix
   A \( n \times M \) matrix where all elements are equal to zero, except for the \( k \)-th diagonal, whose
values are equal to one.

See also:

numpy.eye
   Equivalent array function.

identity
   Square identity matrix.

Examples
>>> import numpy.matlib
>>> np.matlib.eye(3, k=1, dtype=float)
matrix([[ 0., 1., 0.],
       [ 0., 0., 1.],
       [ 0., 0., 0.]])

numpy.matlib.identity(n, dtype=None)
   Returns the square identity matrix of given size.

Parameters
n : int
   Size of the returned identity matrix.

dtype : data-type, optional
   Data-type of the output. Defaults to float.

Returns
out : matrix
   \( n \times n \) matrix with its main diagonal set to one, and all other elements zero.

See also:

numpy.identity
   Equivalent array function.

matlab.eye
   More general matrix identity function.
Examples

```python
>>> import numpy.matlib
>>> np.matlib.identity(3, dtype=int)
matrix([[1, 0, 0],
        [0, 1, 0],
        [0, 0, 1]])
```

`numpy.matlib.repmat(a, m, n)`
Repeat a 0-D to 2-D array or matrix MxN times.

**Parameters**
- `a`: array_like
  The array or matrix to be repeated.
- `m`, `n`: int
  The number of times `a` is repeated along the first and second axes.

**Returns**
- `out`: ndarray
  The result of repeating `a`.

Examples

```python
>>> import numpy.matlib
>>> a0 = np.array(1)
>>> np.matlib.repmat(a0, 2, 3)
array([[1, 1, 1],
       [1, 1, 1]])
```

```python
>>> a1 = np.arange(4)
>>> np.matlib.repmat(a1, 2, 2)
array([[0, 1, 2, 3, 0, 1, 2, 3],
       [0, 1, 2, 3, 0, 1, 2, 3]])
```

```python
>>> a2 = np.asmatrix(np.arange(6).reshape(2, 3))
>>> np.matlib.repmat(a2, 2, 3)
matrix([[0, 1, 2, 0, 1, 2, 0, 1, 2],
        [3, 4, 5, 3, 4, 5, 3, 4, 5],
        [0, 1, 2, 0, 1, 2, 0, 1, 2],
        [3, 4, 5, 3, 4, 5, 3, 4, 5]])
```

`numpy.matlib.rand(*args)`
Return a matrix of random values with given shape.

Create a matrix of the given shape and propagate it with random samples from a uniform distribution over [0, 1).

**Parameters**
- `*args`: Arguments
  Shape of the output. If given as N integers, each integer specifies the size of one dimension. If given as a tuple, this tuple gives the complete shape.

**Returns**
- `out`: ndarray
  The matrix of random values with shape given by `*args`.
See also:

```
numpy.random.randn, numpy.random.rand
```

Examples

```python
>>> import numpy.matlib
>>> np.matlib.rand(2, 3)
matrix([[ 0.68340382, 0.67926887, 0.83271405],
        [ 0.00793551, 0.20468222, 0.95253525]]) #random
```

If the first argument is a tuple, other arguments are ignored:

```python
>>> np.matlib.rand((2, 3), 4)
matrix([[ 0.46898646, 0.15163588, 0.95188261],
        [ 0.59208621, 0.09561818, 0.00583606]]) #random
```

```
numpy.matlib.randn(*args)
```

Return a random matrix with data from the “standard normal” distribution.

```
numpy.random.randn
```

generates a matrix filled with random floats sampled from a univariate “normal” (Gaussian) distribution of mean 0 and variance 1.

Parameters

*args : Arguments

Shape of the output. If given as N integers, each integer specifies the size of one dimension. If given as a tuple, this tuple gives the complete shape.

Returns

Z : matrix of floats

A matrix of floating-point samples drawn from the standard normal distribution.

See also:

```
numpy.random.randn, random.randn
```

Notes

For random samples from \( N(\mu, \sigma^2) \), use:

```
sigma * np.matlib.randn(...) + mu
```

Examples

```python
>>> import numpy.matlib
>>> np.matlib.randn(1)
matrix([[-0.09542833]]) #random
```

```python
>>> np.matlib.randn(1, 2, 3)
matrix([[ 0.16198284, 0.0194571 , 0.18312985],
        [-0.7509172 , 1.61055 , 0.45298599]]) #random
```

Two-by-four matrix of samples from \( N(3, 6.25) \):

```python
>>> 2.5 * np.matlib.randn((2, 4)) + 3
matrix([[ 4.74085004, 8.89381862, 4.09042411, 4.83721922],
        [ 7.52373709, 5.07933944, -2.64043543, 0.45610557]]) #random
```
3.22 Miscellaneous routines

3.22.1 Buffer objects

**getbuffer**(obj [, offset[, size]])
Create a buffer object from the given object referencing a slice of length size starting at offset. Default is the entire buffer. A read-write buffer is attempted followed by a read-only buffer.

- **Parameters**
  - obj : object
  - offset : int, optional
  - size : int, optional

- **Returns**
  - buffer_obj : buffer

**Example**
```python
g = np.eye(3)
x = np.array(1, dtype='S10')
np.getbuffer(x, 5, 3)
```

**newbuffer**(size)
Return a new uninitialized buffer object.

- **Parameters**
  - size : int

- **Returns**
  - newbuffer : buffer object

3.22.2 Performance tuning

**alterdot**
Change `dot`, `vdot`, and `inner` to use accelerated BLAS functions.

**restoredot**
Restore `dot`, `vdot`, and `innerproduct` to the default non-BLAS implementations.

**setbufsize**(size)
Set the size of the buffer used in ufuncs.

**getbufsize**()
Return the size of the buffer used in ufuncs.

**Example**
```python
np.alterdot()
```

Typically, as a user of Numpy, you do not explicitly call this function. If Numpy is built with an accelerated
BLAS, this function is automatically called when Numpy is imported.

When Numpy is built with an accelerated BLAS like ATLAS, these functions are replaced to make use of the faster implementations. The faster implementations only affect float32, float64, complex64, and complex128 arrays. Furthermore, the BLAS API only includes matrix-matrix, matrix-vector, and vector-vector products. Products of arrays with larger dimensionalities use the built in functions and are not accelerated.

See also:

**restoredot**

restoredot undoes the effects of alterdot.

numpy.restoredot()

Restore dot, vdot, and innerproduct to the default non-BLAS implementations.

Typically, the user will only need to call this when troubleshooting and installation problem, reproducing the conditions of a build without an accelerated BLAS, or when being very careful about benchmarking linear algebra operations.

See also:

**altereddot**

restoredot undoes the effects of altereddot.

numpy.setbufsize(size)

Set the size of the buffer used in ufuncs.

**Parameters**

size : int

Size of buffer.

numpy.getbufsize()

Return the size of the buffer used in ufuncs.

**Returns**

getbufsize : int

Size of ufunc buffer in bytes.

### 3.23 Padding Arrays

**pad**(array, pad_width[, mode]) Pads an array.

numpy.pad(array, pad_width, mode=None, **kwargs)

Pads an array.

**Parameters**

array : array_like of rank N

Input array

pad_width : {sequence, int}

Number of values padded to the edges of each axis. ((before_1, after_1), ... (before_N, after_N)) unique pad widths for each axis. ((before, after),) yields same before and after pad for each axis. (pad,) or int is a shortcut for before = after = pad width for all axes.
**mode**: `{str, function}`

One of the following string values or a user supplied function.

- `'constant'`
  Pads with a constant value.

- `'edge'`
  Pads with the edge values of array.

- `'linear_ramp'`
  Pads with the linear ramp between end_value and the array edge value.

- `'maximum'`
  Pads with the maximum value of all or part of the vector along each axis.

- `'mean'`
  Pads with the mean value of all or part of the vector along each axis.

- `'median'`
  Pads with the median value of all or part of the vector along each axis.

- `'minimum'`
  Pads with the minimum value of all or part of the vector along each axis.

- `'reflect'`
  Pads with the reflection of the vector mirrored on the first and last values of the vector along each axis.

- `'symmetric'`
  Pads with the reflection of the vector mirrored along the edge of the array.

- `'wrap'`
  Pads with the wrap of the vector along the axis. The first values are used to pad the end and the end values are used to pad the beginning.

**<function>**

Padding function, see Notes.

**stat_length**: `{sequence, int}`, optional

Used in `maximum`, `mean`, `median`, and `minimum`. Number of values at edge of each axis used to calculate the statistic value.

- `((before_1, after_1), ... (before_N, after_N))` unique statistic lengths for each axis.
- `((before, after),)` yields same before and after statistic lengths for each axis.
- `(stat_length,)` or int is a shortcut for before = after = statistic length for all axes.

Default is `None`, to use the entire axis.

**constant_values**: `{sequence, int}`, optional

Used in `constant`. The values to set the padded values for each axis.

- `((before_1, after_1), ... (before_N, after_N))` unique pad constants for each axis.
- `((before, after),)` yields same before and after constants for each axis.
- `(constant,)` or int is a shortcut for before = after = constant for all axes.

Default is 0.

**end_values**: `{sequence, int}`, optional
Used in ‘linear_ramp’. The values used for the ending value of the linear_ramp and that will form the edge of the padded array.

((before_1, after_1), ... (before_N, after_N)) unique end values for each axis.
((before, after),) yields same before and after end values for each axis.
(constant,) or int is a shortcut for before = after = end value for all axes.

Default is 0.

reflect_type : str {'even', 'odd'}, optional

Used in ‘reflect’, and ‘symmetric’. The ‘even’ style is the default with an unaltered reflection around the edge value. For the ‘odd’ style, the extented part of the array is created by subtracting the reflected values from two times the edge value.

Returns

pad : ndarray

Padded array of rank equal to array with shape increased according to pad_width.

Notes

New in version 1.7.0.

For an array with rank greater than 1, some of the padding of later axes is calculated from padding of previous axes. This is easiest to think about with a rank 2 array where the corners of the padded array are calculated by using padded values from the first axis.

The padding function, if used, should return a rank 1 array equal in length to the vector argument with padded values replaced. It has the following signature:

padding_func(vector, iaxis_pad_width, iaxis, **kwargs)

where

vector
[ndarray] A rank 1 array already padded with zeros. Padded values are vector[:pad_tuple[0]] and vector[-pad_tuple[1]:].

iaxis_pad_width
[tuple] A 2-tuple of ints, iaxis_pad_width[0] represents the number of values padded at the beginning of vector where iaxis_pad_width[1] represents the number of values padded at the end of vector.

iaxis
[int] The axis currently being calculated.

kwargs
[misc] Any keyword arguments the function requires.

Examples

>>> a = [1, 2, 3, 4, 5]
>>> np.lib.pad(a, (2,3), 'constant', constant_values=(4,6))
array([4, 4, 1, 2, 3, 4, 5, 6, 6, 6])

>>> np.lib.pad(a, (2,3), 'edge')
array([1, 1, 1, 2, 3, 4, 5, 5, 5, 5])

>>> np.lib.pad(a, (2,3), 'linear_ramp', end_values=(5,-4))
array([ 5, 3, 1, 2, 3, 4, 5, 2, -1, -4])
```python
>>> np.lib.pad(a, (2,), 'maximum')
array([5, 5, 1, 2, 3, 4, 5, 5, 5])

>>> np.lib.pad(a, (2,), 'mean')
array([3, 3, 1, 2, 3, 4, 5, 3, 3])

>>> np.lib.pad(a, (2,), 'median')
array([3, 3, 1, 2, 3, 4, 5, 3, 3])

>>> a = [[1,2], [3,4]]
>>> np.lib.pad(a, ((3, 2), (2, 3)), 'minimum')
array([[1, 1, 1, 2, 1, 1, 1],
       [1, 1, 1, 2, 1, 1, 1],
       [1, 1, 1, 2, 1, 1, 1],
       [3, 3, 4, 3, 3, 3, 3],
       [1, 1, 1, 2, 1, 1, 1],
       [1, 1, 1, 2, 1, 1, 1]])

>>> a = [1, 2, 3, 4, 5]
>>> np.lib.pad(a, (2,3), 'reflect')
array([3, 2, 1, 2, 3, 4, 5, 4, 3])

>>> np.lib.pad(a, (2,3), 'reflect', reflect_type='odd')
array([-1, 0, 1, 2, 3, 4, 5, 6, 7, 8])

>>> np.lib.pad(a, (2,3), 'symmetric')
array([2, 1, 1, 2, 3, 4, 5, 5, 4, 3])

>>> np.lib.pad(a, (2,3), 'symmetric', reflect_type='odd')
array([0, 1, 1, 2, 3, 4, 5, 5, 6, 7])

>>> np.lib.pad(a, (2,3), 'wrap')
array([4, 5, 1, 2, 3, 4, 5, 1, 2, 3])
```

```python
>>> def padwithtens(vector, pad_width, iaxis, kwargs):
    ...     vector[:pad_width[0]] = 10
    ...     vector[-pad_width[1]:] = 10
    ...     return vector

>>> a = np.arange(6)
>>> a = a.reshape((2,3))

```
Prior to NumPy 1.4, `numpy.poly1d` was the class of choice and it is still available in order to maintain backward compatibility. However, the newer Polynomial package is more complete than `numpy.poly1d` and its convenience classes are better behaved in the numpy environment. Therefore Polynomial is recommended for new coding.

### 3.24.1 Transition notice

The various routines in the Polynomial package all deal with series whose coefficients go from degree zero upward, which is the reverse order of the Poly1d convention. The easy way to remember this is that indexes correspond to degree, i.e., coef[i] is the coefficient of the term of degree i.

### Polynomial Package

New in version 1.4.0.

#### Using the Convenience Classes

The convenience classes provided by the polynomial package are:

<table>
<thead>
<tr>
<th>Name</th>
<th>Provides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polynomial</td>
<td>Power series</td>
</tr>
<tr>
<td>Chebyshev</td>
<td>Chebyshev series</td>
</tr>
<tr>
<td>Legendre</td>
<td>Legendre series</td>
</tr>
<tr>
<td>Laguerre</td>
<td>Laguerre series</td>
</tr>
<tr>
<td>Hermite</td>
<td>Hermite series</td>
</tr>
<tr>
<td>HermiteE</td>
<td>HermiteE series</td>
</tr>
</tbody>
</table>

The series in this context are finite sums of the corresponding polynomial basis functions multiplied by coefficients. For instance, a power series looks like

\[ p(x) = 1 + 2x + 3x^2 \]

and has coefficients [1, 2, 3]. The Chebyshev series with the same coefficients looks like

\[ p(x) = 1T_0(x) + 2T_1(x) + 3T_2(x) \]

and more generally

\[ p(x) = \sum_{i=0}^{n} c_i T_i(x) \]

where in this case the \( T_n \) are the Chebyshev functions of degree \( n \), but could just as easily be the basis functions of any of the other classes. The convention for all the classes is that the coefficient \( c[i] \) goes with the basis function of degree \( i \).

All of the classes have the same methods, and especially they implement the Python numeric operators +, -, *, //, %, divmod, **, ==, and !=. The last two can be a bit problematic due to floating point roundoff errors. We now give a quick demonstration of the various operations using Numpy version 1.7.0.

#### Basics

First we need a polynomial class and a polynomial instance to play with. The classes can be imported directly from the polynomial package or from the module of the relevant type. Here we import from the package and use the conventional Polynomial class because of its familiarity:

```python
>>> from numpy.polynomial import Polynomial as P

>>> p = P([1,2,3])

>>> p
Polynomial([ 1., 2., 3.], [-1., 1.], [-1., 1.])
```
Note that there are three parts to the long version of the printout. The first is the coefficients, the second is the domain, and the third is the window:

```python
>>> p.coef
array([ 1., 2., 3.])
```

```python
>>> p.domain
array([-1., 1.])
```

```python
>>> p.window
array([-1., 1.])
```

Printing a polynomial yields a shorter form without the domain and window:

```python
>>> print p
poly([ 1. 2. 3.])
```

We will deal with the domain and window when we get to fitting, for the moment we ignore them and run through the basic algebraic and arithmetic operations.

Addition and Subtraction:

```python
>>> p + p
Polynomial([ 2., 4., 6.], [-1., 1.], [-1., 1.])
```

```python
>>> p - p
Polynomial([ 0.], [-1., 1.], [-1., 1.])
```

Multiplication:

```python
>>> p * p
Polynomial([ 1., 4., 10., 12., 9.], [-1., 1.], [-1., 1.])
```

Powers:

```python
>>> p**2
Polynomial([ 1., 4., 10., 12., 9.], [-1., 1.], [-1., 1.])
```

Division:

Floor division, `//`, is the division operator for the polynomial classes, polynomials are treated like integers in this regard. For Python versions < 3.x the `/` operator maps to `//'`, as it does for Python, for later versions the `/` will only work for division by scalars. At some point it will be deprecated:

```python
>>> p // P([-1, 1])
Polynomial([ 5., 3.], [-1., 1.], [-1., 1.])
```

Remainder:

```python
>>> p % P([-1, 1])
Polynomial([ 6.], [-1., 1.], [-1., 1.])
```

Divmod:

```python
>>> quo, rem = divmod(p, P([-1, 1]))
>>> quo
Polynomial([ 5., 3.], [-1., 1.], [-1., 1.])
```

```python
>>> rem
Polynomial([ 6.], [-1., 1.], [-1., 1.])
```

Evaluation:

```python
>>> x = np.arange(5)
```

```python
>>> p(x)
array([ 1., 6., 17., 34., 57.])
```
NumPy Reference, Release 1.9.2

```python
>>> x = np.arange(6).reshape(3,2)
>>> p(x)
array([[ 1., 6.],
       [17., 34.],
       [57., 86.]])
Substitution:
Substitute a polynomial for x and expand the result. Here we substitute p in itself leading to a new polynomial of degree 4 after expansion. If the polynomials are regarded as functions this is composition of functions:
```n
```python
>>> p(p)
Polynomial([ 6., 16., 36., 27., [-1., 1.], [-1., 1.])
```
Roots:
```python
>>> p.roots()
array([-0.33333333-0.47140452j, -0.33333333+0.47140452j])
```
It isn’t always convenient to explicitly use Polynomial instances, so tuples, lists, arrays, and scalars are automatically cast in the arithmetic operations:
```python
>>> p + [1, 2, 3]
Polynomial([ 2., 4., 6.], [-1., 1.], [-1., 1.])
>>> [1, 2, 3] * p
Polynomial([ 1., 4., 10., 12., 9.], [-1., 1.], [-1., 1.])
>>> p / 2
Polynomial([ 0.5, 1. , 1.5], [-1., 1.], [-1., 1.])
```
Polynomials that differ in domain, window, or class can’t be mixed in arithmetic:
```python
>>> from numpy.polynomial import Chebyshev as T
>>> p + P([1], domain=[0,1])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<string>", line 213, in __add__
TypeError: Domains differ
>>> p + P([1], window=[0,1])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<string>", line 215, in __add__
TypeError: Windows differ
>>> p + T([1])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<string>", line 211, in __add__
TypeError: Polynomial types differ
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<string>", line 211, in __add__
TypeError: Polynomial types differ
```
But different types can be used for substitution. In fact, this is how conversion of Polynomial classes among themselves is done for type, domain, and window casting:
```python
>>> p(T([0, 1]))
Chebyshev([ 2.5, 2. , 1.5], [-1., 1.], [-1., 1.])
```
Which gives the polynomial p in Chebyshev form. This works because $T_1(x) = x$ and substituting $x$ for $x$ doesn’t change the original polynomial. However, all the multiplications and divisions will be done using Chebyshev series,
hence the type of the result.

Calculus  Polynomial instances can be integrated and differentiated:

```python
>>> from numpy.polynomial import Polynomial as P
>>> p = P([2, 6])
>>> p.integ()
Polynomial([ 0., 2., 3.], [-1., 1.], [-1., 1.])
>>> p.integ(2)
Polynomial([ 0., 0., 1., 1.], [-1., 1.], [-1., 1.])
```

The first example integrates \( p \) once, the second example integrates it twice. By default, the lower bound of the integration and the integration constant are 0, but both can be specified:

```python
>>> p.integ(lbnd=-1)
Polynomial([-1., 2., 3.], [-1., 1.], [-1., 1.])
```

In the first case the lower bound of the integration is set to -1 and the integration constant is 0. In the second the constant of integration is set to 1 as well. Differentiation is simpler since the only option is the number of times the polynomial is differentiated:

```python
>>> p = P([1, 2, 3])
>>> p.deriv(1)
Polynomial([ 2., 6.], [-1., 1.], [-1., 1.])
>>> p.deriv(2)
Polynomial([ 6.], [-1., 1.], [-1., 1.])
```

Other Polynomial Constructors  Constructing polynomials by specifying coefficients is just one way of obtaining a polynomial instance, they may also be created by specifying their roots, by conversion from other polynomial types, and by least squares fits. Fitting is discussed in its own section, the other methods are demonstrated below:

```python
>>> from numpy.polynomial import Polynomial as P
>>> from numpy.polynomial import Chebyshev as T
>>> p = P.fromroots([1, 2, 3])
>>> p
Polynomial([-6., 11., -6., 1.], [-1., 1.], [-1., 1.])
```

In numpy versions >= 1.7.0 the `basis` and `cast` class methods are also available. The cast method works like the convert method while the basis method returns the basis polynomial of given degree:

```python
>>> P.basis(3)
Polynomial([ 0., 0., 0., 1.], [-1., 1.], [-1., 1.])
>>> T.cast(p)
Chebyshev([-9. , 11.75, -3. , 0.25], [-1., 1.], [-1., 1.])
```
Conversions between types can be useful, but it is not recommended for routine use. The loss of numerical precision in passing from a Chebyshev series of degree 50 to a Polynomial series of the same degree can make the results of numerical evaluation essentially random.

Fitting  Fitting is the reason that the domain and window attributes are part of the convenience classes. To illustrate the problem, the values of the Chebyshev polynomials up to degree 5 are plotted below.

In the range -1 <= x <= 1 they are nice, equiripple functions lying between +/- 1. The same plots over the range -2 <= x <= 2 look very different:
As can be seen, the “good” parts have shrunk to insignificance. In using Chebyshev polynomials for fitting we want to use the region where $x$ is between -1 and 1 and that is what the window specifies. However, it is unlikely that the data to be fit has all its data points in that interval, so we use domain to specify the interval where the data points lie. When the fit is done, the domain is first mapped to the window by a linear transformation and the usual least squares fit is done using the mapped data points. The window and domain of the fit are part of the returned series and are automatically used when computing values, derivatives, and such. If they aren’t specified in the call the fitting routine will use the default window and the smallest domain that holds all the data points. This is illustrated below for a fit to a noisy sine curve.

```python
c   >>> import numpy as np
    >>> import matplotlib.pyplot as plt
    >>> from numpy.polynomial import Chebyshev as T
    >>> np.random.seed(11)
    >>> x = np.linspace(0, 2*np.pi, 20)
    >>> y = np.sin(x) + np.random.normal(scale=.1, size=x.shape)
    >>> p = T.fit(x, y, 5)
    >>> plt.plot(x, y, 'o')
    >>> xx, yy = p.linspace()
    >>> plt.plot(xx, yy, lw=2)
    >>> p.domain
    array([ 0. , 6.28318531])
    >>> p.window
    array([-1.,  1.])
    >>> plt.show()
```
Polynomial Module (`numpy.polynomial.polynomial`)

New in version 1.4.0.

This module provides a number of objects (mostly functions) useful for dealing with Polynomial series, including a `Polynomial` class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with such polynomials is in the docstring for its “parent” sub-package, `numpy.polynomial`.)

```
Polynomial(coef[, domain, window])   A power series class.
```

Polynomial Class

class `numpy.polynomial.polynomial.Polynomial(coef, domain=None, window=None)`

A power series class.

The `Polynomial` class provides the standard Python numerical methods `+`, `-`, `*`, `/`, `%`, `divmod`, `**`, and `()` as well as the attributes and methods listed in the `ABCPolyBase` documentation.

Parameters

coef : array_like
    Polynomial coefficients in order of increasing degree, i.e., `(1, 2, 3)` give `1 + 2*x + 3*x**2`.

domain : (2,) array_like, optional
    Domain to use. The interval `[domain[0], domain[1]]` is mapped to the interval `[window[0], window[1]]` by shifting and scaling. The default value is `[-1, 1]`.

window : (2,) array_like, optional
    Window, see `domain` for its use. The default value is `[-1, 1]`.

New in version 1.6.0.

Methods

```
__call__(arg)
```
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<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>basis(deg[, domain, window])</code></td>
<td>Series basis polynomial of degree deg.</td>
</tr>
<tr>
<td><code>cast(series[, domain, window])</code></td>
<td>Convert series to series of this class.</td>
</tr>
<tr>
<td><code>convert([domain, kind, window])</code></td>
<td>Convert series to a different kind and/or domain and/or window.</td>
</tr>
<tr>
<td><code>copy()</code></td>
<td>Return a copy.</td>
</tr>
<tr>
<td><code>cutdeg(deg)</code></td>
<td>Truncate series to the given degree.</td>
</tr>
<tr>
<td><code>degree()</code></td>
<td>The degree of the series.</td>
</tr>
<tr>
<td><code>deriv([m])</code></td>
<td>Differentiate.</td>
</tr>
<tr>
<td><code>fit(x, y, deg[, domain, rcond, full, w, window])</code></td>
<td>Least squares fit to data.</td>
</tr>
<tr>
<td><code>fromroots(roots[, domain, window])</code></td>
<td>Return series instance that has the specified roots.</td>
</tr>
<tr>
<td><code>has_samecoef(other)</code></td>
<td>Check if coefficients match.</td>
</tr>
<tr>
<td><code>has_samedomain(other)</code></td>
<td>Check if domains match.</td>
</tr>
<tr>
<td><code>has_sametype(other)</code></td>
<td>Check if types match.</td>
</tr>
<tr>
<td><code>has_samewindow(other)</code></td>
<td>Check if windows match.</td>
</tr>
<tr>
<td><code>identity([domain, window])</code></td>
<td>Identity function.</td>
</tr>
<tr>
<td><code>integ([m, k, lbnd])</code></td>
<td>Integrate.</td>
</tr>
<tr>
<td><code>linspace([n, domain])</code></td>
<td>Return x, y values at equally spaced points in domain.</td>
</tr>
<tr>
<td><code>mapparms()</code></td>
<td>Return the mapping parameters.</td>
</tr>
<tr>
<td><code>roots()</code></td>
<td>Return the roots of the series polynomial.</td>
</tr>
<tr>
<td><code>trim([tol])</code></td>
<td>Remove trailing coefficients Remove trailing coefficients until a coefficient is reached that is smaller than tol.</td>
</tr>
<tr>
<td><code>truncate(size)</code></td>
<td>Truncate series to length size.</td>
</tr>
</tbody>
</table>

**Polynomial.__call__(arg)**

**classmethod Polynomial.basis**

<table>
<thead>
<tr>
<th>deg, domain=None, window=None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series basis polynomial of degree deg.</td>
</tr>
</tbody>
</table>

Returns the series representing the basis polynomial of degree deg.

New in version 1.7.0.

**Parameters**

deg : int
   Degree of the basis polynomial for the series. Must be >= 0.

domain : {None, array_like}, optional
   If given, the array must be of the form [beg, end], where beg and end are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window : {None, array_like}, optional
   If given, the resulting array must be of the form [beg, end], where beg and end are the endpoints of the window. If None is given then the class window is used. The default is None.

**Returns**

new_series : series
   A series with the coefficient of the deg term set to one and all others zero.

**classmethod Polynomial.cast**

<table>
<thead>
<tr>
<th>series, domain=None, window=None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert series to series of this class.</td>
</tr>
</tbody>
</table>

The series is expected to be an instance of some polynomial series of one of the types supported by by the numpy.polynomial module, but could be some other class that supports the convert method.
New in version 1.7.0.

Parameters

- **series**: The series instance to be converted.
- **domain**: {None, array_like}, optional
  If given, the array must be of the form \([\text{beg}, \text{end}]\), where \(\text{beg}\) and \(\text{end}\) are the endpoints of the domain. If None is given then the class domain is used. The default is None.
- **window**: {None, array_like}, optional
  If given, the resulting array must be of the form \([\text{beg}, \text{end}]\), where \(\text{beg}\) and \(\text{end}\) are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

- **new_series**: A series of the same kind as the calling class and equal to \(\text{series}\) when evaluated.

See also:

- **convert**
  similar instance method

Polynomial.**convert** \((\text{domain}=None, \text{kind}=None, \text{window}=None)\)
Convert series to a different kind and/or domain and/or window.

Parameters

- **domain**: array_like, optional
  The domain of the converted series. If the value is None, the default domain of \(\text{kind}\) is used.
- **kind**: class, optional
  The polynomial series type class to which the current instance should be converted. If \(\text{kind}\) is None, then the class of the current instance is used.
- **window**: array_like, optional
  The window of the converted series. If the value is None, the default window of \(\text{kind}\) is used.

Returns

- **new_series**: The returned class can be of different type than the current instance and/or have a different domain and/or different window.

Notes
Conversion between domains and class types can result in numerically ill defined series.

Polynomial.**copy**()
Return a copy.

Returns

- **new_series**: series
Copy of self.

**Polynomial**. `cutdeg(deg)`

Truncate series to the given degree.

Reduce the degree of the series to `deg` by discarding the high order terms. If `deg` is greater than the current degree a copy of the current series is returned. This can be useful in least squares where the coefficients of the high degree terms may be very small.

New in version 1.5.0.

**Parameters**

deg : non-negative int

The series is reduced to degree `deg` by discarding the high order terms. The value of `deg` must be a non-negative integer.

**Returns**

new_series : series

New instance of series with reduced degree.

**Polynomial**. `degree()`

The degree of the series.

New in version 1.5.0.

**Returns**

degree : int

Degree of the series, one less than the number of coefficients.

**Polynomial**. `deriv(m=1)`

Differentiate.

Return a series instance of that is the derivative of the current series.

**Parameters**

m : non-negative int

The number of integrations to perform.

**Returns**

new_series : series

A new series representing the derivative. The domain is the same as the domain of the differentiated series.

**classmethod** Polynomial. `fit(x, y, deg, domain=None, rcond=None, full=False, w=None, window=None)`

Least squares fit to data.

Return a series instance that is the least squares fit to the data `y` sampled at `x`. The domain of the returned instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

**Parameters**

x : array_like, shape (M,)

x-coordinates of the M sample points (`x[i]`, `y[i]`).

y : array_like, shape (M,) or (M, K)

y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.
deg : int
Degree of the fitting polynomial.

domain : {None, [beg, end], []}, optional
Domain to use for the returned series. If None, then a minimal domain that covers the points \( x \) is chosen. If [] the class domain is used. The default value was the class domain in NumPy 1.4 and None in later versions. The [] option was added in numpy 1.5.0.

rcond : float, optional
Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is \( \text{len}(x) \times \text{eps} \), where eps is the relative precision of the float type, about 2e-16 in most cases.

full : bool, optional
Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w : array_like, shape (M,), optional
Weights. If not None the contribution of each point \((x[i], y[i])\) to the fit is weighted by \(w[i]\). Ideally the weights are chosen so that the errors of the products \(w[i] \times y[i]\) all have the same variance. The default value is None.

New in version 1.5.0.

window : [[beg, end]], optional
Window to use for the returned series. The default value is the default class domain

New in version 1.6.0.

Returns

new_series : series
A series that represents the least squares fit to the data and has the domain specified in the call.

[resid, rank, sv, rcond] : list
These values are only returned if full = True
resid – sum of squared residuals of the least squares fit rank – the numerical rank of the scaled Vandermonde matrix sv – singular values of the scaled Vandermonde matrix rcond – value of rcond.

For more details, see \texttt{linalg.lstsq}.

classmethod Polynomial.fromroots(roots, domain=[], window=None)
Return series instance that has the specified roots.

Returns a series representing the product \((x - r[0]) \times (x - r[1]) \times \ldots \times (x - r[n-1])\), where \( r \) is a list of roots.

Parameters

roots : array_like
List of roots.

domain : [[]. None, array_like], optional
Domain for the resulting series. If None the domain is the interval from the smallest root to the largest. If [...] the domain is the class domain. The default is [...]。

window : {None, array_like}, optional
Window for the returned series. If None the class window is used. The default is None.

Returns
new_series : series
Series with the specified roots.

Polynomial.has_samecoef(other)
Check if coefficients match.
New in version 1.6.0.

Parameters
other : class instance
The other class must have the coef attribute.

Returns
bool : boolean
True if the coefficients are the same, False otherwise.

Polynomial.has_samedomain(other)
Check if domains match.
New in version 1.6.0.

Parameters
other : class instance
The other class must have the domain attribute.

Returns
bool : boolean
True if the domains are the same, False otherwise.

Polynomial.has_sametype(other)
Check if types match.
New in version 1.7.0.

Parameters
other : object
Class instance.

Returns
bool : boolean
True if other is same class as self

Polynomial.has_samewindow(other)
Check if windows match.
New in version 1.6.0.

Parameters
other : class instance
The other class must have the window attribute.
Returns

bool : boolean

True if the windows are the same, False otherwise.

classmethod Polynomial.identity (domain=None, window=None)

Identity function.

If \( p \) is the returned series, then \( p(x) = x \) for all values of \( x \).

Parameters

domain : {None, array_like}, optional

If given, the array must be of the form \([\text{beg}, \text{end}]\), where \text{beg} and \text{end} are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window : {None, array_like}, optional

If given, the resulting array must be of the form \([\text{beg}, \text{end}]\), where \text{beg} and \text{end} are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series : series

Series of representing the identity.

Polynomial.integ (m=1, k=[], lbnd=None)

Integrate.

Return a series instance that is the definite integral of the current series.

Parameters

m : non-negative int

The number of integrations to perform.

k : array_like

Integration constants. The first constant is applied to the first integration, the second to the second, and so on. The list of values must less than or equal to \( m \) in length and any missing values are set to zero.

lbnd : Scalar

The lower bound of the definite integral.

Returns

new_series : series

A new series representing the integral. The domain is the same as the domain of the integrated series.

Polynomial.linspace (n=100, domain=None)

Return \( x, y \) values at equally spaced points in domain.

Returns the \( x, y \) values at \( n \) linearly spaced points across the domain. Here \( y \) is the value of the polynomial at the points \( x \). By default the domain is the same as that of the series instance. This method is intended mostly as a plotting aid.

New in version 1.5.0.

Parameters

n : int, optional
Number of point pairs to return. The default value is 100.

**domain**: [None, array_like], optional

If not None, the specified domain is used instead of that of the calling instance. It should be of the form [beg, end]. The default is None which case the class domain is used.

**Returns**

- **x, y**: ndarray
  x is equal to linspace(self.domain[0], self.domain[1], n) and y is the series evaluated at element of x.

**Polynomial.mapparms()**

Return the mapping parameters.

The returned values define a linear map off + scl*x that is applied to the input arguments before the series is evaluated. The map depends on the domain and window; if the current domain is equal to the window the resulting map is the identity. If the coefficients of the series instance are to be used by themselves outside this class, then the linear function must be substituted for the x in the standard representation of the base polynomials.

**Returns**

- **off, scl**: float or complex
  The mapping function is defined by off + scl*x.

**Notes**

If the current domain is the interval [l1, r1] and the window is [l2, r2], then the linear mapping function L is defined by the equations:

\[
L(l1) = l2 \\
L(r1) = r2 
\]

**Polynomial.roots()**

Return the roots of the series polynomial.

Compute the roots for the series. Note that the accuracy of the roots decrease the further outside the domain they lie.

**Returns**

- **roots**: ndarray
  Array containing the roots of the series.

**Polynomial.trim(tol=0)**

Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than tol or the beginning of the series is reached. If all the coefficients would be removed the series is set to [0]. A new series instance is returned with the new coefficients. The current instance remains unchanged.

**Parameters**

- **tol**: non-negative number.
  All trailing coefficients less than tol will be removed.

**Returns**

- **new_series**: series
  Contains the new set of coefficients.
Polynomial.truncate(size)

Truncate series to length size.

Reduce the series to length size by discarding the high degree terms. The value of size must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

**Parameters**

size : positive int

The series is reduced to length size by discarding the high degree terms. The value of size must be a positive integer.

**Returns**

new_series : series

New instance of series with truncated coefficients.

---

**Basics**

numpy.polynomial.polynomial.polyval(x, c[, tensor])

Evaluate a polynomial at points x.

If c is of length n + 1, this function returns the value

\[ p(x) = c_0 + c_1 \cdot x + \ldots + c_n \cdot x^n \]

The parameter x is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either x or its elements must support addition and multiplication with themselves and with the elements of c.

If c is a 1-D array, then p(x) will have the same shape as x. If c is multidimensional, then the shape of the result depends on the value of tensor. If tensor is true the shape will be c.shape[1:] + x.shape. If tensor is false the shape will be c.shape[1:]. Note that scalars have shape (,).

Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

**Parameters**

x : array_like, compatible object

If x is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, x or its elements must support addition and multiplication with with themselves and with the elements of c.

c : array_like

Array of coefficients ordered so that the coefficients for terms of degree n are contained in c[n]. If c is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of c.
tensor : boolean, optional

If True, the shape of the coefficient array is extended with ones on the right, one for each
dimension of x. Scalars have dimension 0 for this action. The result is that every column
of coefficients in c is evaluated for every element of x. If False, x is broadcast over the
columns of c for the evaluation. This keyword is useful when c is multidimensional.
The default value is True.

New in version 1.7.0.

Returns
values : ndarray, compatible object

The shape of the returned array is described above.

See also:
polyval2d, polygrid2d, polyval3d, polygrid3d

Notes
The evaluation uses Horner’s method.

Examples
>>> from numpy.polynomial.polynomial import polyval
>>> polyval(1, [1,2,3])
6.0
>>> a = np.arange(4).reshape(2,2)
>>> a
array([[0, 1],
       [2, 3]])
>>> polyval(a, [1,2,3])
array([[ 1.,  6.],
       [17., 34.]])
>>> coef = np.arange(4).reshape(2,2)  # multidimensional coefficients
>>> coef
array([[0, 1],
       [2, 3]])
>>> polyval([1,2], coef, tensor=True)
array([[2., 4.],
       [4., 7.]])
>>> polyval([1,2], coef, tensor=False)
array([2., 7.])

numpy.polynomial.polynomial.polyval2d(x, y, c)
Evaluate a 2-D polynomial at points (x, y).
This function returns the value
\[ p(x, y) = \sum_{i,j} c_{i,j} * x^i * y^j \]

The parameters x and y are converted to arrays only if they are tuples or a lists, otherwise they are treated as a
scalars and they must have the same shape after conversion. In either case, either x and y or their elements must
support multiplication and addition both with themselves and with the elements of c.

If c has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the
result will be c.shape[2:] + x.shape.

Parameters
   x, y : array_like, compatible objects
The two dimensional series is evaluated at the points \((x, y)\), where \(x\) and \(y\) must have the same shape. If \(x\) or \(y\) is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.

\(c\) : array_like

Array of coefficients ordered so that the coefficient of the term of multi-degree \(i,j\) is contained in \(c[i,j]\). If \(c\) has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns
values : ndarray, compatible object

The values of the two dimensional polynomial at points formed with pairs of corresponding values from \(x\) and \(y\).

See also:
polyval, polygrid2d, polyval3d, polygrid3d

Notes
New in version 1.7.0.

numpy.polynomial.polynomial.polyval3d(x, y, z, c)

Evaluate a 3-D polynomial at points \((x, y, z)\).

This function returns the values:

\[ p(x, y, z) = \sum_{i,j,k} c_{i,j,k} \cdot x^i \cdot y^j \cdot z^k \]

The parameters \(x\), \(y\), and \(z\) are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either \(x\), \(y\), and \(z\) or their elements must support multiplication and addition both with themselves and with the elements of \(c\).

If \(c\) has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be \(c.shape[3:] + x.shape\).

Parameters
\(x, y, z\) : array_like, compatible object

The three dimensional series is evaluated at the points \((x, y, z)\), where \(x\), \(y\), and \(z\) must have the same shape. If any of \(x\), \(y\), or \(z\) is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn’t an ndarray it is treated as a scalar.

\(c\) : array_like

Array of coefficients ordered so that the coefficient of the term of multi-degree \(i,j,k\) is contained in \(c[i,j,k]\). If \(c\) has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

Returns
values : ndarray, compatible object

The values of the multidimensional polynomial on points formed with triples of corresponding values from \(x\), \(y\), and \(z\).

See also:
polyval, polyval2d, polygrid2d, polygrid3d
**numpy.polynomial.polynomial.polygrid2d**

**polygrid2d**

```
(x, y, c)
```

Evaluate a 2-D polynomial on the Cartesian product of `x` and `y`.

This function returns the values:

\[ p(a, b) = \sum_{i,j} c_{i,j} * a^i * b^j \]

where the points \((a, b)\) consist of all pairs formed by taking \(a\) from \(x\) and \(b\) from \(y\). The resulting points form a grid with \(x\) in the first dimension and \(y\) in the second.

The parameters `x` and `y` are converted to arrays only if they are tuples or lists, otherwise they are treated as scalars. In either case, either `x` and `y` or their elements must support multiplication and addition both with themselves and with the elements of \(c\).

If \(c\) has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be \(c.shape[2:] + x.shape + y.shape\).

**Parameters**

- **x, y**: array_like, compatible objects
  - The two dimensional series is evaluated at the points in the Cartesian product of `x` and `y`.
  - If `x` or `y` is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

- **c**: array_like
  - Array of coefficients ordered so that the coefficients for terms of degree \(i,j\) are contained in \(c[i,j]\). If \(c\) has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

**Returns**

- **values**: ndarray, compatible object
  - The values of the two dimensional polynomial at points in the Cartesian product of `x` and `y`.

**See also:**

polyval, polyval2d, polyval3d, polygrid3d

**Notes**

New in version 1.7.0.

```
(x, y, z, c)
```

Evaluate a 3-D polynomial on the Cartesian product of `x`, `y` and `z`.

This function returns the values:

\[ p(a, b, c) = \sum_{i,j,k} c_{i,j,k} * a^i * b^j * c^k \]

where the points \((a, b, c)\) consist of all triples formed by taking \(a\) from \(x\), \(b\) from \(y\), and \(c\) from \(z\). The resulting points form a grid with \(x\) in the first dimension, \(y\) in the second, and \(z\) in the third.

The parameters `x`, `y`, and `z` are converted to arrays only if they are tuples or lists, otherwise they are treated as scalars. In either case, either `x`, `y`, and `z` or their elements must support multiplication and addition both with themselves and with the elements of `c`.
If `c` has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be `c.shape[3:] + x.shape + y.shape + z.shape`.

**Parameters**
- `x, y, z`: array_like, compatible objects
  The three dimensional series is evaluated at the points in the Cartesian product of `x`, `y`, and `z`. If `x`, `y`, or `z` is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.
- `c`: array_like
  Array of coefficients ordered so that the coefficients for terms of degree `i,j` are contained in `c[i, j]`. If `c` has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

**Returns**
- `values`: ndarray, compatible object
  The values of the two dimensional polynomial at points in the Cartesian product of `x` and `y`.

**See also:**
- `polyval`, `polyval2d`, `polygrid2d`, `polyval3d`

**Notes**
New in version 1.7.0.

```python
numpy.polynomial.polynomial.polyroots(c)
```
Compute the roots of a polynomial.

Return the roots (a.k.a. “zeros”) of the polynomial

\[ p(x) = \sum_i c[i] \cdot x^i. \]

**Parameters**
- `c`: 1-D array_like
  1-D array of polynomial coefficients.

**Returns**
- `out`: ndarray
  Array of the roots of the polynomial. If all the roots are real, then `out` is also real, otherwise it is complex.

**See also:**
- `chebroots`

**Notes**

The root estimates are obtained as the eigenvalues of the companion matrix, Roots far from the origin of the complex plane may have large errors due to the numerical instability of the power series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton’s method.
Examples

```python
>>> import numpy.polynomial.polynomial as npoly
>>> npoly.polyroots(npoly.polyfromroots((-1,0,1)))
array([-1., 0., 1.])
```

```
>>> npoly.polyroots(npoly.polyfromroots((-1,0,1))).dtype
dtype('float64')
```

```python
>>> j = complex(0,1)
>>> npoly.polyroots(npoly.polyfromroots((-j,0,j)))
array([ 0.00000000e+00+0.j, 0.00000000e+00+1.j, 2.77555756e-17-1.j])
```

```python
numpy.polynomial.polynomial.polyfromroots(roots)
```
Generate a monic polynomial with given roots.
Return the coefficients of the polynomial

\[ p(x) = (x - r_0)(x - r_1) \ldots (x - r_n), \]

where the \( r_n \) are the roots specified in \( \text{roots} \). If a zero has multiplicity \( n \), then it must appear in \( \text{roots} \) \( n \) times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then \( \text{roots} \) looks something like \[ 2, 2, 2, 3, 3 \]. The roots can appear in any order.
If the returned coefficients are \( c \), then
\[ p(x) = c_0 + c_1x + \ldots + x^n \]
The coefficient of the last term is 1 for monic polynomials in this form.

Parameters
roots : array_like
  Sequence containing the roots.

Returns
out : ndarray
  1-D array of the polynomial’s coefficients If all the roots are real, then \( \text{out} \) is also real, otherwise it is complex. (see Examples below).

See also:
chebfromroots, legfromroots, lagfromroots, hermfromroots, hermefromroots

Notes
The coefficients are determined by multiplying together linear factors of the form \( (x - r_i) \), i.e.
\[ p(x) = (x - r_0)(x - r_1) \ldots (x - r_n) \]
where \( n = \text{len}(\text{roots}) - 1 \); note that this implies that \( 1 \) is always returned for \( a_n \).

Examples
```python
>>> from numpy.polynomial import polynomial as P
>>> P.polyfromroots((-1,0,1)) # x(x - 1)(x + 1) = x^3 - x
array([ 0., -1., 0., 1.])
```
```python
>>> j = complex(0,1)
>>> P.polyfromroots((-j,0,j)) # complex returned, though values are real
array([ 1.+0.j, 0.+0.j, 1.+0.j])
```
Fitting

numpy.polynomial.polynomial.polyfit (x, y, deg[, rcond, full, w])

Least-squares fit of a polynomial to data.

Return the coefficients of a polynomial of degree $deg$ that is the least squares fit to the data values $y$ given at points $x$. If $y$ is 1-D the returned coefficients will also be 1-D. If $y$ is 2-D multiple fits are done, one for each column of $y$, and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

$$p(x) = c_0 + c_1 * x + ... + c_n * x^n,$$

where $n$ is $deg$.

Parameters

- **x**: array_like, shape ($M$)
x-coordinates of the $M$ sample (data) points ($x[i]$, $y[i]$).

- **y**: array_like, shape ($M$) or ($M$, $K$)
y-coordinates of the sample points. Several sets of sample points sharing the same x-coordinates can be (independently) fit with one call to polyfit by passing in for $y$ a 2-D array that contains one data set per column.

- **deg**: int
  Degree of the polynomial(s) to be fit.

- **rcond**: float, optional
  Relative condition number of the fit. Singular values smaller than $rcond$, relative to the largest singular value, will be ignored. The default value is $\text{len}(x) * \text{eps}$, where $\text{eps}$ is the relative precision of the platform’s float type, about $2e-16$ in most cases.

- **full**: bool, optional
  Switch determining the nature of the return value. When False (the default) just the coefficients are returned; when True, diagnostic information from the singular value decomposition (used to solve the fit’s matrix equation) is also returned.

- **w**: array_like, shape ($M$), optional
 Weights. If not None, the contribution of each point ($x[i], y[i]$) to the fit is weighted by $w[i]$. Ideally the weights are chosen so that the errors of the products $w[i] * y[i]$ all have the same variance. The default value is None.

New in version 1.5.0.

Returns

- **coef**: ndarray, shape ($deg + 1.$) or ($deg + 1$, $K$)
  Polynomial coefficients ordered from low to high. If $y$ was 2-D, the coefficients in column $k$ of $\text{coef}$ represent the polynomial fit to the data in $y$'s $k$-th column.

- **[residuals, rank, singular_values, rcond]**: list
These values are only returned if `full = True`
resid – sum of squared residuals of the least squares fit rank – the numerical rank of
the scaled Vandermonde matrix sv – singular values of the scaled Vandermonde matrix
rcond – value of `rcond`.
For more details, see `linalg.lstsq`.

**Raises**

**RankWarning**

Raised if the matrix in the least-squares fit is rank deficient. The warning is only raised
if `full == False`. The warnings can be turned off by:

```python
>>> import warnings
>>> warnings.simplefilter('ignore', RankWarning)
```

**See also:**
chebfit, legfit, lagfit, hermfit, hermfit
polyval
Evaluates a polynomial.
polyvander
Vandermonde matrix for powers.
linalg.lstsq
Computes a least-squares fit from the matrix.
scipy.interpolate.UnivariateSpline
Computes spline fits.

**Notes**
The solution is the coefficients of the polynomial $\rho$ that minimizes the sum of the weighted squared errors

$$E = \sum_j w_j^2 \cdot |y_j - \rho(x_j)|^2,$$

where the $w_j$ are the weights. This problem is solved by setting up the (typically) over-determined matrix equation:

$$V(x) \cdot c = w \cdot y,$$

where $V$ is the weighted pseudo Vandermonde matrix of $x$, $c$ are the coefficients to be solved for, $w$ are the
weights, and $y$ are the observed values. This equation is then solved using the singular value decomposition of $V$.

If some of the singular values of $V$ are so small that they are neglected (and `full == False`), a `RankWarning` will
be raised. This means that the coefficient values may be poorly determined. Fitting to a lower order polynomial
will usually get rid of the warning (but may not be what you want, of course; if you have independent reason(s)
for choosing the degree which isn’t working, you may have to: a) reconsider those reasons, and/or b) reconsider
the quality of your data). The `rcond` parameter can also be set to a value smaller than its default, but the resulting
fit may be spurious and have large contributions from roundoff error.

Polynomial fits using double precision tend to “fail” at about (polynomial) degree 20. Fits using Chebyshev or
Legendre series are generally better conditioned, but much can still depend on the distribution of the sample
points and the smoothness of the data. If the quality of the fit is inadequate, splines may be a good alternative.
Examples

```python
>>> from numpy.polynomial import polynomial as P
>>> x = np.linspace(-1,1,51)  # x "data": [-1, -0.96, ..., 0.96, 1]
>>> y = x**3 - x + np.random.randn(len(x))  # x^3 - x + N(0,1) "noise"
>>> c, stats = P.polyfit(x,y,3,full=True)
>>> c  # c[0], c[2] should be approx. 0, c[1] approx. -1, c[3] approx. 1
array([ 0.01909725, -1.30598256, -0.00577963, 1.02644286])
>>> stats  # note the large SSR, explaining the rather poor results
(array([ 38.06116253]), 4, array([ 1.38446749, 1.32119158, 0.50443316, 0.28853036]), 1.1324274851176597e-014)
```

Same thing without the added noise

```python
>>> y = x**3 - x
>>> c, stats = P.polyfit(x,y,3,full=True)
>>> c  # c[0], c[2] should be "very close to 0", c[1] ~= -1, c[3] ~= 1
array([-1.73362882e-17, -1.00000000e+00, -2.67471909e-16, 1.00000000e+00])
>>> stats  # note the minuscule SSR
(array([ 7.46346754e-31]), 4, array([ 1.38446749, 1.32119158, 0.50443316, 0.28853036]), 1.1324274851176597e-014)
```

```
```
where \(0 \leq i \leq \text{deg}[0]\) and \(0 \leq j \leq \text{deg}[1]\). The leading indices of \(V\) index the points \((x, y)\) and the last index encodes the powers of \(x\) and \(y\).

If \(V = \text{polyvander2d}(x, y, [\text{xdeg}, \text{ydeg}])\), then the columns of \(V\) correspond to the elements of a 2-D coefficient array \(c\) of shape \((\text{xdeg} + 1, \text{ydeg} + 1)\) in the order

\[
c_{00}, c_{01}, c_{02}, ..., c_{10}, c_{11}, c_{12}...
\]

and \(\text{np.dot}(V, c.\text{flat})\) and \(\text{polyval2d}(x, y, c)\) will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D polynomials of the same degrees and sample points.

**Parameters**

- \(x, y\): array_like
  - Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

- \(\text{deg}\): list of ints
  - List of maximum degrees of the form \([x_\text{deg}, y_\text{deg}]\).

**Returns**

- \(\text{vander2d}\): ndarray
  - The shape of the returned matrix is \(x.\text{shape} + \text{(order,)}\), where \(\text{order} = (\text{deg}[0] + 1) * (\text{deg}[1] + 1)\). The dtype will be the same as the converted \(x\) and \(y\).

**See also:**

\(\text{polyvander, polyvander3d, polyval3d}\)

\(\text{numpy.polynomial.polynomial.polyvander3d}(x, y, z, \text{deg})\)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees \(\text{deg}\) and sample points \((x, y, z)\). If \(l, m, n\) are the given degrees in \(x, y, z\), then The pseudo-Vandermonde matrix is defined by

\[
V[\ldots, (m + 1)(n + 1)i + (n + 1)j + k] = x^i * y^j * z^k,
\]

where \(0 \leq i \leq l\), \(0 \leq j \leq m\), and \(0 \leq j \leq n\). The leading indices of \(V\) index the points \((x, y, z)\) and the last index encodes the powers of \(x, y,\) and \(z\).

If \(V = \text{polyvander3d}(x, y, z, [\text{xdeg}, \text{ydeg}, \text{zdeg}])\), then the columns of \(V\) correspond to the elements of a 3-D coefficient array \(c\) of shape \((\text{xdeg} + 1, \text{ydeg} + 1, \text{zdeg} + 1)\) in the order

\[
c_{000}, c_{001}, c_{002}, ..., c_{010}, c_{011}, c_{012}...
\]

and \(\text{np.dot}(V, c.\text{flat})\) and \(\text{polyval3d}(x, y, z, c)\) will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D polynomials of the same degrees and sample points.

**Parameters**

- \(x, y, z\): array_like
  - Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

- \(\text{deg}\): list of ints
  - List of maximum degrees of the form \([x_\text{deg}, y_\text{deg}, z_\text{deg}]\).
Returns

vander3d : ndarray

The shape of the returned matrix is \textit{x.shape + (order,)} where \textit{order} = \textit{(deg[0] + 1) * (deg[1] + 1) * (deg[2] + 1)}. The dtype will be the same as the converted \textit{x}, \textit{y}, and \textit{z}.

See also:

polyvander, polyvander3d, polyval3d

Notes

New in version 1.7.0.

\| polyder(c[, m, scl, axis]) \| Differentiate a polynomial.
\| polyint(c[, m, k, lbnd, scl, axis]) \| Integrate a polynomial.

Calculus

\texttt{numpy.polynomial.polynomial.polyder}(c, m=1, scl=1, axis=0)

Differentiate a polynomial.

Returns the polynomial coefficients \textit{c} differentiated \textit{m} times along \textit{axis}. At each iteration the result is multiplied by \textit{scl} (the scaling factor is for use in a linear change of variable). The argument \textit{c} is an array of coefficients from low to high degree along each axis, e.g., \texttt{[1,2,3]} represents the polynomial \texttt{1 + 2*x + 3*x**2} while \texttt{[[1,2],[1,2]]} represents \texttt{1 + 1*x + 2*y + 2*x*y} if \textit{axis}=0 is \textit{x} and \textit{axis}=1 is \textit{y}.

Parameters

\textit{c} : array_like

Array of polynomial coefficients. If \textit{c} is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

\textit{m} : int, optional

Number of derivatives taken, must be non-negative. (Default: 1)

\textit{scl} : scalar, optional

Each differentiation is multiplied by \textit{scl}. The end result is multiplication by \textit{scl**m}. This is for use in a linear change of variable. (Default: 1)

\textit{axis} : int, optional

Axis over which the derivative is taken. (Default: 0).

New in version 1.7.0.

Returns

\textit{der} : ndarray

Polynomial coefficients of the derivative.

See also:

polyint

Examples

\texttt{>>> from numpy.polynomial import polynomial as P}
\texttt{>>> c = (1,2,3,4) # 1 + 2*x + 3*x**2 + 4*x**3}
\texttt{>>> P.polyder(c) # (d/dx)(c) = 2 + 6x + 12x**2}
NumPy Reference, Release 1.9.2

array([[ 2., 6., 12.]])
>>> P.polyder(c, 3)  # (d**3/dx**3)(c) = 24
array([ 24.])

array([-2., -6., -12.])
>>> P.polyder(c, 2, -1)  # (d**2/d(-x)**2)(c) = 6 + 24x
array([ 6., 24.])

numpy.polynomial.polynomial.polyint(c, m=1, k=[], lbnd=0, scl=1, axis=0)
Integrate a polynomial.

Returns the polynomial coefficients c integrated m times from lbnd along axis. At each iteration the resulting series is multiplied by scl and an integration constant, k, is added. The scaling factor is for use in a linear change of variable. (“Buyer beware”: note that, depending on what one is doing, one may want scl to be the reciprocal of what one might expect; for more information, see the Notes section below.) The argument c is an array of coefficients, from low to high degree along each axis, e.g., [1,2,3] represents the polynomial 1 + 2*x + 3*x**2 while [[1,2],[1,2]] represents 1 + 1*x + 2*y + 2*x*y if axis=0 is x and axis=1 is y.

Parameters
- c : array_like
  1-D array of polynomial coefficients, ordered from low to high.
- m : int, optional
  Order of integration, must be positive. (Default: 1)
- k : {[], list, scalar}, optional
  Integration constant(s). The value of the first integral at zero is the first value in the list, the value of the second integral at zero is the second value, etc. If k == [] (the default), all constants are set to zero. If m == 1, a single scalar can be given instead of a list.
- lbnd : scalar, optional
  The lower bound of the integral. (Default: 0)
- scl : scalar, optional
  Following each integration the result is multiplied by scl before the integration constant is added. (Default: 1)
- axis : int, optional
  Axis over which the integral is taken. (Default: 0).

New in version 1.7.0.

Returns
- S : ndarray
  Coefficient array of the integral.

Raises
- ValueError
  If m < 1, len(k) > m.

See also:
- polyder
Notes
Note that the result of each integration is multiplied by scl. Why is this important to note? Say one is making a linear change of variable \( u = ax + b \) in an integral relative to \( x \). Then \( dx = du/a \), so one will need to set scl equal to \( 1/a \) - perhaps not what one would have first thought.

Examples
>>> from numpy.polynomial import polynomial as P
>>> c = (1,2,3)
>>> P.polyint(c)  # should return array([0, 1, 1, 1])
array([ 0., 1., 1., 1.])
>>> P.polyint(c,3)  # should return array([0, 0, 1/6, 1/12, 1/20])
array([ 0. , 0. , 0.16666667, 0.08333333, 0.05 ])
>>> P.polyint(c,k=3)  # should return array([3, 1, 1, 1])
array([ 3., 1., 1., 1.])
>>> P.polyint(c,lbnd=-2)  # should return array([6, 1, 1, 1])
array([ 6., 1., 1., 1.])
>>> P.polyint(c,scl=-2)  # should return array([0, -2, -2, -2])
array([ 0., -2., -2., -2.])

docstring
polyadd(c1, c2) Add one polynomial to another.
polysub(c1, c2) Subtract one polynomial from another.
polymul(c1, c2) Multiply one polynomial by another.
polymulx(c) Multiply a polynomial by x.
polydiv(c1, c2) Divide one polynomial by another.
polypow(c, pow[, maxpower]) Raise a polynomial to a power.

Algebra
numpy.polynomial.polynomial.polyadd(c1, c2)
Add one polynomial to another.

Returns
1-D arrays of polynomial coefficients ordered from low to high.

Parameters

c1, c2 : array_like

See also:
polysub, polymul, polydiv, polypow

Examples
>>> from numpy.polynomial import polynomial as P
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> sum = P.polyadd(c1,c2); sum
array([ 4., 4., 4.])
```python
>>> P.polyval(2, sum)  # 4 + 4(2) + 4(2**2)
28.0
```

```python
del polynomial.polynomial.polysub(c1, c2)
```

Subtract one polynomial from another.

Returns the difference of two polynomials $c1 - c2$. The arguments are sequences of coefficients from lowest order term to highest, i.e., $[1,2,3]$ represents the polynomial $1 + 2x + 3x^2$.

Parameters

- `c1, c2` : array_like
  1-D arrays of polynomial coefficients ordered from low to high.

Returns

- `out` : ndarray
  Of coefficients representing their difference.

See also:

polyadd, polymul, polydiv, polypow

Examples

```python
>>> from numpy.polynomial import polynomial as P
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> P.polysub(c1, c2)
array([-2., 0., 2.])
>>> P.polysub(c2, c1)  # -P.polysub(c1,c2)
array([ 2., 0., -2.])
```

```python
del polynomial.polynomial.polymul(c1, c2)
```

Multiply one polynomial by another.

Returns the product of two polynomials $c1 \times c2$. The arguments are sequences of coefficients, from lowest order term to highest, e.g., $[1,2,3]$ represents the polynomial $1 + 2x + 3x^2$.

Parameters

- `c1, c2` : array_like
  1-D arrays of coefficients representing a polynomial, relative to the “standard” basis, and ordered from lowest order term to highest.

Returns

- `out` : ndarray
  Of the coefficients of their product.

See also:

polyadd, polysub, polydiv, polypow

Examples

```python
>>> from numpy.polynomial import polynomial as P
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> P.polymul(c1, c2)
array([ 3., 8., 14., 8., 3.])
```

```python
del polynomial.polynomial.polymulx(c)
```

Multiply a polynomial by $x$. 

3.24. Polynomials
Multiply the polynomial \(c\) by \(x\), where \(x\) is the independent variable.

**Parameters**
- \(c\) : array_like
  1-D array of polynomial coefficients ordered from low to high.

**Returns**
- \(out\) : ndarray
  Array representing the result of the multiplication.

**Notes**
New in version 1.5.0.

```
numpy.polynomial.polynomial.polydiv(c1, c2)
```
Divide one polynomial by another.

Returns the quotient-with-remainder of two polynomials \(c_1 / c_2\). The arguments are sequences of coefficients, from lowest order term to highest, e.g., \([1,2,3]\) represents \(1 + 2*x + 3*x^2\).

**Parameters**
- \(c1, c2\) : array_like
  1-D arrays of polynomial coefficients ordered from low to high.

**Returns**
- \([quo, rem]\) : ndarrays
  Of coefficient series representing the quotient and remainder.

**See also:**
polyadd, polysub, polymul, polypow

**Examples**
```python
>>> from numpy.polynomial import polynomial as P
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> P.polydiv(c1,c2)
(array([ 3.]), array([-8., -4.]))
>>> P.polydiv(c2,c1)
(array([ 0.33333333]), array([ 2.66666667, 1.33333333]))
```

```
numpy.polynomial.polynomial.polypow(c, pow, maxpower=None)
```
Raise a polynomial to a power.

Returns the polynomial \(c\) raised to the power \(pow\). The argument \(c\) is a sequence of coefficients ordered from low to high. i.e., \([1,2,3]\) is the series \(1 + 2*x + 3*x^2\).

**Parameters**
- \(c\) : array_like
  1-D array of array of series coefficients ordered from low to high degree.
- \(pow\) : integer
  Power to which the series will be raised
- \(maxpower\) : integer, optional
  Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16
Returns

coeff: ndarray

Power series of power.

See also:

polyadd, polysub, polymul, polydiv

polycompanion(c)  Return the companion matrix of c.
polydomain
polyzero
polyone
polyx
polytrim(c[, tol])  Remove “small” “trailing” coefficients from a polynomial.
polyline(off, scl)  Returns an array representing a linear polynomial.

Miscellaneous

numpy.polynomial.polynomial.polycompanion(c)

Return the companion matrix of c.

The companion matrix for power series cannot be made symmetric by scaling the basis, so this function differs
from those for the orthogonal polynomials.

Parameters
c: array_like

1-D array of polynomial coefficients ordered from low to high degree.

Returns
mat: ndarray

Companion matrix of dimensions (deg, deg).

Notes

New in version 1.7.0.
numpy.polynomial.polynomial.polydomain = array([-1, 1])
numpy.polynomial.polynomial.polyzero = array([0])
numpy.polynomial.polynomial.polyone = array([1])
numpy.polynomial.polynomial.polyx = array([0, 1])
numpy.polynomial.polynomial.polytrim(c, tol=0)

Remove “small” “trailing” coefficients from a polynomial.

“Small” means “small in absolute value” and is controlled by the parameter tol; “trailing” means highest order
coefficient(s), e.g., in [0, 1, 1, 0, 0] (which represents 0 + x + x**2 + 0*x**3 + 0*x**4) both the 3-rd and 4-th order coefficients
would be “trimmed.”

Parameters
c: array_like

1-d array of coefficients, ordered from lowest order to highest.
tol : number, optional

Trailing (i.e., highest order) elements with absolute value less than or equal to tol (default value is zero) are removed.

Returns

trimmed : ndarray

1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

Raises

ValueError

If tol < 0

See also:

trimseq

Examples

>>> from numpy import polynomial as P
>>> P.trimcoef((0,0,3,0,5,0,0))
array([0., 0., 3., 0., 5.])
>>> P.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3) # item == tol is trimmed
array([0.])
>>> i = complex(0,1)  # works for complex
>>> P.trimcoef((3e-4,1e-3*(1-i),5e-4,2e-5*(1+i)), 1e-3)
array([0.0003+0.j , 0.0010-0.001j])

numpy.polynomial.polynomial.polyline(off, scl)

Returns an array representing a linear polynomial.

Parameters

off, scl : scalars

The “y-intercept” and “slope” of the line, respectively.

Returns

y : ndarray

This module’s representation of the linear polynomial off + scl*x.

See also:

tcheb

Examples

>>> from numpy.polynomial import polynomial as P
>>> P.polyline(1,-1)
array([1, -1])
>>> P.polyval(1, P.polyline(1,-1)) # should be 0
0.0

Chebyshev Module (numpy.polynomial.chebyshev)

New in version 1.4.0.

This module provides a number of objects (mostly functions) useful for dealing with Chebyshev series, including a Chebyshev class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with such polynomials is in the docstring for its “parent” sub-package, numpy.polynomial).
**Chebyshev class**

```python
class numpy.polynomial.chebyshev.Chebyshev(coef[, domain, window])
```

A Chebyshev series class.

The Chebyshev class provides the standard Python numerical methods `+`, `-`, `*`, `/`, `//`, `%`, `divmod`, `**`, and `()` as well as the methods listed below.

**Parameters**
- **coef**: array_like
  - Chebyshev coefficients in order of increasing degree, i.e., `(1, 2, 3)` gives
    
    \[ 1 \cdot T_0(x) + 2 \cdot T_1(x) + 3 \cdot T_2(x) \].

- **domain**: `(2,)` array_like, optional
  - Domain to use. The interval `[domain[0], domain[1]]` is mapped to the interval `[window[0], window[1]]` by shifting and scaling. The default value is 
    
    \([-1, 1]\].

- **window**: `(2,)` array_like, optional
  - Window, see domain for its use. The default value is 
    
    \([-1, 1]\].

New in version 1.6.0.

**Methods**

- **__call__(arg)**
  - Series basis polynomial of degree `deg`. Returns the series representing the basis polynomial of degree `deg`.

- **basis(deg[, domain, window])**
  - Convert series to series of this class.

- **cast(series[, domain, window])**
  - Convert series to a different kind and/or domain and/or window.

- **copy()**
  - Return a copy.

- **cutdeg(deg)**
  - Truncate series to the given degree.

- **degree()**
  - The degree of the series.

- **deriv([m])**
  - Differentiate.

- **fit(x, y, deg[, domain, rcond, full, w, window])**
  - Least squares fit to data.

- **fromroots(roots[, domain, window])**
  - Return series instance that has the specified roots.

- **has_samecoef(other)**
  - Check if coefficients match.

- **has_samedomain(other)**
  - Check if domains match.

- **has_sametype(other)**
  - Check if types match.

- **has_samewindow(other)**
  - Check if windows match.

- **identity([domain, window])**
  - Identity function.

- **integ([m, k, lbnd])**
  - Integrate.

- **linspace([n, domain])**
  - Return x, y values at equally spaced points in domain.

- **mapparms()**
  - Return the mapping parameters.

- **roots()**
  - Return the roots of the series polynomial.

- **trim([tol])**
  - Remove trailing coefficients until a coefficient is reached whose absolute value greater than `tol` or the beginning of the series is reached.

- **truncate(size)**
  - Truncate series to length `size`.

**classmethod** **Chebyshev.basis** *(deg[, domain=None, window=None])*  

Returns the series representing the basis polynomial of degree `deg`.  

### 3.24. Polynomials

1009
New in version 1.7.0.

Parameters

deg : int

Degree of the basis polynomial for the series. Must be >= 0.

domain : {None, array_like}, optional

If given, the array must be of the form [beg, end], where beg and end are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window : {None, array_like}, optional

If given, the resulting array must be of the form [beg, end], where beg and end are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series : series

A series with the coefficient of the deg term set to one and all others zero.

classmethod Chebyshev.cast(series, domain=None, window=None)

Convert series to series of this class.

The series is expected to be an instance of some polynomial series of one of the types supported by the numpy.polynomial module, but could be some other class that supports the convert method.

New in version 1.7.0.

Parameters

series : series

The series instance to be converted.

domain : {None, array_like}, optional

If given, the array must be of the form [beg, end], where beg and end are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window : {None, array_like}, optional

If given, the resulting array must be of the form [beg, end], where beg and end are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series : series

A series of the same kind as the calling class and equal to series when evaluated.

See also:

convert

similar instance method

Chebyshev.convert(domain=None, kind=None, window=None)

Convert series to a different kind and/or domain and/or window.

Parameters

domain : array_like, optional
The domain of the converted series. If the value is None, the default domain of kind is used.

**kind** : class, optional
The polynomial series type class to which the current instance should be converted. If kind is None, then the class of the current instance is used.

**window** : array_like, optional
The window of the converted series. If the value is None, the default window of kind is used.

**Returns**

**new_series** : series
The returned class can be of different type than the current instance and/or have a different domain and/or different window.

**Notes**
Conversion between domains and class types can result in numerically ill defined series.

**Chebyshev**.copy()
Return a copy.

**Returns**

**new_series** : series
Copy of self.

**Chebyshev**.cutdeg(deg)
Truncate series to the given degree.

Reduce the degree of the series to deg by discarding the high order terms. If deg is greater than the current degree a copy of the current series is returned. This can be useful in least squares where the coefficients of the high degree terms may be very small.

New in version 1.5.0.

**Parameters**

**deg** : non-negative int
The series is reduced to degree deg by discarding the high order terms. The value of deg must be a non-negative integer.

**Returns**

**new_series** : series
New instance of series with reduced degree.

**Chebyshev**.degree()
The degree of the series.

New in version 1.5.0.

**Returns**

**degree** : int
Degree of the series, one less than the number of coefficients.

**Chebyshev**.deriv(m=1)
Differentiate.

Return a series instance of that is the derivative of the current series.
Parameters

\(m\) : non-negative int

The number of integrations to perform.

Returns

\(new\_series\) : series

A new series representing the derivative. The domain is the same as the domain of the differentiated series.

classmethod \(Chebyshev.f\_it\) \((x, y, deg, domain=None, rcond=None, full=False, w=None, window=None)\)

Least squares fit to data.

Return a series instance that is the least squares fit to the data \(y\) sampled at \(x\). The domain of the returned instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

Parameters

\(x\) : array_like, shape (M,)

x-coordinates of the M sample points \((x[i], y[i])\).

\(y\) : array_like, shape (M,) or (M, K)

y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

\(deg\) : int

Degree of the fitting polynomial.

\(domain\) : {None, [beg, end], []}, optional

Domain to use for the returned series. If None, then a minimal domain that covers the points \(x\) is chosen. If [] the class domain is used. The default value was the class domain in NumPy 1.4 and None in later versions. The [] option was added in numpy 1.5.0.

\(rcond\) : float, optional

Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is \(\text{len}(x)\)\*\(eps\), where \(eps\) is the relative precision of the float type, about 2e-16 in most cases.

\(full\) : bool, optional

Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

\(w\) : array_like, shape (M,), optional

Weights. If not None the contribution of each point \((x[i], y[i])\) to the fit is weighted by \(w[i]\). Ideally the weights are chosen so that the errors of the products \(w[i]*y[i]\) all have the same variance. The default value is None.

New in version 1.5.0.

\(window\) : {[beg, end]}, optional

Window to use for the returned series. The default value is the default class domain

New in version 1.6.0.
Returns

new_series : series

A series that represents the least squares fit to the data and has the domain specified in
the call.

[resid, rank, sv, rcond] : list

These values are only returned if full = True

resid – sum of squared residuals of the least squares fit
rank – the numerical rank of
the scaled Vandermonde matrix
sv – singular values of the scaled Vandermonde matrix
rcond – value of rcond.

For more details, see linalg.lstsq.

classmethod Chebyshev.fromroots(roots, domain=[], window=None)

Return series instance that has the specified roots.

Parameters

roots : array_like

List of roots.

domain : [ ], None, array_like, optional

Domain for the resulting series. If None the domain is the interval from the smallest
root to the largest. If [] the domain is the class domain. The default is [].

window : [ None, array_like ], optional

Window for the returned series. If None the class window is used. The default is None.

Returns

new_series : series

Series with the specified roots.

Chebyshev.has_samecoef(other)

Check if coefficients match.

New in version 1.6.0.

Parameters

other : class instance

The other class must have the coef attribute.

Returns

bool : boolean

True if the coefficients are the same, False otherwise.

Chebyshev.has_samedomain(other)

Check if domains match.

New in version 1.6.0.

Parameters

other : class instance

The other class must have the domain attribute.
Returns
boole : boolean

True if the domains are the same, False otherwise.

\texttt{Chebyshev.\ has\_sametype (other)}
Check if types match.

New in version 1.7.0.

Parameters
other : object

Class instance.

Returns
boole : boolean

True if other is same class as self

\texttt{Chebyshev.\ has\_samewindow (other)}
Check if windows match.

New in version 1.6.0.

Parameters
other : class instance

The other class must have the \texttt{window} attribute.

Returns
boole : boolean

True if the windows are the same, False otherwise.

\texttt{classmethod Chebyshev.\ identity (domain=None, window=None)}
Identity function.

If \( p \) is the returned series, then \( p(x) = x \) for all values of \( x \).

Parameters
domain : \{None, array_like\}, optional

If given, the array must be of the form \([\text{beg}, \text{end}]\), where \( \text{beg} \) and \( \text{end} \) are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window : \{None, array_like\}, optional

If given, the resulting array must be of the form \([\text{beg}, \text{end}]\), where \( \text{beg} \) and \( \text{end} \) are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns
\texttt{new\_series} : series

Series of representing the identity.

\texttt{Chebyshev.\ integ (m=1, k=[], lbnd=None)}
Integrate.

Return a series instance that is the definite integral of the current series.

Parameters
m : non-negative int
The number of integrations to perform.

\( k \) : array_like

Integration constants. The first constant is applied to the first integration, the second to the second, and so on. The list of values must less than or equal to \( m \) in length and any missing values are set to zero.

\( lbnd \) : Scalar

The lower bound of the definite integral.

Returns

- **new_series** : series

  A new series representing the integral. The domain is the same as the domain of the integrated series.

**Chebyshev.linspace** \((n=100, domain=None)\)

Return \( x, y \) values at equally spaced points in domain.

Returns the \( x, y \) values at \( n \) linearly spaced points across the domain. Here \( y \) is the value of the polynomial at the points \( x \). By default the domain is the same as that of the series instance. This method is intended mostly as a plotting aid.

New in version 1.5.0.

Parameters

- **n** : int, optional

  Number of point pairs to return. The default value is 100.

- **domain** : {None, array_like}, optional

  If not None, the specified domain is used instead of that of the calling instance. It should be of the form \([\text{beg}, \text{end}]\). The default is None which case the class domain is used.

Returns

- **x**, **y** : ndarray

  \( x \) is equal to linspace(self.domain[0], self.domain[1], n) and \( y \) is the series evaluated at element of \( x \).

**Notes**

If the current domain is the interval \([l1, \ r1]\) and the window is \([l2, \ r2]\), then the linear mapping function \( L \) is defined by the equations:

\[
L(l1) = l2
L(r1) = r2
\]
Chebyshev.roots()

Return the roots of the series polynomial.

Compute the roots for the series. Note that the accuracy of the roots decrease the further outside the domain they lie.

Returns
- roots : ndarray
  Array containing the roots of the series.

Chebyshev.trim(tol=0)

Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than tol or the beginning of the series is reached. If all the coefficients would be removed the series is set to \([0]\). A new series instance is returned with the new coefficients. The current instance remains unchanged.

Parameters
- tol : non-negative number.
  All trailing coefficients less than tol will be removed.

Returns
- new_series : series
  Contains the new set of coefficients.

Chebyshev.truncate(size)

Truncate series to length size.

Reduce the series to length size by discarding the high degree terms. The value of size must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters
- size : positive int
  The series is reduced to length size by discarding the high degree terms. The value of size must be a positive integer.

Returns
- new_series : series
  New instance of series with truncated coefficients.

chebval(x, c[, tensor]) Evaluate a Chebyshev series at points x.

If c is of length \(n + 1\), this function returns the value:

\[ p(x) = c_0 \ast T_0(x) + c_1 \ast T_1(x) + \ldots + c_n \ast T_n(x) \]
The parameter $x$ is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either $x$ or its elements must support multiplication and addition both with themselves and with the elements of $c$.

If $c$ is a 1-D array, then $p(x)$ will have the same shape as $x$. If $c$ is multidimensional, then the shape of the result depends on the value of $tensor$. If $tensor$ is true the shape will be $c.shape[1:] + x.shape$. If $tensor$ is false the shape will be $c.shape[1:]$. Note that scalars have shape (,).

Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

**Parameters**

- $x$: array_like, compatible object
  
  If $x$ is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, $x$ or its elements must support addition and multiplication with with themselves and with the elements of $c$.

- $c$: array_like
  
  Array of coefficients ordered so that the coefficients for terms of degree $n$ are contained in $c[n]$. If $c$ is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of $c$.

- $tensor$: boolean, optional
  
  If True, the shape of the coefficient array is extended with ones on the right, one for each dimension of $x$. Scalars have dimension 0 for this action. The result is that every column of coefficients in $c$ is evaluated for every element of $x$. If False, $x$ is broadcast over the columns of $c$ for the evaluation. This keyword is useful when $c$ is multidimensional. The default value is True.

**Returns**

- $values$: ndarray, algebra_like
  
  The shape of the return value is described above.

**See also:**

- `chebval2d`, `chebgrid2d`, `chebval3d`, `chebgrid3d`

**Notes**

The evaluation uses Clenshaw recursion, aka synthetic division.

```python
numpy.polynomial.chebyshev.chebval2d(x, y, c)
```

Evaluate a 2-D Chebyshev series at points $(x, y)$.

This function returns the values:

$$p(x, y) = \sum_{i,j} c_{i,j} \cdot T_i(x) \cdot T_j(y)$$

The parameters $x$ and $y$ are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either $x$ and $y$ or their elements must support multiplication and addition both with themselves and with the elements of $c$.

If $c$ is a 1-D array a one is implicitly appended to its shape to make it 2-D. The shape of the result will be $c.shape[2:] + x.shape$.

**Parameters**

- $x, y$: array_like, compatible objects
The two dimensional series is evaluated at the points \((x, y)\), where \(x\) and \(y\) must have the same shape. If \(x\) or \(y\) is a list or tuple, it is first converted to an \(\text{ndarray}\), otherwise it is left unchanged and if it isn’t an \(\text{ndarray}\) it is treated as a scalar.

\[
c : \text{array_like}
\]

Array of coefficients ordered so that the coefficient of the term of multi-degree \(i,j\) is contained in \(c[i, j]\). If \(c\) has dimension greater than 2 the remaining indices enumerate multiple sets of coefficients.

**Returns**

\[
\text{values} : \text{ndarray, compatible object}
\]

The values of the two dimensional Chebyshev series at points formed from pairs of corresponding values from \(x\) and \(y\).

**See also:**

`chebval`, `chebgrid2d`, `chebval3d`, `chebgrid3d`

**Notes**

`numpy.polynomial.chebyshev.chebval3d(x, y, z, c)`

Evaluate a 3-D Chebyshev series at points \((x, y, z)\).

This function returns the values:

\[
p(x, y, z) = \sum_{i,j,k} c_{i,j,k} \cdot T_i(x) \cdot T_j(y) \cdot T_k(z)
\]

The parameters \(x\), \(y\), and \(z\) are converted to arrays only if they are tuples or a lists, otherwise they are treated as scalars and they must have the same shape after conversion. In either case, either \(x\), \(y\), and \(z\) or their elements must support multiplication and addition both with themselves and with the elements of \(c\).

If \(c\) has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be \(c.shape[3:] + x.shape\).

**Parameters**

\[
x, y, z : \text{array_like, compatible object}
\]

The three dimensional series is evaluated at the points \((x, y, z)\), where \(x\), \(y\), and \(z\) must have the same shape. If any of \(x\), \(y\), or \(z\) is a list or tuple, it is first converted to an \(\text{ndarray}\), otherwise it is left unchanged and if it isn’t an \(\text{ndarray}\) it is treated as a scalar.

\[
c : \text{array_like}
\]

Array of coefficients ordered so that the coefficient of the term of multi-degree \(i,j,k\) is contained in \(c[i, j, k]\). If \(c\) has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

**Returns**

\[
\text{values} : \text{ndarray, compatible object}
\]

The values of the multidimensional polynomial on points formed with triples of corresponding values from \(x\), \(y\), and \(z\).

**See also:**

`chebval`, `chebval2d`, `chebgrid2d`, `chebgrid3d`
numpy.polynomial.chebyshev.chebgrid2d(x, y, c)

Evaluate a 2-D Chebyshev series on the Cartesian product of x and y.

This function returns the values:

\[ p(a, b) = \sum_{i,j} c_{i,j} \cdot T_i(a) \cdot T_j(b), \]

where the points \((a, b)\) consist of all pairs formed by taking \(a\) from \(x\) and \(b\) from \(y\). The resulting points form a grid with \(x\) in the first dimension and \(y\) in the second.

The parameters \(x\) and \(y\) are converted to arrays only if they are tuples or a lists, otherwise they are treated as scalars. In either case, either \(x\) and \(y\) or their elements must support multiplication and addition both with themselves and with the elements of \(c\).

If \(c\) has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be \(c\.shape[2:] + x\.shape + y\.shape\).

Parameters
- \(x, y\) : array_like, compatible objects
  The two dimensional series is evaluated at the points in the Cartesian product of \(x\) and \(y\). If \(x\) or \(y\) is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.
- \(c\) : array_like
  Array of coefficients ordered so that the coefficient of the term of multi-degree \(i,j\) is contained in \(c[i,j]\). If \(c\) has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns
- \(values\) : ndarray, compatible object
  The values of the two dimensional Chebyshev series at points in the Cartesian product of \(x\) and \(y\).

See also:
- chebval, chebval2d, chebval3d, chebgrid3d

Notes
numpy.polynomial.chebyshev.chebgrid3d(x, y, z, c)

Evaluate a 3-D Chebyshev series on the Cartesian product of \(x, y,\) and \(z\).

This function returns the values:

\[ p(a, b, c) = \sum_{i,j,k} c_{i,j,k} \cdot T_i(a) \cdot T_j(b) \cdot T_k(c) \]

where the points \((a, b, c)\) consist of all triples formed by taking \(a\) from \(x\), \(b\) from \(y\), and \(c\) from \(z\). The resulting points form a grid with \(x\) in the first dimension, \(y\) in the second, and \(z\) in the third.

The parameters \(x, y,\) and \(z\) are converted to arrays only if they are tuples or a lists, otherwise they are treated as scalars. In either case, either \(x, y,\) and \(z\) or their elements must support multiplication and addition both with themselves and with the elements of \(c\).

If \(c\) has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be \(c\.shape[3:] + x\.shape + y\.shape + z\.shape\).
Parameters

x, y, z : array_like, compatible objects

The three dimensional series is evaluated at the points in the Cartesian product of x, y, and z. If x, y, or z is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.

c : array_like

Array of coefficients ordered so that the coefficients for terms of degree i,j are contained in c[i,j]. If c has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values : ndarray, compatible object

The values of the two dimensional polynomial at points in the Cartesian product of x and y.

See also:
chebval, chebval2d, chebgrid2d, chebval3d

Notes

numpy.polynomial.chebyshev.chebroots(c)

Compute the roots of a Chebyshev series.

Return the roots (a.k.a. “zeros”) of the polynomial

\[ p(x) = \sum c[i] \cdot T_i(x). \]

Parameters

c : 1-D array_like

1-D array of coefficients.

Returns

out : ndarray

Array of the roots of the series. If all the roots are real, then out is also real, otherwise it is complex.

See also:
polyroots, legroots, lagroots, hermroots, hermeroots

Notes

The root estimates are obtained as the eigenvalues of the companion matrix. Roots far from the origin of the complex plane may have large errors due to the numerical instability of the series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton’s method.

The Chebyshev series basis polynomials aren’t powers of x so the results of this function may seem unintuitive.

Examples

```python
>>> import numpy.polynomial.chebyshev as cheb
>>> cheb.chebroots((-1, 1,-1, 1)) # T3 - T2 + T1 - T0 has real roots
array([ -5.00000000e-01, 2.60860684e-17, 1.00000000e+00])
```
numpy.polynomial.chebyshev.chebfromroots(roots)

Generate a Chebyshev series with given roots.

The function returns the coefficients of the polynomial

\[ p(x) = (x - r_0) \cdot (x - r_1) \cdot \ldots \cdot (x - r_n), \]

in Chebyshev form, where the \( r_n \) are the roots specified in \( \text{roots} \). If a zero has multiplicity \( n \), then it must appear in \( \text{roots} \) \( n \) times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then \( \text{roots} \) looks something like \([2, 2, 2, 3, 3]\). The roots can appear in any order.

If the returned coefficients are \( c \), then

\[ p(x) = c_0 + c_1 \cdot T_1(x) + \ldots + c_n \cdot T_n(x) \]

The coefficient of the last term is not generally 1 for monic polynomials in Chebyshev form.

Parameters

roots : array_like

Sequence containing the roots.

Returns

out : ndarray

1-D array of coefficients. If all roots are real then \( \text{out} \) is a real array, if some of the roots are complex, then \( \text{out} \) is complex even if all the coefficients in the result are real (see Examples below).

See also:

polyfromroots, legfromroots, lagfromroots, hermfromroots, hermefromroots.

Examples

```python
>>> import numpy.polynomial.chebyshev as C
>>> C.chebfromroots((-1,0,1))  # x^3 - x relative to the standard basis
array([ 0. , -0.25, 0. , 0.25])
```

```python
>>> j = complex(0,1)
>>> C.chebfromroots((-j,j))  # x^2 + 1 relative to the standard basis
array([ 1.5+0.j, 0.0+0.j, 0.5+0.j])
```

Fitting

numpy.polynomial.chebyshev.chebfit(x, y, deg[, rcond, full, w]) Least squares fit of Chebyshev series to data.

Return the coefficients of a Legendre series of degree \( \text{deg} \) that is the least squares fit to the data values \( y \) given at points \( x \). If \( y \) is 1-D the returned coefficients will also be 1-D. If \( y \) is 2-D multiple fits are done, one for each column of \( y \), and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

\[ p(x) = c_0 + c_1 \cdot T_1(x) + \ldots + c_n \cdot T_n(x), \]

where \( n \) is \( \text{deg} \).
Parameters

x : array_like, shape (M,)
    x-coordinates of the M sample points (x[i], y[i]).

y : array_like, shape (M,) or (M, K)
    y-coordinates of the sample points. Several data sets of sample points sharing the same
    x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset
    per column.

deg : int
    Degree of the fitting series

rcond : float, optional
    Relative condition number of the fit. Singular values smaller than this relative to the
    largest singular value will be ignored. The default value is len(x)*eps, where eps is the
    relative precision of the float type, about 2e-16 in most cases.

full : bool, optional
    Switch determining nature of return value. When it is False (the default) just the coeffi-
    cients are returned, when True diagnostic information from the singular value decom-
    position is also returned.

w : array_like, shape (M,), optional
    Weights. If not None, the contribution of each point (x[i],y[i]) to the fit is
    weighted by w[i]. Ideally the weights are chosen so that the errors of the products
    w[i]*y[i] all have the same variance. The default value is None.
    New in version 1.5.0.

Returns

coef : ndarray, shape (M,) or (M, K)
    Chebyshev coefficients ordered from low to high. If y was 2-D, the coefficients for the
    data in column k of y are in column k.

[residuals, rank, singular_values, rcond] : list
    These values are only returned if full = True

    resid – sum of squared residuals of the least squares fit
    rank – the numerical rank of
    the scaled Vandermonde matrix sv – singular values of the scaled Vandermonde matrix
    rcond – value of rcond.

    For more details, see linalg.lstsq.

Warns

RankWarning
    The rank of the coefficient matrix in the least-squares fit is deficient. The warning is
    only raised if full = False. The warnings can be turned off by

    >>> import warnings
    >>> warnings.simplefilter('ignore', RankWarning)

See also:

polyfit, legfit, lagfit, hermfit, hermeval
chebval
Evaluates a Chebyshev series.

chebvander
Vandermonde matrix of Chebyshev series.

chebweight
Chebyshev weight function.

linalg.lstsq
Computes a least-squares fit from the matrix.

scipy.interpolate.UnivariateSpline
Computes spline fits.

Notes
The solution is the coefficients of the Chebyshev series \( p \) that minimizes the sum of the weighted squared errors

\[ E = \sum_j w_j^2 \cdot |y_j - p(x_j)|^2, \]

where \( w_j \) are the weights. This problem is solved by setting up as the (typically) overdetermined matrix equation

\[ V(x) \cdot c = w \cdot y, \]

where \( V \) is the weighted pseudo Vandermonde matrix of \( x \), \( c \) are the coefficients to be solved for, \( w \) are the weights, and \( y \) are the observed values. This equation is then solved using the singular value decomposition of \( V \).

If some of the singular values of \( V \) are so small that they are neglected, then a *RankWarning* will be issued. This means that the coefficient values may be poorly determined. Using a lower order fit will usually get rid of the warning. The *rcond* parameter can also be set to a value smaller than its default, but the resulting fit may be spurious and have large contributions from roundoff error.

Fits using Chebyshev series are usually better conditioned than fits using power series, but much can depend on the distribution of the sample points and the smoothness of the data. If the quality of the fit is inadequate splines may be a good alternative.

References

[R60] numpy.polynomial.chebyshev.chebvander \( (x, \deg) \)
Pseudo-Vandermonde matrix of given degree.

Returns the pseudo-Vandermonde matrix of degree \( \deg \) and sample points \( x \). The pseudo-Vandermonde matrix is defined by

\[ V[\ldots, i] = T_i(x), \]

where \( 0 \leq i \leq \deg \). The leading indices of \( V \) index the elements of \( x \) and the last index is the degree of the Chebyshev polynomial.

If \( c \) is a 1-D array of coefficients of length \( n + 1 \) and \( V \) is the matrix \( V = \text{chebvander}(x, n) \), then \( \text{np.dot}(V, c) \) and \( \text{chebval}(x, c) \) are the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of Chebyshev series of the same degree and sample points.

Parameters
\[
x : \text{array_like}
\]
Array of points. The dtype is converted to float64 or complex128 depending on whether any of the elements are complex. If x is scalar it is converted to a 1-D array.

```
deg : int
    Degree of the resulting matrix.
```

**Returns**

```
vander : ndarray
    The pseudo Vandermonde matrix. The shape of the returned matrix is \(x.shape + (deg + 1,)\), where The last index is the degree of the corresponding Chebyshev polynomial. The dtype will be the same as the converted x.
```

```
numpy.polynomial.chebyshev.chebvander2d(x, y, deg)
    Pseudo-Vandermonde matrix of given degrees.
```

Returns the pseudo-Vandermonde matrix of degrees `deg` and sample points `(x, y)`. The pseudo-Vandermonde matrix is defined by

\[
V[\ldots, deg[1] * i + j] = T_i(x) * T_j(y),
\]

where \(0 <= i <= deg[0]\) and \(0 <= j <= deg[1]\). The leading indices of \(V\) index the points \((x, y)\) and the last index encodes the degrees of the Chebyshev polynomials.

```
If \(V = \text{chebvander2d}(x, y, [xdeg, ydeg])\), then the columns of \(V\) correspond to the elements of a 2-D coefficient array \(c\) of shape \((xdeg + 1, ydeg + 1)\) in the order

\[
c_{00}, c_{01}, c_{02}, \ldots, c_{10}, c_{11}, c_{12}, \ldots
\]

and \(\text{np.dot}(V, c.flat)\) and \(\text{chebval2d}(x, y, c)\) will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D Chebyshev series of the same degrees and sample points.

**Parameters**

```
x, y : array_like
    Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex.
    Scalars are converted to 1-D arrays.
```

```
deg : list of ints
    List of maximum degrees of the form \([x\_deg, y\_deg]\).
```

**Returns**

```
vander2d : ndarray
    The shape of the returned matrix is \(x.shape + (\text{order},)\), where \(\text{order} = (deg[0] + 1) * (deg[1] + 1)\). The dtype will be the same as the converted \(x\) and \(y\).
```

See also:

```
chebvander, chebvander3d, chebval3d
```

**Notes**

```
numpy.polynomial.chebyshev.chebvander3d(x, y, z, deg)
    Pseudo-Vandermonde matrix of given degrees.
```

Returns the pseudo-Vandermonde matrix of degrees `deg` and sample points `(x, y, z)`. If \(l, m, n\) are the given degrees in \(x, y, z\), then The pseudo-Vandermonde matrix is defined by

\[
V[\ldots, (m + 1)(n + 1)i + (n + 1)j + k] = T_i(x) * T_j(y) * T_k(z),
\]
where $0 \leq i \leq l$, $0 \leq j \leq m$, and $0 \leq j \leq n$. The leading indices of $V$ index the points $(x, y, z)$ and the last index encodes the degrees of the Chebyshev polynomials.

If $V = \text{chebvander3d}(x, y, z, [xdeg, ydeg, zdeg])$, then the columns of $V$ correspond to the elements of a 3-D coefficient array $c$ of shape $(xdeg + 1, ydeg + 1, zdeg + 1)$ in the order $c_{000}, c_{001}, c_{002}, ..., c_{101}, c_{102}, c_{112}, ...$

and $\text{np.dot}(V, c\text{.flat})$ and $\text{chebval3d}(x, y, z, c)$ will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D Chebyshev series of the same degrees and sample points.

**Parameters**
- $x, y, z$: array_like
  Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.
- $\text{deg}$: list of ints
  List of maximum degrees of the form $[x\_deg, y\_deg, z\_deg]$.

**Returns**
- $\text{vander3d}$: ndarray
  The shape of the returned matrix is $x\_\text{shape} + (\text{order},)$, where $\text{order} = (\text{deg}[0] + 1) * (\text{deg}[1] + 1) * (\text{deg}[2] + 1)$. The dtype will be the same as the converted $x, y, \text{and } z$.

**See also:**
- $\text{chebvander}$, $\text{chebvander3d}$, $\text{chebval3d}$

**Notes**
- $\text{chebder}(c[, m, scl, axis])$ Differentiate a Chebyshev series.
- $\text{chebint}(c[, m, k, lbnd, scl, axis])$ Integrate a Chebyshev series.

**Calculus**

numpy.polynomial.chebyshev.chebder ($c, m=1, scl=1, axis=0$) Differentiate a Chebyshev series.

Returns the Chebyshev series coefficients $c$ differentiated $m$ times along $axis$. At each iteration the result is multiplied by $scl$ (the scaling factor is for use in a linear change of variable). The argument $c$ is an array of coefficients from low to high degree along each axis, e.g., $[1, 2, 3]$ represents the series $1*T_0 + 2*T_1 + 3*T_2$ while $[[1, 2], [1, 2]]$ represents $1*T_0(x)*T_0(y) + 1*T_1(x)*T_0(y) + 2*T_0(x)*T_1(y) + 2*T_1(x)*T_1(y)$ if axis=0 is $x$ and axis=1 is $y$.

**Parameters**
- $c$: array_like
  Array of Chebyshev series coefficients. If $c$ is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.
- $m$: int, optional
  Number of derivatives taken, must be non-negative. (Default: 1)
- $scl$: scalar, optional
Each differentiation is multiplied by \( scl \). The end result is multiplication by \( scl**m \). This is for use in a linear change of variable. (Default: 1)

**axis** : int, optional

Axis over which the derivative is taken. (Default: 0).

New in version 1.7.0.

**Returns**

**der** : ndarray

Chebyshev series of the derivative.

**See also:**

chebint

**Notes**

In general, the result of differentiating a C-series needs to be “reprojected” onto the C-series basis set. Thus, typically, the result of this function is “unintuitive,” albeit correct; see Examples section below.

**Examples**

```python
>>> from numpy.polynomial import chebyshev as C
>>> c = (1,2,3,4)
>>> C.chebder(c)
array([[ 14., 12., 24.]])
>>> C.chebder(c,3)
array([ 96.])
>>> C.chebder(c,scl=-1)
array([-14., -12., -24.])
>>> C.chebder(c,2,-1)
array([ 12., 96.])
```

Integrate a Chebyshev series.

**Parameters**

- **c** : array_like
  - Array of Chebyshev series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

- **m** : int, optional
  - Order of integration, must be positive. (Default: 1)

- **k** : [()], list, scalar, optional
  - Integration constant(s). The value of the first integral at zero is the first value in the list, the value of the second integral at zero is the second value, etc. If \( k == [] \) (the default), all constants are set to zero. If \( m == 1 \), a single scalar can be given instead of a list.

- **lbnd** : scalar, optional
  - Lower bound of integration. (Default: 0)

- **scl** : scalar, optional
  - Scaling factor for result. (Default: 1)

- **axis** : int, optional
  - Axis over which to integrate. (Default: 0).

New in version 1.7.0.
**lbnd** : scalar, optional
The lower bound of the integral. (Default: 0)

**scl** : scalar, optional
Following each integration the result is multiplied by scl before the integration constant is added. (Default: 1)

**axis** : int, optional
Axis over which the integral is taken. (Default: 0).
New in version 1.7.0.

Returns

**S** : ndarray
C-series coefficients of the integral.

Raises

**ValueError**
If m < 1, len(k) > m, np.isscalar(lbnd) == False, or np.isscalar(scl) == False.

See also:

chebder

Notes

Note that the result of each integration is multiplied by scl. Why is this important to note? Say one is making a linear change of variable \( u = ax + b \) in an integral relative to x. Then \( \text{math}: dx = du/a \), so one will need to set scl equal to \( 1/a \) - perhaps not what one would have first thought.

Also note that, in general, the result of integrating a C-series needs to be “reprojected” onto the C-series basis set. Thus, typically, the result of this function is “unintuitive,” albeit correct; see Examples section below.

Examples

```python
>>> from numpy.polynomial import chebyshev as C
>>> c = (1,2,3)
>>> C.chebint(c)
array([ 0.5, -0.5, 0.5, 0.5])
>>> C.chebint(c,3)
array([ 0.03125 , -0.1875 , 0.04166667, -0.05208333, 0.01041667,
       0.00625 ])
>>> C.chebint(c, k=3)
array([ 3.5, -0.5, 0.5, 0.5])
>>> C.chebint(c,lbnd=-2)
array([ 8.5, -0.5, 0.5, 0.5])
>>> C.chebint(c,scl=-2)
array([-1., 1., -1., -1.])
```

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Algebra

**numpy.polynomial.chebyshev.chebadd(c1, c2)**

Add one Chebyshev series to another.

Returns the sum of two Chebyshev series \( c1 + c2 \). The arguments are sequences of coefficients ordered from lowest order term to highest, i.e., \([1,2,3]\) represents the series \( T_0 + 2 \cdot T_1 + 3 \cdot T_2 \).

**Parameters**
- **c1**, **c2**: array_like
  1-D arrays of Chebyshev series coefficients ordered from low to high.

**Returns**
- **out**: ndarray
  Array representing the Chebyshev series of their sum.

**See also:**
chebsub, chebmul, chebdiff, chebpow

**Notes**
Unlike multiplication, division, etc., the sum of two Chebyshev series is a Chebyshev series (without having to “reproject” the result onto the basis set) so addition, just like that of “standard” polynomials, is simply “component-wise.”

**Examples**

```python
>>> from numpy.polynomial import chebyshev as C
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> C.chebadd(c1,c2)
array([ 4.,  4.,  4.])
```

**numpy.polynomial.chebyshev.chebsub(c1, c2)**

Subtract one Chebyshev series from another.

Returns the difference of two Chebyshev series \( c1 - c2 \). The sequences of coefficients are from lowest order term to highest, i.e., \([1,2,3]\) represents the series \( T_0 + 2 \cdot T_1 + 3 \cdot T_2 \).

**Parameters**
- **c1**, **c2**: array_like
  1-D arrays of Chebyshev series coefficients ordered from low to high.

**Returns**
- **out**: ndarray
  Of Chebyshev series coefficients representing their difference.

**See also:**
chebadd, chebmul, chebdiv, chebpow

**Notes**
Unlike multiplication, division, etc., the difference of two Chebyshev series is a Chebyshev series (without having to “reproject” the result onto the basis set) so subtraction, just like that of “standard” polynomials, is simply “component-wise.”
Examples

```python
>>> from numpy.polynomial import chebyshev as C
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> C.chebsub(c1,c2)
array([-2., 0., 2.])
>>> C.chebsub(c2,c1)  # -C.chebsub(c1,c2)
array([ 2., 0., -2.])
```

`numpy.polynomial.chebyshev.chebmul(c1,c2)`
Multiply one Chebyshev series by another.

Returns the product of two Chebyshev series `c1 * c2`. The arguments are sequences of coefficients, from lowest order “term” to highest, e.g., `[1,2,3]` represents the series \( T_0 + 2T_1 + 3T_2 \).

**Parameters**
- `c1, c2`: array_like

**Returns**
- `out`: ndarray

Of Chebyshev series coefficients representing their product.

**See also:**
chebadd, chebsub, chebdiv, chebpow

**Notes**

In general, the (polynomial) product of two C-series results in terms that are not in the Chebyshev polynomial basis set. Thus, to express the product as a C-series, it is typically necessary to “reproject” the product onto said basis set, which typically produces “unintuitive live” (but correct) results; see Examples section below.

Examples

```python
>>> from numpy.polynomial import chebyshev as C
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> C.chebmul(c1,c2)  # multiplication requires “reprojection”
array([ 6.5, 12. , 12. , 4. , 1.5])
```

`numpy.polynomial.chebyshev.chebmulx(c)`
Multiply a Chebyshev series by x.

Multiply the polynomial \( c \) by x, where x is the independent variable.

**Parameters**
- `c`: array_like

**Returns**
- `out`: ndarray

Array representing the result of the multiplication.

**Notes**

New in version 1.5.0.
numpy.polynomial.chebyshev.chebdiv(c1, c2)
Divide one Chebyshev series by another.

Returns the quotient-with-remainder of two Chebyshev series c1 / c2. The arguments are sequences of coefficients from lowest order “term” to highest, e.g., [1,2,3] represents the series T_0 + 2*T_1 + 3*T_2.

Parameters
   c1, c2 : array_like
     1-D arrays of Chebyshev series coefficients ordered from low to high.

Returns
   [quo, rem] : ndarrays
     Of Chebyshev series coefficients representing the quotient and remainder.

See also:
chebadd, chebsub, chebmul, chebpow

Notes
In general, the (polynomial) division of one C-series by another results in quotient and remainder terms that are not in the Chebyshev polynomial basis set. Thus, to express these results as C-series, it is typically necessary to “reproject” the results onto said basis set, which typically produces “unintuitive” (but correct) results; see Examples section below.

Examples
>>> from numpy.polynomial import chebyshev as C
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> C.chebdiv(c1,c2) # quotient "intuitive," remainder not
(array([ 3.]), array([-8., -4.]))
>>> c2 = (0,1,2,3)
>>> C.chebdiv(c2,c1) # neither "intuitive"
(array([ 0., 2.]), array([-2., -4.]))

numpy.polynomial.chebyshev.chebpow(c, pow, maxpower=16)
Raise a Chebyshev series to a power.

Returns the Chebyshev series c raised to the power pow. The argument c is a sequence of coefficients ordered from low to high, i.e., [1,2,3] is the series T_0 + 2*T_1 + 3*T_2.

Parameters
   c : array_like
     1-D array of Chebyshev series coefficients ordered from low to high.
   pow : integer
     Power to which the series will be raised
   maxpower : integer, optional
     Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16

Returns
   coef : ndarray
     Chebyshev series of power.
See also:

chebadd, chebsub, chebmul, chebddiv

**chebgauss**(deg)  Gauss-Chebyshev quadrature.

**chebweight**(x)  The weight function of the Chebyshev polynomials.

---

**Quadrature**

`numpy.polynomial.chebyshev.chebgauss(deg)`  
Gauss-Chebyshev quadrature.

Computes the sample points and weights for Gauss-Chebyshev quadrature. These sample points and weights will correctly integrate polynomials of degree $2 \times \text{deg} - 1$ or less over the interval $[-1, 1]$ with the weight function $f(x) = 1/\sqrt{1 - x^2}$.

**Parameters**

- **deg**: int  
  Number of sample points and weights. It must be $\geq 1$.

**Returns**

- **x**: ndarray  
  1-D ndarray containing the sample points.

- **y**: ndarray  
  1-D ndarray containing the weights.

**Notes**

New in version 1.7.0.

The results have only been tested up to degree 100, higher degrees may be problematic. For Gauss-Chebyshev there are closed form solutions for the sample points and weights. If $n = \text{deg}$, then

$$x_i = \cos\left(\pi (2i - 1) / (2n)\right)$$

$$w_i = \pi / n$$

`numpy.polynomial.chebyshev.chebweight(x)`  
The weight function of the Chebyshev polynomials.

The weight function is $1/\sqrt{1 - x^2}$ and the interval of integration is $[-1, 1]$. The Chebyshev polynomials are orthogonal, but not normalized, with respect to this weight function.

**Parameters**

- **x**: array_like  
  Values at which the weight function will be computed.

**Returns**

- **w**: ndarray  
  The weight function at $x$.

**Notes**

New in version 1.7.0.
**numpy.polynomial.chebyshev.chebcompanion** (c)

Return the scaled companion matrix of c.

The basis polynomials are scaled so that the companion matrix is symmetric when c is a Chebyshev basis polynomial. This provides better eigenvalue estimates than the unscaled case and for basis polynomials the eigenvalues are guaranteed to be real if `numpy.linalg.eigvalsh` is used to obtain them.

**Parameters**
- c : array_like
  1-D array of Chebyshev series coefficients ordered from low to high degree.

**Returns**
- mat : ndarray
  Scaled companion matrix of dimensions (deg, deg).

**Notes**

**numpy.polynomial.chebyshev.chebdomain** = array([-1, 1])

**numpy.polynomial.chebyshev.chebzero** = array([0])

**numpy.polynomial.chebyshev.chebone** = array([1])

**numpy.polynomial.chebyshev.chebx** = array([0, 1])

**numpy.polynomial.chebyshev.chebtrim** (c, tol=0)

Remove “small” “trailing” coefficients from a polynomial.

“Small” means “small in absolute value” and is controlled by the parameter `tol`; “trailing” means highest order coefficient(s), e.g., in \[0, 1, 1, 0, 0\] (which represents \(0 + x + x^2 + 0\cdot x^3 + 0\cdot x^4\)) both the 3-rd and 4-th order coefficients would be “trimmed.”

**Parameters**
- c : array_like
  1-d array of coefficients, ordered from lowest order to highest.
- tol : number, optional
  Trailing (i.e., highest order) elements with absolute value less than or equal to `tol` (default value is zero) are removed.

**Returns**
- trimmed : ndarray
1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

**Raises**

*ValueError*

If $\text{tol} < 0$

**See also:**

trimseq

**Examples**

```python
>>> from numpy import polynomial as P
>>> P.trimcoef((0,0,3,0,5,0,0))
array([ 0., 3., 0., 5.])
>>> P.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3)  # item == tol is trimmed
array([ 0.])
>>> i = complex(0,1)  # works for complex
>>> P.trimcoef((3e-4,1e-3*(1-i),5e-4,2e-5*(1+i)), 1e-3)
array([ 0.0003+0.j , 0.0010-0.001j])
```

*numpy.polynomial.chebyshev.chebline(off, scl)*

Chebyshev series whose graph is a straight line.

**Parameters**

*off, scl*: scalars

The specified line is given by $\text{off} + \text{scl} \cdot x$.

**Returns**

*y*: ndarray

This module’s representation of the Chebyshev series for $\text{off} + \text{scl} \cdot x$.

**See also:**

polyline

**Examples**

```python
>>> import numpy.polynomial.chebyshev as C
>>> C.chebline(3,2)
array([3, 2])
>>> C.chebval(-3, C.chebline(3,2))  # should be -3
-3.0
```

*numpy.polynomial.chebyshev.cheb2poly(c)*

Convert a Chebyshev series to a polynomial.

Convert an array representing the coefficients of a Chebyshev series, ordered from lowest degree to highest, to an array of the coefficients of the equivalent polynomial (relative to the “standard” basis) ordered from lowest to highest degree.

**Parameters**

*c*: array_like

1-D array containing the Chebyshev series coefficients, ordered from lowest order term to highest.

**Returns**

*pol*: ndarray
1-D array containing the coefficients of the equivalent polynomial (relative to the “standard” basis) ordered from lowest order term to highest.

See also:

poly2cheb

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```python
>>> from numpy import polynomial as P
>>> c = P.Chebyshev(range(4))
>>> c
Chebyshev([ 0., 1., 2., 3.], [-1., 1.])
>>> p = c.convert(kind=P.Polynomial)
>>> p
Polynomial([-2., -8., 4., 12.], [-1., 1.])
>>> P.cheb2poly(range(4))
array([-2., -8., 4., 12.])
```

numpy.polynomial.chebyshev.poly2cheb(pol)

Convert a polynomial to a Chebyshev series.

Convert an array representing the coefficients of a polynomial (relative to the “standard” basis) ordered from lowest degree to highest, to an array of the coefficients of the equivalent Chebyshev series, ordered from lowest to highest degree.

Parameters

pol : array_like

1-D array containing the polynomial coefficients

Returns

c : ndarray

1-D array containing the coefficients of the equivalent Chebyshev series.

See also:

cheb2poly

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```python
>>> from numpy import polynomial as P
>>> p = P.Polynomial(range(4))
>>> p
Polynomial([ 0., 1., 2., 3.], [-1., 1.])
>>> c = p.convert(kind=P.Chebyshev)
>>> c
Chebyshev([ 1. , 3.25, 1. , 0.75], [-1., 1.])
>>> P.poly2cheb(range(4))
array([ 1. , 3.25, 1. , 0.75])
```
Legendre Module (numpy.polynomial.legendre)

New in version 1.6.0.

This module provides a number of objects (mostly functions) useful for dealing with Legendre series, including a Legendre class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with such polynomials is in the docstring for its “parent” sub-package, numpy.polynomial).

Legendre class (numpy.polynomial.legendre.Legendre (coef[, domain, window])) A Legendre series class.

Legendre Class

class numpy.polynomial.legendre.Legendre (coef, domain=None, window=None)
A Legendre series class.

The Legendre class provides the standard Python numerical methods ‘+’, ‘-‘, ‘*’, ‘/’, ‘%’, ‘divmod’, ‘**’, and ‘()’ as well as the attributes and methods listed in the ABCPolyBase documentation.

Parameters

coef : array_like
Legendre coefficients in order of increasing degree, i.e., (1, 2, 3) gives 1*P_0(x) + 2*P_1(x) + 3*P_2(x).

domain : (2,) array_like, optional
Domain to use. The interval [domain[0], domain[1]] is mapped to the interval [window[0], window[1]] by shifting and scaling. The default value is [-1, 1].

window : (2,) array_like, optional
Window, see domain for its use. The default value is [-1, 1].

New in version 1.6.0.

Methods

__call__(arg) Series basis polynomial of degree deg.
cast(series[, domain, window]) Convert series to series of this class.
convert([domain, kind, window]) Convert series to a different kind and/or domain and/or window.
copy() Return a copy.
cutdeg(deg) Truncate series to the given degree.
degree() The degree of the series.
deriv([m]) Differentiate.
fit(x, y, deg[, domain, rcond, full, w, window]) Least squares fit to data.
fromroots(roots[, domain, window]) Return series instance that has the specified roots.
has_samecoef(other) Check if coefficients match.
has_samedomain(other) Check if domains match.
has_sametype(other) Check if types match.
has_samewindow(other) Check if windows match.
identity([domain, window]) Identity function.
innt(m, k, lbnd) Integrate.
linspace([n, domain]) Return x, y values at equally spaced points in domain.
mapparms() Return the mapping parameters.
roots() Return the roots of the series polynomial.
trim([tol]) Remove trailing coefficients Remove trailing coefficients until a coefficient is reached.
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<td>Truncate series to length size.</td>
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Legendre.__call__(arg)

**classmethod** Legendre.basis(deg, domain=None, window=None)

Series basis polynomial of degree deg.

Returns the series representing the basis polynomial of degree deg.

New in version 1.7.0.

**Parameters**

- **deg** : int
  
  Degree of the basis polynomial for the series. Must be >= 0.

- **domain** : {None, array_like}, optional
  
  If given, the array must be of the form [beg, end], where beg and end are the endpoints of the domain. If None is given then the class domain is used. The default is None.

- **window** : {None, array_like}, optional
  
  If given, the resulting array must be of the form [beg, end], where beg and end are the endpoints of the window. If None is given then the class window is used. The default is None.

**Returns**

- **new_series** : series
  
  A series with the coefficient of the deg term set to one and all others zero.

**classmethod** Legendre.cast(series, domain=None, window=None)

Convert series to series of this class.

The series is expected to be an instance of some polynomial series of one of the types supported by the numpy.polynomial module, but could be some other class that supports the convert method.

New in version 1.7.0.

**Parameters**

- **series** : series
  
  The series instance to be converted.

- **domain** : {None, array_like}, optional
  
  If given, the array must be of the form [beg, end], where beg and end are the endpoints of the domain. If None is given then the class domain is used. The default is None.

- **window** : {None, array_like}, optional
  
  If given, the resulting array must be of the form [beg, end], where beg and end are the endpoints of the window. If None is given then the class window is used. The default is None.

**Returns**

- **new_series** : series
  
  A series of the same kind as the calling class and equal to series when evaluated.
See also:

convert

similar instance method

Legendre.convert(domain=None, kind=None, window=None)

Convert series to a different kind and/or domain and/or window.

Parameters

domain : array_like, optional

The domain of the converted series. If the value is None, the default domain of kind is used.

kind : class, optional

The polynomial series type class to which the current instance should be converted. If kind is None, then the class of the current instance is used.

window : array_like, optional

The window of the converted series. If the value is None, the default window of kind is used.

Returns

new_series : series

The returned class can be of different type than the current instance and/or have a different domain and/or different window.

Notes

Conversion between domains and class types can result in numerically ill defined series.

Legendre.copy()

Return a copy.

Returns

new_series : series

Copy of self.

Legendre.cutdeg(deg)

Truncate series to the given degree.

Reduce the degree of the series to deg by discarding the high order terms. If deg is greater than the current degree a copy of the current series is returned. This can be useful in least squares where the coefficients of the high degree terms may be very small.

New in version 1.5.0.

Parameters

deg : non-negative int

The series is reduced to degree deg by discarding the high order terms. The value of deg must be a non-negative integer.

Returns

new_series : series

New instance of series with reduced degree.
Legendre.degree()

The degree of the series.

New in version 1.5.0.

Returns

degree : int

Degree of the series, one less than the number of coefficients.

Legendre.deriv(m=1)

Differentiate.

Return a series instance of that is the derivative of the current series.

Parameters

m : non-negative int

The number of integrations to perform.

Returns

new_series : series

A new series representing the derivative. The domain is the same as the domain of the differentiated series.

classmethod Legendre.fit(x, y, deg=None, domain=None, rcond=None, full=False, w=None, window=None)

Least squares fit to data.

Return a series instance that is the least squares fit to the data y sampled at x. The domain of the returned instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

Parameters

x : array_like, shape (M,)

x-coordinates of the M sample points (x[i], y[i]).

y : array_like, shape (M,) or (M, K)

y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

deg : int

Degree of the fitting polynomial.

domain : [None, [beg, end], []], optional

Domain to use for the returned series. If None, then a minimal domain that covers the points x is chosen. If [] the class domain is used. The default value was the class domain in NumPy 1.4 and None in later versions. The [] option was added in numpy 1.5.0.

rcond : float, optional

Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

full : bool, optional

Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.
w : array_like, shape (M,), optional

Weights. If not None the contribution of each point \((x[i], y[i])\) to the fit is weighted by \(w[i]\). Ideally the weights are chosen so that the errors of the products \(w[i] \cdot y[i]\) all have the same variance. The default value is None.

New in version 1.5.0.

window : [(beg, end)], optional

Window to use for the returned series. The default value is the default class domain

New in version 1.6.0.

Returns

new_series : series

A series that represents the least squares fit to the data and has the domain specified in the call.

[resid, rank, sv, rcond] : list

These values are only returned if full = True

resid – sum of squared residuals of the least squares fit rank – the numerical rank of the scaled Vandermonde matrix sv – singular values of the scaled Vandermonde matrix rcond – value of rcond.

For more details, see linalg.lstsq.

classmethod Legendre.fromroots(roots, domain=[], window=None)

Return series instance that has the specified roots.

Returns a series representing the product \((x - r[0]) \cdot (x - r[1]) \cdot ... \cdot (x - r[n-1])\), where \(r\) is a list of roots.

Parameters

roots : array_like

List of roots.

domain : [[], None, array_like], optional

Domain for the resulting series. If None the domain is the interval from the smallest root to the largest. If [] the domain is the class domain. The default is [].

window : [None, array_like], optional

Window for the returned series. If None the class window is used. The default is None.

Returns

new_series : series

Series with the specified roots.

Legendre.has_samecoef(other)

Check if coefficients match.

New in version 1.6.0.

Parameters

other : class instance

The other class must have the coef attribute.

Returns

bool : boolean
True if the coefficients are the same, False otherwise.

Legendre has_samedomain(other)
Check if domains match.
New in version 1.6.0.

Parameters
other : class instance
The other class must have the domain attribute.

Returns
bool : boolean
True if the domains are the same, False otherwise.

Legendre has_sametype(other)
Check if types match.
New in version 1.7.0.

Parameters
other : object
Class instance.

Returns
bool : boolean
True if other is same class as self.

Legendre has_samewindow(other)
Check if windows match.
New in version 1.6.0.

Parameters
other : class instance
The other class must have the window attribute.

Returns
bool : boolean
True if the windows are the same, False otherwise.

classmethod Legendre.identity(domain=None, window=None)
Identity function.
If p is the returned series, then p(x) == x for all values of x.

Parameters
domain : {None, array_like}, optional
If given, the array must be of the form [beg, end], where beg and end are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window : {None, array_like}, optional
If given, the resulting array must be of the form [beg, end], where beg and end are the endpoints of the window. If None is given then the class window is used. The default is None.
Returns
new_series : series
Series of representing the identity.

Legendre.integ(m=1, k=[], lbnd=None)
Integrate.

Return a series instance that is the definite integral of the current series.

Parameters
m : non-negative int
The number of integrations to perform.
k : array_like
Integration constants. The first constant is applied to the first integration, the second to
the second, and so on. The list of values must less than or equal to m in length and any
missing values are set to zero.

lbnd : Scalar
The lower bound of the definite integral.

Returns
new_series : series
A new series representing the integral. The domain is the same as the domain of the
integrated series.

Legendre.linspace(n=100, domain=None)
Return x, y values at equally spaced points in domain.

Returns the x, y values at n linearly spaced points across the domain. Here y is the value of the polynomial
at the points x. By default the domain is the same as that of the series instance. This method is intended
mostly as a plotting aid.

New in version 1.5.0.

Parameters
n : int, optional
Number of point pairs to return. The default value is 100.
domain : [None, array_like], optional
If not None, the specified domain is used instead of that of the calling instance. It should
be of the form [beg, end]. The default is None which case the class domain is used.

Returns
x, y : ndarray
x is equal to linspace(self.domain[0], self.domain[1], n) and y is the series evaluated at
element of x.

Legendre.mapparms()
Return the mapping parameters.

The returned values define a linear map off + scl*x that is applied to the input arguments before
the series is evaluated. The map depends on the domain and window; if the current domain is equal
to the window the resulting map is the identity. If the coefficients of the series instance are to be used
by themselves outside this class, then the linear function must be substituted for the x in the standard
representation of the base polynomials.
Returns

off, scl : float or complex

The mapping function is defined by off + scl*x.

Notes

If the current domain is the interval \([l1, r1]\) and the window is \([l2, r2]\), then the linear mapping function \(L\) is defined by the equations:

\[
L(l1) = l2 \\
L(r1) = r2
\]

Legendre.\(\text{roots}()\)

Return the roots of the series polynomial.

Compute the roots for the series. Note that the accuracy of the roots decrease the further outside the domain they lie.

Returns

roots : ndarray

Array containing the roots of the series.

Legendre.\(\text{trim}(\text{tol}=0)\)

Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than \(\text{tol}\) or the beginning of the series is reached. If all the coefficients would be removed the series is set to \([0]\). A new series instance is returned with the new coefficients. The current instance remains unchanged.

Parameters

tol : non-negative number.

All trailing coefficients less than \(\text{tol}\) will be removed.

Returns

new_series : series

Contains the new set of coefficients.

Legendre.\(\text{truncate}(\text{size})\)

Truncate series to length \(\text{size}\).

Reduce the series to length \(\text{size}\) by discarding the high degree terms. The value of \(\text{size}\) must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

size : positive int

The series is reduced to length \(\text{size}\) by discarding the high degree terms. The value of \(\text{size}\) must be a positive integer.

Returns

new_series : series

New instance of series with truncated coefficients.
### NumPy Reference, Release 1.9.2

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<td><code>legval3d(x, y, z, c)</code></td>
<td>Evaluate a 3-D Legendre series at points (x, y, z).</td>
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<tr>
<td><code>leggrid2d(x, y, c)</code></td>
<td>Evaluate a 2-D Legendre series on the Cartesian product of x and y.</td>
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<td><code>leggrid3d(x, y, z, c)</code></td>
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#### Basics

```python
numpy.polynomial.legendre.legval(x, c, tensor=True)
```
Evaluate a Legendre series at points `x`.

If `c` is of length `n + 1`, this function returns the value:

\[ p(x) = c_0 \cdot L_0(x) + c_1 \cdot L_1(x) + \ldots + c_n \cdot L_n(x) \]

The parameter `x` is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either `x` or its elements must support multiplication and addition both with themselves and with the elements of `c`.

If `c` is a 1-D array, then `p(x)` will have the same shape as `x`. If `c` is multidimensional, then the shape of the result depends on the value of `tensor`. If `tensor` is true the shape will be `c.shape[1:] + x.shape`. If `tensor` is false the shape will be `c.shape[1:]`. Note that scalars have shape `()`. Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

#### Parameters

- `x`: array_like, compatible object
  - If `x` is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, `x` or its elements must support addition and multiplication with with themselves and with the elements of `c`.

- `c`: array_like
  - Array of coefficients ordered so that the coefficients for terms of degree `n` are contained in `c[n]`. If `c` is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of `c`.

- `tensor`: boolean, optional
  - If True, the shape of the coefficient array is extended with ones on the right, one for each dimension of `x`. Scalars have dimension 0 for this action. The result is that every column of coefficients in `c` is evaluated for every element of `x`. If False, `x` is broadcast over the columns of `c` for the evaluation. This keyword is useful when `c` is multidimensional. The default value is True.

New in version 1.7.0.

#### Returns

- `values`: ndarray, algebra_like
  - The shape of the return value is described above.

#### See also:

- `legval2d`, `leggrid2d`, `legval3d`, `leggrid3d`

---

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Notes

The evaluation uses Clenshaw recursion, aka synthetic division.

```
numpy.polynomial.legendre.legval2d(x, y, c)
```

Evaluate a 2-D Legendre series at points (x, y).

This function returns the values:

\[
p(x, y) = \sum_{i,j} c_{i,j} \cdot L_i(x) \cdot L_j(y)
\]

The parameters x and y are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either x and y or their elements must support multiplication and addition both with themselves and with the elements of c.

If c is a 1-D array a one is implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape.

Parameters

- **x, y**: array_like, compatible objects
  - The two dimensional series is evaluated at the points (x, y), where x and y must have the same shape. If x or y is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn’t an ndarray it is treated as a scalar.

- **c**: array_like
  - Array of coefficients ordered so that the coefficient of the term of multi-degree i,j is contained in c[i, j]. If c has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

- **values**: ndarray, compatible object
  - The values of the two dimensional Legendre series at points formed from pairs of corresponding values from x and y.

See also:

`legval, leggrid2d, legval3d, leggrid3d`

Notes

```
numpy.polynomial.legendre.legval3d(x, y, z, c)
```

Evaluate a 3-D Legendre series at points (x, y, z).

This function returns the values:

\[
p(x, y, z) = \sum_{i,j,k} c_{i,j,k} \cdot L_i(x) \cdot L_j(y) \cdot L_k(z)
\]

The parameters x, y, and z are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either x, y, and z or their elements must support multiplication and addition both with themselves and with the elements of c.

If c has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape.

Parameters

- **x, y, z**: array_like, compatible object
  - The three dimensional series is evaluated at the points (x, y, z), where x, y, and z must have the same shape. If any of x, y, or z is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn’t an ndarray it is treated as a scalar.
c : array_like

Array of coefficients ordered so that the coefficient of the term of multi-degree i,j,k is contained in c[i,j,k]. If c has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

Returns
values : ndarray, compatible object

The values of the multidimensional polynomial on points formed with triples of corresponding values from x, y, and z.

See also:
legval, legval2d, leggrid2d, leggrid3d

Notes
numpy.polynomial.legendre.leggrid2d(x, y, c)

Evaluate a 2-D Legendre series on the Cartesian product of x and y.

This function returns the values:

\[ p(a, b) = \sum_{i,j} c_{i,j} * L_i(a) * L_j(b) \]

where the points (a, b) consist of all pairs formed by taking a from x and b from y. The resulting points form a grid with x in the first dimension and y in the second.

The parameters x and y are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either x and y or their elements must support multiplication and addition both with themselves and with the elements of c.

If c has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape + y.shape.

Parameters
x, y : array_like, compatible objects

The two dimensional series is evaluated at the points in the Cartesian product of x and y. If x or y is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.

c : array_like

Array of coefficients ordered so that the coefficient of the term of multi-degree i,j is contained in c[i,j]. If c has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns
values : ndarray, compatible object

The values of the two dimensional Chebyshev series at points in the Cartesian product of x and y.

See also:
legval, legval2d, legval3d, leggrid3d

Notes
numpy.polynomial.legendre.leggrid3d(x, y, z, c)

Evaluate a 3-D Legendre series on the Cartesian product of x, y, and z.
This function returns the values:

\[ p(a, b, c) = \sum_{i,j,k} c_{i,j,k} \cdot L_i(a) \cdot L_j(b) \cdot L_k(c) \]

where the points \((a, b, c)\) consist of all triples formed by taking \(a\) from \(x\), \(b\) from \(y\), and \(c\) from \(z\). The resulting points form a grid with \(x\) in the first dimension, \(y\) in the second, and \(z\) in the third.

The parameters \(x\), \(y\), and \(z\) are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either \(x\), \(y\), and \(z\) or their elements must support multiplication and addition both with themselves and with the elements of \(c\).

If \(c\) has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be \(c\).shape[3:] + \(x\).shape + \(y\).shape + \(z\).shape.

**Parameters**

- \(x, y, z\) : array_like, compatible objects
  
The three dimensional series is evaluated at the points in the Cartesian product of \(x\), \(y\), and \(z\). If \(x\), \(y\), or \(z\) is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.

- \(c\) : array_like
  
  Array of coefficients ordered so that the coefficients for terms of degree \(i,j\) are contained in \(c[i, j]\). If \(c\) has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

**Returns**

- **values** : ndarray, compatible object
  
The values of the two dimensional polynomial at points in the Cartesian product of \(x\) and \(y\).

**See also:**

- `legval`, `legval2d`, `leggrid2d`, `legval3d`

**Notes**

`numpy.polynomial.legendre.legroots(c)`

Compute the roots of a Legendre series.

Return the roots (a.k.a. “zeros”) of the polynomial

\[ p(x) = \sum_i c[i] \cdot L_i(x). \]

**Parameters**

- \(c\) : 1-D array_like

  1-D array of coefficients.

**Returns**

- **out** : ndarray

  Array of the roots of the series. If all the roots are real, then \(out\) is also real, otherwise it is complex.

**See also:**

- `polyroots`, `chebroots`, `lagroots`, `hermroots`, `hermeroots`
Notes

The root estimates are obtained as the eigenvalues of the companion matrix. Roots far from the origin of the complex plane may have large errors due to the numerical instability of the series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton’s method.

The Legendre series basis polynomials aren’t powers of $x$ so the results of this function may seem unintuitive.

Examples

```python
>>> import numpy.polynomial.legendre as leg
>>> leg.legroots((1, 2, 3, 4))  # 4L_3 + 3L_2 + 2L_1 + L_0, all real roots
array([-0.85099543, -0.11407192, 0.51506735])
```

`numpy.polynomial.legendre.legfromroots(roots)`

Generate a Legendre series with given roots.

The function returns the coefficients of the polynomial

$$p(x) = (x - r_0) * (x - r_1) * ... * (x - r_n),$$

in Legendre form, where the $r_n$ are the roots specified in `roots`. If a zero has multiplicity n, then it must appear in `roots` n times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then `roots` looks something like [-1, 2, 2, 2, 3, 3]. The roots can appear in any order.

If the returned coefficients are $c$, then

$$p(x) = c_0 + c_1 * L_1(x) + ... + c_n * L_n(x)$$

The coefficient of the last term is not generally 1 for monic polynomials in Legendre form.

Parameters

- `roots`: array_like
  Sequence containing the roots.

Returns

- `out`: ndarray
  1-D array of coefficients. If all roots are real then `out` is a real array, if some of the roots are complex, then `out` is complex even if all the coefficients in the result are real (see Examples below).

See also:

- `polyfromroots`, `chebfromroots`, `lagfromroots`, `hermfromroots`, `hermefromroots`.

Examples

```python
>>> import numpy.polynomial.legendre as L
>>> L.legfromroots((-1,0,1))  # x^3 - x relative to the standard basis
array([0. , -0.4, 0. , 0.4])
>>> j = complex(0,1)
>>> L.legfromroots((-j,j))  # x^2 + 1 relative to the standard basis
array([1.33333333+0.j, 0.00000000+0.j, 0.66666667+0.j])
```

`legfit(x, y, deg[, rcond, full, w])` Least squares fit of Legendre series to data.
Table 3.141 – continued from previous page

<table>
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<th>Function</th>
<th>Description</th>
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<td><code>legvander(x, deg)</code></td>
<td>Pseudo-Vandermonde matrix of given degree.</td>
</tr>
<tr>
<td><code>legvander2d(x, y, deg)</code></td>
<td>Pseudo-Vandermonde matrix of given degrees.</td>
</tr>
<tr>
<td><code>legvander3d(x, y, z, deg)</code></td>
<td>Pseudo-Vandermonde matrix of given degrees.</td>
</tr>
</tbody>
</table>

### Fitting

**Fitting**

```python
numpy.polynomial.legendre.legfit(x, y, deg, rcond=None, full=False, w=None)
```

Least squares fit of Legendre series to data.

Return the coefficients of a Legendre series of degree `deg` that is the least squares fit to the data values `y` given at points `x`. If `y` is 1-D the returned coefficients will also be 1-D. If `y` is 2-D multiple fits are done, one for each column of `y`, and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

\[ p(x) = c_0 + c_1 * L_1(x) + \ldots + c_n * L_n(x), \]

where `n` is `deg`.

**Parameters**

- `x` : array_like, shape (M,)
  - x-coordinates of the M sample points (x[i], y[i]).

- `y` : array_like, shape (M,) or (M, K)
  - y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

- `deg` : int
  - Degree of the fitting polynomial

- `rcond` : float, optional
  - Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

- `full` : bool, optional
  - Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

- `w` : array_like, shape (M,), optional
  - Weights. If not None, the contribution of each point (x[i], y[i]) to the fit is weighted by w[i]. Ideally the weights are chosen so that the errors of the products w[i] * y[i] all have the same variance. The default value is None.

**Returns**

- `coef` : ndarray, shape (M,) or (M, K)
  - Legendre coefficients ordered from low to high. If `y` was 2-D, the coefficients for the data in column k of `y` are in column k.

- `[residuals, rank, singular_values, rcond]` : list

New in version 1.5.0.
These values are only returned if `full = True`

`resid` – sum of squared residuals of the least squares fit
`rank` – the numerical rank of the scaled Vandermonde matrix
`sv` – singular values of the scaled Vandermonde matrix
`rcond` – value of `rcond`.

For more details, see `linalg.lstsq`.

**Warns**

- **RankWarning**
  
  The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if `full = False`. The warnings can be turned off by

  ```python
  >>> import warnings
  >>> warnings.simplefilter('ignore', RankWarning)
  ```

**See also:**

- `chebfit`, `polyfit`, `lagfit`, `hermfit`, `hermefit`

**legval**

  Evaluates a Legendre series.

**legvander**

  Vandermonde matrix of Legendre series.

**legweight**

  Legendre weight function (= 1).

**linalg.lstsq**

  Computes a least-squares fit from the matrix.

**scipy.interpolate.UnivariateSpline**

  Computes spline fits.

**Notes**

The solution is the coefficients of the Legendre series \( p \) that minimizes the sum of the weighted squared errors

\[
E = \sum_j w_j^2 \cdot |y_j - p(x_j)|^2,
\]

where \( w_j \) are the weights. This problem is solved by setting up as the (typically) overdetermined matrix equation

\[
V(x) \cdot c = w \cdot y,
\]

where \( V \) is the weighted pseudo Vandermonde matrix of \( x \), \( c \) are the coefficients to be solved for, \( w \) are the weights, and \( y \) are the observed values. This equation is then solved using the singular value decomposition of \( V \).

If some of the singular values of \( V \) are so small that they are neglected, then a **RankWarning** will be issued. This means that the coefficient values may be poorly determined. Using a lower order fit will usually get rid of the warning. The `rcond` parameter can also be set to a value smaller than its default, but the resulting fit may be spurious and have large contributions from roundoff error.

Fits using Legendre series are usually better conditioned than fits using power series, but much can depend on the distribution of the sample points and the smoothness of the data. If the quality of the fit is inadequate splines may be a good alternative.
References

[R64]
numpy.polynomial.legendre.legvander(x, deg)

Pseudo-Vandermonde matrix of given degree.

Returns the pseudo-Vandermonde matrix of degree deg and sample points x. The pseudo-Vandermonde matrix is defined by

\[ V[\ldots, i] = L_i(x) \]

where 0 <= i <= deg. The leading indices of V index the elements of x and the last index is the degree of the Legendre polynomial.

If c is a 1-D array of coefficients of length n + 1 and V is the array \( V = \text{legvander}(x, n) \), then \( \text{np.dot}(V, c) \) and \( \text{legval}(x, c) \) are the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of Legendre series of the same degree and sample points.

Parameters

x : array_like

Array of points. The dtype is converted to float64 or complex128 depending on whether any of the elements are complex. If x is scalar it is converted to a 1-D array.

deg : int

Degree of the resulting matrix.

Returns

vander : ndarray

The pseudo-Vandermonde matrix. The shape of the returned matrix is \( x.shape + (deg + 1,) \), where The last index is the degree of the corresponding Legendre polynomial. The dtype will be the same as the converted x.

numpy.polynomial.legendre.legvander2d(x, y, deg)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees deg and sample points (x, y). The pseudo-Vandermonde matrix is defined by

\[ V[\ldots, deg[1] * i + j] = L_i(x) * L_j(y), \]

where 0 <= i <= deg[0] and 0 <= j <= deg[1]. The leading indices of V index the points (x, y) and the last index encodes the degrees of the Legendre polynomials.

If \( V = \text{legvander2d}(x, y, [xdeg, ydeg]) \), then the columns of V correspond to the elements of a 2-D coefficient array c of shape (xdeg + 1, ydeg + 1) in the order

\[ c_00, c_{01}, c_{02} \ldots, c_{10}, c_{11}, c_{12} \ldots \]

and \( \text{np.dot}(V, c.flat) \) and \( \text{legval2d}(x, y, c) \) will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D Legendre series of the same degrees and sample points.

Parameters

x, y : array_like

Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg : list of ints
List of maximum degrees of the form \([x_{\text{deg}}, y_{\text{deg}}]\).

**Returns**

\[ \text{\texttt{vander2d}} : \text{ndarray} \]

The shape of the returned matrix is \(x.\text{shape} + (\text{order,})\), where \(\text{order} = (\text{deg}[0] + 1) \times (\text{deg}[1] + 1)\). The dtype will be the same as the converted \(x\) and \(y\).

**See also:**

\texttt{legvander}, \texttt{legvander3d}, \texttt{legval3d}

**Notes**

\texttt{numpy.polynomial.legendre.legvander3d}(x, y, z, deg)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees \(deg\) and sample points \((x, y, z)\). If \(l, m, n\) are the given degrees in \(x, y, z\), then

\[
V[\ldots,(m + 1)(n + 1)i + (n + 1)j + k] = L_i(x) \times L_j(y) \times L_k(z),
\]

where \(0 \leq i \leq l\), \(0 \leq j \leq m\), and \(0 \leq j \leq n\). The leading indices of \(V\) index the points \((x, y, z)\) and the last index encodes the degrees of the Legendre polynomials.

If \(V = \text{legvander3d}(x, y, z, \text{[xdeg, ydeg, zdeg]})\), then the columns of \(V\) correspond to the elements of a 3-D coefficient array \(c\) of shape \((xdeg + 1, ydeg + 1, zdeg + 1)\) in the order

\[
\begin{align*}
&c_{000}, c_{001}, c_{002}, \ldots, c_{010}, c_{011}, c_{012}, \ldots \\
&\end{align*}
\]

and \(\text{np.dot}(V, c.\text{flat})\) and \(\text{legval3d}(x, y, z, c)\) will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D Legendre series of the same degrees and sample points.

**Parameters**

\(x, y, z : \text{array_like}\)

Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

\(\text{deg} : \text{list of ints}\)

List of maximum degrees of the form \([x_{\text{deg}}, y_{\text{deg}}, z_{\text{deg}}]\).

**Returns**

\[ \text{\texttt{vander3d}} : \text{ndarray} \]

The shape of the returned matrix is \(x.\text{shape} + (\text{order,})\), where \(\text{order} = (\text{deg}[0] + 1) \times (\text{deg}[1] + 1) \times (\text{deg}[2] + 1)\). The dtype will be the same as the converted \(x, y,\) and \(z\).

**See also:**

\texttt{legvander}, \texttt{legvander3d}, \texttt{legval3d}

**Notes**

\texttt{legder}(c[, m, scl, axis]) Differentiate a Legendre series.

\texttt{legint}(c[, m, k, lbnd, scl, axis]) Integrate a Legendre series.

**Calculus**

3.24. Polynomials
numpy.polynomial.legendre.legder(c, m=1, scl=1, axis=0)
Differentiate a Legendre series.

Returns the Legendre series coefficients $c$ differentiated $m$ times along $axis$. At each iteration the result is multiplied by $scl$ (the scaling factor is for use in a linear change of variable). The argument $c$ is an array of coefficients from low to high degree along each axis, e.g., $[1,2,3]$ represents the series $1*L_0 + 2*L_1 + 3*L_2$ while $[[1,2],[1,2]]$ represents $1*L_0(x)*L_0(y) + 1*L_1(x)*L_0(y) + 2*L_0(x)*L_1(y) + 2*L_1(x)*L_1(y)$ if axis=0 is $x$ and axis=1 is $y$.

Parameters

c : array_like
Array of Legendre series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m : int, optional
Number of derivatives taken, must be non-negative. (Default: 1)

scl : scalar, optional
Each differentiation is multiplied by $scl$. The end result is multiplication by $scl**m$. This is for use in a linear change of variable. (Default: 1)

axis : int, optional
Axis over which the derivative is taken. (Default: 0).

New in version 1.7.0.

Returns
der : ndarray
Legendre series of the derivative.

See also:

legint

Notes

In general, the result of differentiating a Legendre series does not resemble the same operation on a power series. Thus the result of this function may be “unintuitive,” albeit correct; see Examples section below.

Examples

```python
>>> from numpy.polynomial import legendre as L
>>> c = (1,2,3,4)
>>> L.legder(c)
array([ 6.,  9., 20.])
>>> L.legder(c, 3)
array([ 60.])
>>> L.legder(c, scl=-1)
array([-6., -9., -20.])
>>> L.legder(c, 2,-1)
array([ 9., 60.])
```

numpy.polynomial.legendre.legint(c, m=1, k=[], lbnd=0, scl=1, axis=0)
Integrate a Legendre series.

Returns the Legendre series coefficients $c$ integrated $m$ times from $lbnd$ along $axis$. At each iteration the resulting series is multiplied by $scl$ and an integration constant, $k$, is added. The scaling factor is for use in a linear change of variable. (“Buyer beware”: note that, depending on what one is doing, one may want $scl$ to
be the reciprocal of what one might expect; for more information, see the Notes section below.) The argument c is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series $L_0 + 2*L_1 + 3*L_2$ while [[1,2],[1,2]] represents $1*L_0(x)*L_0(y) + 1*L_1(x)*L_0(y) + 2*L_0(x)*L_1(y) + 2*L_1(x)*L_1(y)$ if axis=0 is $x$ and axis=1 is $y$.

**Parameters**

- **c**: array_like
  
  Array of Legendre series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

- **m**: int, optional
  
  Order of integration, must be positive. (Default: 1)

- **k**: {[], list, scalar}, optional
  
  Integration constant(s). The value of the first integral at $lbnd$ is the first value in the list, the value of the second integral at $lbnd$ is the second value, etc. If $k == []$ (the default), all constants are set to zero. If $m == 1$, a single scalar can be given instead of a list.

- **lbnd**: scalar, optional
  
  The lower bound of the integral. (Default: 0)

- **scl**: scalar, optional
  
  Following each integration the result is multiplied by $scl$ before the integration constant is added. (Default: 1)

- **axis**: int, optional
  
  Axis over which the integral is taken. (Default: 0).

**Returns**

- **S**: ndarray
  
  Legendre series coefficient array of the integral.

**Raises**

- **ValueError**
  
  If $m < 0$, $len(k) > m$, np.isscalar(lbnd) == False, or np.isscalar(scl) == False.

**See also:**

- legder

**Notes**

Note that the result of each integration is multiplied by $scl$. Why is this important to note? Say one is making a linear change of variable $u = ax + b$ in an integral relative to $x$. Then .. math:: dx = du/a, so one will need to set $scl$ equal to $1/a$ - perhaps not what one would have first thought.

Also note that, in general, the result of integrating a C-series needs to be “reprojected” onto the C-series basis set. Thus, typically, the result of this function is “unintuitive,” albeit correct; see Examples section below.
Examples

```python
>>> from numpy.polynomial import legendre as L
>>> c = (1,2,3)
>>> L.legint(c)
array([ 0.33333333, 0.4 , 0.66666667, 0.6 ])
>>> L.legint(c, 3)
array([ 1.66666667e-02, -1.78571429e-02, 4.76190476e-02,
    -1.73472348e-18, 1.90476190e-02, 9.52380952e-03])
>>> L.legint(c, k=3)
array([ 3.33333333, 0.4 , 0.66666667, 0.6 ])
>>> L.legint(c, lbnd=-2)
array([ 7.33333333, 0.4 , 0.66666667, 0.6 ])
>>> L.legint(c, scl=2)
array([ 0.66666667, 0.8 , 1.33333333, 1.2 ])```

Algebra

numpy.polynomial.legendre.legadd(c1, c2)

Add one Legendre series to another.

Returns the sum of two Legendre series c1 + c2. The arguments are sequences of coefficients ordered from lowest order term to highest, i.e., [1,2,3] represents the series \( P_0 + 2*P_1 + 3*P_2 \).

Parameters

- **c1, c2**: array_like

1-D array_like of Legendre series coefficients ordered from low to high.

Returns

- **out**: ndarray

Array representing the Legendre series of their sum.

See also:

- legsub, legmul, legdiv, legpow

Notes

Unlike multiplication, division, etc., the sum of two Legendre series is a Legendre series (without having to “re-project” the result onto the basis set) so addition, just like that of “standard” polynomials, is simply “component-wise.”

Examples

```python
>>> from numpy.polynomial import legendre as L
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> L.legadd(c1, c2)
array([ 4., 4., 4.])
```
numpy.polynomial.legendre.\texttt{legsub}(c1, c2)
Subtract one Legendre series from another.

Returns the difference of two Legendre series \( c1 - c2 \). The sequences of coefficients are from lowest order term to highest, i.e., \([1,2,3]\) represents the series \( P_0 + 2P_1 + 3P_2 \).

**Parameters**
- \texttt{c1, c2}: array_like
  1-D arrays of Legendre series coefficients ordered from low to high.

**Returns**
- \texttt{out}: ndarray
  Of Legendre series coefficients representing their difference.

**See also:**
\texttt{legadd, legmul, legdiv, legpow}

**Notes**
Unlike multiplication, division, etc., the difference of two Legendre series is a Legendre series (without having to "reproject" the result onto the basis set) so subtraction, just like that of “standard” polynomials, is simply “component-wise.”

**Examples**

```python
>>> from numpy.polynomial import legendre as L
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> L.legsub(c1,c2)
array([-2., 0., 2.])
>>> L.legsub(c2,c1)  # -L.legsub(c1,c2)
array([ 2., 0., -2.])
```

numpy.polynomial.legendre.\texttt{legmul}(c1, c2)
Multiply one Legendre series by another.

Returns the product of two Legendre series \( c1 \times c2 \). The arguments are sequences of coefficients, from lowest order “term” to highest, e.g., \([1,2,3]\) represents the series \( P_0 + 2P_1 + 3P_2 \).

**Parameters**
- \texttt{c1, c2}: array_like
  1-D arrays of Legendre series coefficients ordered from low to high.

**Returns**
- \texttt{out}: ndarray
  Of Legendre series coefficients representing their product.

**See also:**
\texttt{legadd, legsub, legdiv, legpow}

**Notes**
In general, the (polynomial) product of two C-series results in terms that are not in the Legendre polynomial basis set. Thus, to express the product as a Legendre series, it is necessary to “reproject” the product onto said basis set, which may produce “unintuitive” (but correct) results; see Examples section below.
Examples

```python
>>> from numpy.polynomial import legendre as L
>>> c1 = (1,2,3)
>>> c2 = (3,2)
>>> L.legmul(c1,c2) # multiplication requires "reprojection"
array([-4.33333333, 10.4 , 11.66666667, 3.6 ])
```

numpy.polynomial.legendre.legmulx(c)

Multiply a Legendre series by x.

Multiply the Legendre series \(c\) by \(x\), where \(x\) is the independent variable.

Parameters

- `c` : array_like
  1-D array of Legendre series coefficients ordered from low to high.

Returns

- `out` : ndarray
  Array representing the result of the multiplication.

Notes

The multiplication uses the recursion relationship for Legendre polynomials in the form

\[
xP_i(x) = ((i + 1) \ast P_{i+1}(x) + i \ast P_{i-1}(x))/(2i + 1)
\]

numpy.polynomial.legendre.legdiv(c1, c2)

Divide one Legendre series by another.

Returns the quotient-with-remainder of two Legendre series \(c1 / c2\). The arguments are sequences of coefficients from lowest order “term” to highest, e.g., \([1,2,3]\) represents the series \(P_0 + 2P_1 + 3P_2\).

Parameters

- `c1, c2` : array_like
  1-D arrays of Legendre series coefficients ordered from low to high.

Returns

- `quo, rem` : ndarrays
  Of Legendre series coefficients representing the quotient and remainder.

See also:

`legadd, legsub, legmul, legpow`

Notes

In general, the (polynomial) division of one Legendre series by another results in quotient and remainder terms that are not in the Legendre polynomial basis set. Thus, to express these results as a Legendre series, it is necessary to “reproject” the results onto the Legendre basis set, which may produce “unintuitive” (but correct) results; see Examples section below.

Examples

```python
>>> from numpy.polynomial import legendre as L
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> L.legdiv(c1,c2) # quotient "intuitive," remainder not
(array([ 3.]), array([-8., -4.])))
```
```python
>>> c2 = (0,1,2,3)
>>> L.legdiv(c2,c1) # neither "intuitive"
(array([-0.07407407, 1.66666667]), array([-1.03703704, -2.51851852]))
```

```python
numpy.polynomial.legendre.legpow(c, pow, maxpower=16)

Raise a Legendre series to a power.

Returns the Legendre series c raised to the power pow. The argument c is a sequence of coefficients ordered from low to high. i.e., [1,2,3] is the series \( P_0 + 2\cdot P_1 + 3\cdot P_2 \).

**Parameters**
- **c**: array_like
  1-D array of Legendre series coefficients ordered from low to high.
- **pow**: integer
  Power to which the series will be raised
- **maxpower**: integer, optional
  Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16

**Returns**
- **coef**: ndarray
  Legendre series of power.

**See also:**
- legadd, legsub, legmul, legdiv
- leggauss(deg) Gauss-Legendre quadrature.
- legweight(x) Weight function of the Legendre polynomials.
```

**Quadrature**

```python
numpy.polynomial.legendre.leggauss(deg)

Gauss-Legendre quadrature.

Computes the sample points and weights for Gauss-Legendre quadrature. These sample points and weights will correctly integrate polynomials of degree \( 2\cdot deg - 1 \) or less over the interval \([-1,1]\) with the weight function \( f(x) = 1 \).

**Parameters**
- **deg**: int
  Number of sample points and weights. It must be \( \geq 1 \).

**Returns**
- **x**: ndarray
  1-D ndarray containing the sample points.
- **y**: ndarray
  1-D ndarray containing the weights.
```

3.24. Polynomials
The results have only been tested up to degree 100, higher degrees may be problematic. The weights are determined by using the fact that

\[ w_k = c / (L'_n(x_k) \ast L_{n-1}(x_k)) \]

where \( c \) is a constant independent of \( k \) and \( x_k \) is the \( k \)'th root of \( L_n \), and then scaling the results to get the right value when integrating 1.

numpy.polynomial.legendre.legweight(x)

Weight function of the Legendre polynomials.

The weight function is \( 1 \) and the interval of integration is \([-1, 1]\). The Legendre polynomials are orthogonal, but not normalized, with respect to this weight function.

Parameters
- x : array_like
  Values at which the weight function will be computed.

Returns
- w : ndarray
  The weight function at \( x \).

Notes

**miscellaneous**

numpy.polynomial.legendre.legcompanion(c)

Return the scaled companion matrix of \( c \).

The basis polynomials are scaled so that the companion matrix is symmetric when \( c \) is an Legendre basis polynomial. This provides better eigenvalue estimates than the unscaled case and for basis polynomials the eigenvalues are guaranteed to be real if `numpy.linalg.eigvalsh` is used to obtain them.

Parameters
- c : array_like
  1-D array of Legendre series coefficients ordered from low to high degree.

Returns
- mat : ndarray
  Scaled companion matrix of dimensions (deg, deg).

Notes

numpy.polynomial.legendre.legdomain = array([-1, 1])
numpy.polynomial.legendre.\texttt{legzero} = array([0])

numpy.polynomial.legendre.\texttt{legone} = array([1])

numpy.polynomial.legendre.\texttt{legx} = array([0, 1])

\begin{verbatim}
numpy.polynomial.legendre.\texttt{legtrim}(c, tol=0)
Remove “small” “trailing” coefficients from a polynomial.

“Small” means “small in absolute value” and is controlled by the parameter \texttt{tol}; “trailing” means highest order coefficient(s), e.g., in [0, 1, 1, 0, 0] (which represents 0 + x + x**2 + 0*x**3 + 0*x**4) both the 3-rd and 4-th order coefficients would be “trimmed.”

Parameters
\begin{itemize}
  \item \texttt{c} : array_like
    1-d array of coefficients, ordered from lowest order to highest.
  \item \texttt{tol} : number, optional
    Trailing (i.e., highest order) elements with absolute value less than or equal to \texttt{tol} (default value is zero) are removed.
\end{itemize}

Returns
\begin{itemize}
  \item \texttt{trimmed} : ndarray
    1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.
\end{itemize}

Raises
\begin{itemize}
  \item \texttt{ValueError}
    If \texttt{tol} \textless 0
\end{itemize}
\end{verbatim}

See also:
\texttt{trimseq}

Examples
\begin{verbatim}
>>> from numpy import polynomial as P
>>> P.trimcoef((0,0,3,0,5,0,0))
array([ 0., 0., 3., 0., 5.])
>>> P.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3) # item == tol is trimmed
array([ 0.])
>>> i = complex(0,1) # works for complex
>>> P.trimcoef((3e-4,1e-3*(1-i),5e-4,2e-5*(1+i)), 1e-3)
array([ 0.0003+0.j , 0.0010-0.001j])
\end{verbatim}

numpy.polynomial.legendre.\texttt{legline}(off, scl)
Legendre series whose graph is a straight line.

Parameters
\begin{itemize}
  \item \texttt{off, scl} : scalars
    The specified line is given by \texttt{off + scl*x}.
\end{itemize}

Returns
\begin{itemize}
  \item \texttt{y} : ndarray
    This module’s representation of the Legendre series for \texttt{off + scl*x}.
\end{itemize}
See also:
polyline, chebline

Examples

```python
>>> import numpy.polynomial.legendre as L
>>> L.legline(3, 2)
array([3, 2])
>>> L.legval(-3, L.legline(3, 2))  # should be -3
-3.0
```

numpy.polynomial.legendre.leg2poly(c)

Convert a Legendre series to a polynomial.

Convert an array representing the coefficients of a Legendre series, ordered from lowest degree to highest, to an array of the coefficients of the equivalent polynomial (relative to the “standard” basis) ordered from lowest to highest degree.

Parameters

- `c`: array_like
  1-D array containing the Legendre series coefficients, ordered from lowest order term to highest.

Returns

- `pol`: ndarray
  1-D array containing the coefficients of the equivalent polynomial (relative to the “standard” basis) ordered from lowest order term to highest.

See also:
poly2leg

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```python
>>> c = P.Legendre(range(4))
>>> c
Legendre([ 0., 1., 2., 3.], [-1., 1.])
>>> p = c.convert(kind=P.Polynomial)
>>> p
Polynomial([-1. , -3.5, 3. , 7.5], [-1., 1.])
>>> P.leg2poly(range(4))
array([-1. , -3.5, 3. , 7.5])
```

numpy.polynomial.legendre.poly2leg(pol)

Convert a polynomial to a Legendre series.

Convert an array representing the coefficients of a polynomial (relative to the “standard” basis) ordered from lowest degree to highest, to an array of the coefficients of the equivalent Legendre series, ordered from lowest to highest degree.

Parameters

- `pol`: array_like
  1-D array containing the polynomial coefficients
Returns

.. _laguerre-class:

\[ c \in \text{ndarray} \]

1-D array containing the coefficients of the equivalent Legendre series.

See also:

.. autosummary::
   :toctree: generated/

leg2poly

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```python
>>> from numpy import polynomial as P
>>> p = P.Polynomial(np.arange(4))
>>> p
Polynomial([ 0., 1., 2., 3.], [-1., 1.])
>>> c = P.Legendre(P.poly2leg(p.coef))
>>> c
Legendre([ 1.0, 3.25, 1.0, 0.75], [-1., 1.])
```

Laguerre Module

.. autosummary::
   :toctree: generated/

Laguerre

New in version 1.6.0.

This module provides a number of objects (mostly functions) useful for dealing with Laguerre series, including a Laguerre class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with such polynomials is in the docstring for its “parent” sub-package, :mod:`~numpy.polynomial`).

```
Laguerre(coef[, domain, window])  A Laguerre series class.
```

Laguerre Class

.. autosummary::
   :toctree: generated/

.. automethod:: Laguerre

Laguerre Class

.. autosummary::
   :toctree: generated/

.. automethod:: Laguerre

The Laguerre class provides the standard Python numerical methods `+`, `-`, `*`, `/`, `//`, `%`, `divmod`, `**`, and `()` as well as the attributes and methods listed in the ABCPolyBase documentation.

Parameters

- **coef** : array_like
  Laguerre coefficients in order of increasing degree, i.e., \((1, 2, 3)\) gives \(1L_0(x) + 2L_1(x) + 3L_2(x)\).

- **domain** : (2,) array_like, optional
  Domain to use. The interval \([\text{domain}[0], \text{domain}[1]]\) is mapped to the interval \([\text{window}[0], \text{window}[1]]\) by shifting and scaling. The default value is \([0, 1]\).

- **window** : (2,) array_like, optional
  Window, see domain for its use. The default value is \([0, 1]\).

Methods

New in version 1.6.0.
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<td><code>cast([domain, kind, window])</code></td>
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<td><code>copy()</code></td>
<td>Return a copy.</td>
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<td>Truncate series to the given degree.</td>
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<td><code>trim([tol])</code></td>
<td>Remove trailing coefficients until a coefficient is reached or the beginning is reached.</td>
</tr>
<tr>
<td><code>truncate(size)</code></td>
<td>Truncate series to length <code>size</code>.</td>
</tr>
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</table>

**Laguerre.__call__(arg)**

**class method** Laguerre.basis

```
deg, domain=None, window=None
```

Series basis polynomial of degree `deg`.

Returns the series representing the basis polynomial of degree `deg`.

New in version 1.7.0.

**Parameters**

- `deg` : int
  Degree of the basis polynomial for the series. Must be \( \geq 0 \).

- `domain` : `{None, array_like}`, optional
  If given, the array must be of the form \([\text{beg}, \text{end}]\), where \(\text{beg}\) and \(\text{end}\) are the endpoints of the domain. If None is given then the class domain is used. The default is None.

- `window` : `{None, array_like}`, optional
  If given, the resulting array must be of the form \([\text{beg}, \text{end}]\), where \(\text{beg}\) and \(\text{end}\) are the endpoints of the window. If None is given then the class window is used. The default is None.

**Returns**

- `new_series` : `series`
  A series with the coefficient of the `deg` term set to one and all others zero.

**class method** Laguerre.cast

```
domain=None, window=None
```

Convert series to series of this class.
The `series` is expected to be an instance of some polynomial series of one of the types supported by the `numpy.polynomial` module, but could be some other class that supports the convert method.

New in version 1.7.0.

**Parameters**

- **series**: series
  
  The series instance to be converted.

- **domain**: `{None, array_like}`, optional
  
  If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If `None` is given then the class domain is used. The default is `None`.

- **window**: `{None, array_like}`, optional
  
  If given, the resulting array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If `None` is given then the class window is used. The default is `None`.

**Returns**

- **new_series**: series
  
  A series of the same kind as the calling class and equal to `series` when evaluated.

**See also:**

- `convert` similar instance method

Laguerre method `convert` (domain=None, kind=None, window=None)

Convert series to a different kind and/or domain and/or window.

**Parameters**

- **domain**: array_like, optional
  
  The domain of the converted series. If the value is `None`, the default domain of `kind` is used.

- **kind**: class, optional
  
  The polynomial series type class to which the current instance should be converted. If `kind` is `None`, then the class of the current instance is used.

- **window**: array_like, optional
  
  The window of the converted series. If the value is `None`, the default window of `kind` is used.

**Returns**

- **new_series**: series
  
  The returned class can be of different type than the current instance and/or have a different domain and/or different window.

**Notes**

Conversion between domains and class types can result in numerically ill defined series.
Returns

new_series : series
Copy of self.

Laguerre.cutdeg(deg)
Truncate series to the given degree.
Reduce the degree of the series to deg by discarding the high order terms. If deg is greater than the current
degree a copy of the current series is returned. This can be useful in least squares where the coefficients of
the high degree terms may be very small.
New in version 1.5.0.

Parameters

deg : non-negative int
The series is reduced to degree deg by discarding the high order terms. The value of deg
must be a non-negative integer.

Returns

new_series : series
New instance of series with reduced degree.

Laguerre.degree()
The degree of the series.
New in version 1.5.0.

Returns

degree : int
Degree of the series, one less than the number of coefficients.

Laguerre.deriv(m=1)
Differentiate.
Return a series instance of that is the derivative of the current series.

Parameters

m : non-negative int
The number of integrations to perform.

Returns

new_series : series
A new series representing the derivative. The domain is the same as the domain of the
differentiated series.

classmethod Laguerre.fit(x, y, deg, domain=None, rcond=None, full=False, w=None, window=None)
Least squares fit to data.
Return a series instance that is the least squares fit to the data y sampled at x. The domain of the returned
instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

Parameters

x : array_like, shape (M,)
x-coordinates of the M sample points (x[i], y[i]).
y : array_like, shape (M,) or (M, K)
y-coordinates of the sample points. Several data sets of sample points sharing the same 
x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset 
per column.

**deg** : int

Degree of the fitting polynomial.

**domain** : {None, [beg, end], []}, optional

Domain to use for the returned series. If None, then a minimal domain that covers the 
points x is chosen. If [] the class domain is used. The default value was the class 
domain in NumPy 1.4 and None in later versions. The [] option was added in numpy 
1.5.0.

**rcond** : float, optional

Relative condition number of the fit. Singular values smaller than this relative to the 
largest singular value will be ignored. The default value is len(x)*eps, where eps is the 
relative precision of the float type, about 2e-16 in most cases.

**full** : bool, optional

Switch determining nature of return value. When it is False (the default) just the coeff-
icients are returned, when True diagnostic information from the singular value decom-
position is also returned.

**w** : array_like, shape (M,), optional

Weights. If not None the contribution of each point \((x[i],y[i])\) to the fit is 
weighted by \(w[i]\). Ideally the weights are chosen so that the errors of the products 
\(w[i]*y[i]\) all have the same variance. The default value is None.

New in version 1.5.0.

**window** : {[beg, end]}, optional

Window to use for the returned series. The default value is the default class domain

New in version 1.6.0.

**Returns**

new_series : series

A series that represents the least squares fit to the data and has the domain specified in 
the call.

[resid, rank, sv, rcond] : list

These values are only returned if full = True

resid – sum of squared residuals of the least squares fit 
rank – the numerical rank of 
the scaled Vandermonde matrix 
sv – singular values of the scaled Vandermonde matrix 
rcond – value of rcond.

For more details, see linalg.lstsq.

**classmethod Laguerre.fromroots** (roots, domain=[], window=None)

Return series instance that has the specified roots.

Returns a series representing the product \((x - r[0])*(x - r[1])*...*(x - r[n-1])\), where 
r is a list of roots.

**Parameters**

roots : array_like
List of roots.

- **domain**: list, None, array_like, optional
  Domain for the resulting series. If None the domain is the interval from the smallest root to the largest. If [] the domain is the class domain. The default is [].

- **window**: list, None, array_like, optional
  Window for the returned series. If None the class window is used. The default is None.

**Returns**

- **new_series**: series
  Series with the specified roots.

---

**Laguerre**

**.has_samecoef**(other)

Check if coefficients match.

New in version 1.6.0.

**Parameters**

- **other**: class instance
  The other class must have the coef attribute.

**Returns**

- **bool**: boolean
  True if the coefficients are the same, False otherwise.

**Laguerre**.has_samedomain**(other)

Check if domains match.

New in version 1.6.0.

**Parameters**

- **other**: class instance
  The other class must have the domain attribute.

**Returns**

- **bool**: boolean
  True if the domains are the same, False otherwise.

**Laguerre**.has_sametype**(other)

Check if types match.

New in version 1.7.0.

**Parameters**

- **other**: object
  Class instance.

**Returns**

- **bool**: boolean
  True if other is same class as self

**Laguerre**.has_samewindow**(other)

Check if windows match.

New in version 1.6.0.
Parameters
other : class instance

The other class must have the window attribute.

Returns
bool : boolean

True if the windows are the same, False otherwise.

classmethod Laguerre.identity (domain=None, window=None)

Identity function.

If p is the returned series, then p(x) == x for all values of x.

Parameters
domain : {None, array_like}, optional

If given, the array must be of the form [beg, end], where beg and end are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window : {None, array_like}, optional

If given, the resulting array must be if the form [beg, end], where beg and end are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns
new_series : series

Series of representing the identity.

Laguerre.integ (m=1, k=[], lbnd=None)

Integrate.

Return a series instance that is the definite integral of the current series.

Parameters
m : non-negative int

The number of integrations to perform.

k : array_like

Integration constants. The first constant is applied to the first integration, the second to the second, and so on. The list of values must less than or equal to m in length and any missing values are set to zero.

lbnd : Scalar

The lower bound of the definite integral.

Returns
new_series : series

A new series representing the integral. The domain is the same as the domain of the integrated series.

Laguerre.linspace (n=100, domain=None)

Return x, y values at equally spaced points in domain.

Returns the x, y values at n linearly spaced points across the domain. Here y is the value of the polynomial at the points x. By default the domain is the same as that of the series instance. This method is intended mostly as a plotting aid.
New in version 1.5.0.

**Parameters**

- **n**: int, optional
  - Number of point pairs to return. The default value is 100.

- **domain**: {None, array_like}, optional
  - If not None, the specified domain is used instead of that of the calling instance. It should be of the form \([\text{beg, end}]\). The default is None which case the class domain is used.

**Returns**

- **x, y**: ndarray
  - x is equal to linspace(self.domain[0], self.domain[1], n) and y is the series evaluated at element of x.

**Laguerre.mapparms()**

Return the mapping parameters.

The returned values define a linear map \(\text{off} + \text{scl} \times x\) that is applied to the input arguments before the series is evaluated. The map depends on the domain and window; if the current domain is equal to the window the resulting map is the identity. If the coefficients of the series instance are to be used by themselves outside this class, then the linear function must be substituted for the \(x\) in the standard representation of the base polynomials.

**Returns**

- **off, scl**: float or complex
  - The mapping function is defined by \(\text{off} + \text{scl} \times x\).

**Notes**

If the current domain is the interval \([l1, r1]\) and the window is \([l2, r2]\), then the linear mapping function \(L\) is defined by the equations:

\[
L(l1) = l2 \\
L(r1) = r2
\]

**Laguerre.roots()**

Return the roots of the series polynomial.

Compute the roots for the series. Note that the accuracy of the roots decrease the further outside the domain they lie.

**Returns**

- **roots**: ndarray
  - Array containing the roots of the series.

**Laguerre.trim(tol=0)**

Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than \(tol\) or the beginning of the series is reached. If all the coefficients would be removed the series is set to \([0]\). A new series instance is returned with the new coefficients. The current instance remains unchanged.

**Parameters**

- **tol**: non-negative number.
  - All trailing coefficients less than \(tol\) will be removed.
Returns

new_series : series

Contains the new set of coefficients.

Laguerre.truncate(size)

Truncate series to length size.

Reduce the series to length size by discarding the high degree terms. The value of size must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

size : positive int

The series is reduced to length size by discarding the high degree terms. The value of size must be a positive integer.

Returns

new_series : series

New instance of series with truncated coefficients.

Basics

numpy.polynomial.laguerre.lagval(x, c[, tensor])

Evaluate a Laguerre series at points x.

If c is of length n + 1, this function returns the value:

\[ p(x) = c_0 * L_0(x) + c_1 * L_1(x) + ... + c_n * L_n(x) \]

The parameter x is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either x or its elements must support multiplication and addition both with themselves and with the elements of c.

If c is a 1-D array, then \( p(x) \) will have the same shape as x. If c is multidimensional, then the shape of the result depends on the value of tensor. If tensor is true the shape will be c.shape[1:] + x.shape. If tensor is false the shape will be c.shape[1:]. Note that scalars have shape (,).

Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

Parameters

x : array_like, compatible object

If x is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, x or its elements must support addition and multiplication with with themselves and with the elements of c.

c : array_like
Array of coefficients ordered so that the coefficients for terms of degree n are contained in c[n]. If c is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of c.

**tensor** : boolean, optional

If True, the shape of the coefficient array is extended with ones on the right, one for each dimension of x. Scalars have dimension 0 for this action. The result is that every column of coefficients in c is evaluated for every element of x. If False, x is broadcast over the columns of c for the evaluation. This keyword is useful when c is multidimensional. The default value is True.

New in version 1.7.0.

**Returns**

- **values** : ndarray, algebra_like

    The shape of the return value is described above.

**See also:**

lagval2d, laggrid2d, lagval3d, laggrid3d

**Notes**

The evaluation uses Clenshaw recursion, aka synthetic division.

**Examples**

```python
>>> from numpy.polynomial.laguerre import lagval
>>> coef = [1, 2, 3]
>>> lagval(1, coef)
-0.5
>>> lagval([[1,2],[3,4]], coef)
array([[[-0.5, -4.],
        [-4.5, -2.]]])
```

numpy.polynomial.laguerre.lagval2d(x, y, c)

Evaluate a 2-D Laguerre series at points (x, y).

This function returns the values:

\[ p(x, y) = \sum_{i,j} c_{ij} \cdot L_i(x) \cdot L_j(y) \]

The parameters x and y are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either x and y or their elements must support multiplication and addition both with themselves and with the elements of c.

If c is a 1-D array a one is implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape.

**Parameters**

- **x, y** : array_like, compatible objects

    The two dimensional series is evaluated at the points (x, y), where x and y must have the same shape. If x or y is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn’t an ndarray it is treated as a scalar.

- **c** : array_like
Array of coefficients ordered so that the coefficient of the term of multi-degree $i, j$ is contained in $c[i, j]$. If $c$ has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values : ndarray, compatible object

The values of the two dimensional polynomial at points formed with pairs of corresponding values from $x$ and $y$.

See also:

lagval, laggrid2d, lagval3d, laggrid3d

Notes

numpy.polynomial.laguerre.lagval3d(x, y, z, c)

Evaluate a 3-D Laguerre series at points $(x, y, z)$.

This function returns the values:

$$p(x, y, z) = \sum_{i,j,k} c_{i,j,k} \cdot L_i(x) \cdot L_j(y) \cdot L_k(z)$$

The parameters $x$, $y$, and $z$ are converted to arrays only if they are tuples or a lists, otherwise they are treated as scalars and they must have the same shape after conversion. In either case, either $x$, $y$, and $z$ or their elements must support multiplication and addition both with themselves and with the elements of $c$.

If $c$ has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be $c$'s shape[3:] + $x$.shape.

Parameters

$x, y, z : \text{array_like, compatible object}$

The three dimensional series is evaluated at the points $(x, y, z)$, where $x$, $y$, and $z$ must have the same shape. If any of $x$, $y$, or $z$ is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn’t an ndarray it is treated as a scalar.

c : array_like

Array of coefficients ordered so that the coefficient of the term of multi-degree $i, j, k$ is contained in $c[i, j, k]$. If $c$ has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

Returns

values : ndarray, compatible object

The values of the multidimension polynomial on points formed with triples of corresponding values from $x$, $y$, and $z$.

See also:

lagval, lagval2d, laggrid2d, laggrid3d

Notes

numpy.polynomial.laguerre.laggrid2d(x, y, c)

Evaluate a 2-D Laguerre series on the Cartesian product of $x$ and $y$.

This function returns the values:

$$p(a, b) = \sum_{i,j} c_{i,j} \cdot L_i(a) \cdot L_j(b)$$
where the points \((a, b)\) consist of all pairs formed by taking \(a\) from \(x\) and \(b\) from \(y\). The resulting points form a grid with \(x\) in the first dimension and \(y\) in the second.

The parameters \(x\) and \(y\) are converted to arrays only if they are tuples or a lists, otherwise they are treated as scalars. In either case, either \(x\) and \(y\) or their elements must support multiplication and addition both with themselves and with the elements of \(c\).

If \(c\) has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be \(c.shape[2:] + x.shape + y.shape\).

**Parameters**

- \(x, y\) : array_like, compatible objects

  The two dimensional series is evaluated at the points in the Cartesian product of \(x\) and \(y\). If \(x\) or \(y\) is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.

- \(c\) : array_like

  Array of coefficients ordered so that the coefficient of the term of multi-degree \(i,j\) is contained in \(c[i,j]\). If \(c\) has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

**Returns**

- \(values\) : ndarray, compatible object

  The values of the two dimensional Chebyshev series at points in the Cartesian product of \(x\) and \(y\).

**See also:**

-lagval, lagval2d, lagval3d, laggrid3d

**Notes**

- *numpy.polynomial.laguerre.laggrid3d* \((x, y, z, c)\)

  Evaluate a 3-D Laguerre series on the Cartesian product of \(x\), \(y\), and \(z\).

  This function returns the values:

  \[
  p(a, b, c) = \sum_{i,j,k} c[i,j,k] \cdot L_i(a) \cdot L_j(b) \cdot L_k(c)
  \]

  where the points \((a, b, c)\) consist of all triples formed by taking \(a\) from \(x\), \(b\) from \(y\), and \(c\) from \(z\). The resulting points form a grid with \(x\) in the first dimension, \(y\) in the second, and \(z\) in the third.

  The parameters \(x\), \(y\), and \(z\) are converted to arrays only if they are tuples or a lists, otherwise they are treated as scalars. In either case, either \(x\), \(y\), and \(z\) or their elements must support multiplication and addition both with themselves and with the elements of \(c\).

  If \(c\) has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be \(c.shape[3:] + x.shape + y.shape + z.shape\).

**Parameters**

- \(x, y, z\) : array_like, compatible objects

  The three dimensional series is evaluated at the points in the Cartesian product of \(x\), \(y\), and \(z\). If \(x\), \(y\), or \(z\) is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.

- \(c\) : array_like
Array of coefficients ordered so that the coefficients for terms of degree i,j are contained in \( c[i, j] \). If \( c \) has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values : ndarray, compatible object

The values of the two dimensional polynomial at points in the Cartesian product of \( x \) and \( y \).

See also:

lagval, lagval2d, laggrid2d, lagval1d

Notes

NumPy Reference, Release 1.9.2

numpy.polynomial.laguerre.lagroots(c)

Compute the roots of a Laguerre series.

Return the roots (a.k.a. “zeros”) of the polynomial

\[ p(x) = \sum_i c[i] * L_i(x). \]

Parameters

- c : 1-D array_like
  - 1-D array of coefficients.

Returns

out : ndarray

Array of the roots of the series. If all the roots are real, then \( out \) is also real, otherwise it is complex.

See also:

polyroots, legroots, chebroots, hermroots, hermeroots

Notes

The root estimates are obtained as the eigenvalues of the companion matrix, Roots far from the origin of the complex plane may have large errors due to the numerical instability of the series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton’s method.

The Laguerre series basis polynomials aren’t powers of \( x \) so the results of this function may seem unintuitive.

Examples

```python
>>> from numpy.polynomial.laguerre import lagroots, lagfromroots

>>> coef = lagfromroots([0, 1, 2])
>>> coef
array([ 2., -8., 12., -6.])
>>> lagroots(coef)
array([-4.44089210e-16, 1.00000000e+00, 2.00000000e+00])
```

numpy.polynomial.laguerre.lagfromroots(roots)

Generate a Laguerre series with given roots.

The function returns the coefficients of the polynomial

\[ p(x) = (x - r_0) \times (x - r_1) \times ... \times (x - r_n), \]
in Laguerre form, where the \( r_n \) are the roots specified in \( \text{roots} \). If a zero has multiplicity \( n \), then it must appear in \( \text{roots} \) \( n \) times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then \( \text{roots} \) looks something like \([2, 2, 2, 3, 3]\). The roots can appear in any order.

If the returned coefficients are \( c \), then

\[
p(x) = c_0 + c_1 * L_1(x) + ... + c_n * L_n(x)
\]

The coefficient of the last term is not generally 1 for monic polynomials in Laguerre form.

**Parameters**
- \( \text{roots} \) : array_like  
  Sequence containing the roots.

**Returns**
- \( \text{out} \) : ndarray  
  1-D array of coefficients. If all roots are real then \( \text{out} \) is a real array, if some of the roots are complex, then \( \text{out} \) is complex even if all the coefficients in the result are real (see Examples below).

**See also:**
- \( \text{polyfromroots} \), \( \text{legfromroots} \), \( \text{chebfromroots} \), \( \text{hermfromroots} \).

**Examples**

```python
>>> from numpy.polynomial.laguerre import lagfromroots, lagval
>>> coef = lagfromroots((-1, 0, 1))
>>> lagval((-1, 0, 1), coef)
array([ 0., 0., 0.])
>>> coef = lagfromroots((-1j, 1j))
>>> lagval((-1j, 1j), coef)
array([ 0.+0.j, 0.+0.j])
```

```python
>>> from numpy.polynomial.laguerre import lagfit
>>> lagfit(x, y, deg[, rcond, full, w])  
Least squares fit of Laguerre series to data.
```

Fitting

```
numpy.polynomial.laguerre.lagfit(x, y, deg[, rcond=None, full=False, w=None)
Least squares fit of Laguerre series to data.
```

Return the coefficients of a Laguerre series of degree \( deg \) that is the least squares fit to the data values \( y \) given at points \( x \). If \( y \) is 1-D the returned coefficients will also be 1-D. If \( y \) is 2-D multiple fits are done, one for each column of \( y \), and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

\[
p(x) = c_0 + c_1 * L_1(x) + ... + c_n * L_n(x),
\]

where \( n \) is \( deg \).

**Parameters**
- \( x \) : array_like, shape (M,)  
  x-coordinates of the M sample points \( (x[i], y[i]) \).
- \( y \) : array_like, shape (M,) or (M, K)
y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

**deg**: int
- Degree of the fitting polynomial

**rcond**: float, optional
- Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is \(\text{len}(x) \times \text{eps}\), where \(\text{eps}\) is the relative precision of the float type, about 2e-16 in most cases.

**full**: bool, optional
- Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

**w**: array_like, shape \((M,)\), optional
- Weights. If not None, the contribution of each point \((x[i],y[i])\) to the fit is weighted by \(w[i]\). Ideally the weights are chosen so that the errors of the products \(w[i] \times y[i]\) all have the same variance. The default value is None.

**Returns**
- **coef**: ndarray, shape \((M,)\) or \((M, K)\)
  - Laguerre coefficients ordered from low to high. If \(y\) was 2-D, the coefficients for the data in column \(k\) of \(y\) are in column \(k\).

- **[residuals, rank, singular_values, rcond]**: list
  - These values are only returned if \(full = True\)
  - resid – sum of squared residuals of the least squares fit rank – the numerical rank of the scaled Vandermonde matrix \(sv\) – singular values of the scaled Vandermonde matrix \(rcond\) – value of \(rcond\).

For more details, see `linalg.lstsq`.

**Warns**
- **RankWarning**
  - The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if \(full = False\). The warnings can be turned off by

  ```python
  >>> import warnings
  >>> warnings.simplefilter('ignore', RankWarning)
  ```

**See also**
- `chebfit`, `legfit`, `polyfit`, `hermfit`, `hermefit`
- `lagval`
  - Evaluates a Laguerre series.
- `lagvander`
  - pseudo Vandermonde matrix of Laguerre series.
- `lagweight`
  - Laguerre weight function.

---

**3.24. Polynomials**
linalg.lstsq

Computes a least-squares fit from the matrix.

scipy.interpolate.UnivariateSpline

Computes spline fits.

Notes

The solution is the coefficients of the Laguerre series $p$ that minimizes the sum of the weighted squared errors

$$ E = \sum_j w_j^2 \cdot |y_j - p(x_j)|^2, $$

where the $w_j$ are the weights. This problem is solved by setting up as the (typically) overdetermined matrix equation

$$ V(x) \cdot c = w \cdot y, $$

where $V$ is the weighted pseudo Vandermonde matrix of $x$, $c$ are the coefficients to be solved for, $w$ are the weights, and $y$ are the observed values. This equation is then solved using the singular value decomposition of $V$.

If some of the singular values of $V$ are so small that they are neglected, then a RankWarning will be issued. This means that the coefficient values may be poorly determined. Using a lower order fit will usually get rid of the warning. The rcond parameter can also be set to a value smaller than its default, but the resulting fit may be spurious and have large contributions from roundoff error.

Fits using Laguerre series are probably most useful when the data can be approximated by $\sqrt{w(x)} \cdot p(x)$, where $w(x)$ is the Laguerre weight. In that case the weight $\sqrt{w(x[i])}$ should be used together with data values $y[i]/\sqrt{w(x[i])}$. The weight function is available as lagweight.

References

[R63]

Examples

```python
>>> from numpy.polynomial.laguerre import lagfit, lagval
>>> x = np.linspace(0, 10)
>>> err = np.random.randn(len(x))/10
>>> y = lagval(x, [1, 2, 3]) + err
>>> lagfit(x, y, 2)
array([ 0.96971004, 2.00193749, 3.00288744])
```

numpy.polynomial.laguerre.lagvander(x, deg)

Pseudo-Vandermonde matrix of given degree.

Returns the pseudo-Vandermonde matrix of degree $deg$ and sample points $x$. The pseudo-Vandermonde matrix is defined by

$$ V[\ldots, i] = L_i(x) $$

where $0 <= i <= deg$. The leading indices of $V$ index the elements of $x$ and the last index is the degree of the Laguerre polynomial.

If $c$ is a 1-D array of coefficients of length $n + 1$ and $V$ is the array $V = \text{lagvander}(x, n)$, then np.dot($V, c$) and lagval($x, c$) are the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of Laguerre series of the same degree and sample points.

Parameters

- $x$: array_like
Array of points. The dtype is converted to float64 or complex128 depending on whether any of the elements are complex. If $x$ is scalar it is converted to a 1-D array.

**deg** : int

Degree of the resulting matrix.

**Returns**

**vander** : ndarray

The pseudo-Vandermonde matrix. The shape of the returned matrix is $x$.shape + (deg + 1,), where the last index is the degree of the corresponding Laguerre polynomial. The dtype will be the same as the converted $x$.

**Examples**

```python
>>> from numpy.polynomial.laguerre import lagvander
>>> x = np.array([0, 1, 2])
>>> lagvander(x, 3)
array([[ 1. ,  1. ,  1. ,  1. ],
       [ 1. ,  0. , -0.5, -0.66666667],
       [ 1. , -1. , -1. , -0.33333333]])
```

**numpy.polynomial.laguerre.lagvander2d** ($x$, $y$, $deg$)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees $deg$ and sample points ($x$, $y$). The pseudo-Vandermonde matrix is defined by

$$V[..., deg[1] * i + j] = L_i(x) * L_j(y),$$

where $0 <= i <= deg[0]$ and $0 <= j <= deg[1]$. The leading indices of $V$ index the points ($x$, $y$) and the last index encodes the degrees of the Laguerre polynomials.

If $V = lagvander2d(x, y, [xdeg, ydeg])$, then the columns of $V$ correspond to the elements of a 2-D coefficient array $c$ of shape (xdeg + 1, ydeg + 1) in the order

$c_{00}, c_{01}, c_{02}, ..., c_{10}, c_{11}, c_{12}...$

and np.dot ($V$, c.flat) and lagval2d ($x$, $y$, $c$) will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D Laguerre series of the same degrees and sample points.

**Parameters**

$x$, $y$ : array_like

Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

$deg$ : list of ints

List of maximum degrees of the form [x_deg, y_deg].

**Returns**

$vander2d$ : ndarray

The shape of the returned matrix is $x$.shape + (order,), where $order = (deg[0] + 1) * (deg[1] + 1)$. The dtype will be the same as the converted $x$ and $y$.

**See also**:

lagvander, lagvander3d, lagval3d
NumPy Reference, Release 1.9.2

Notes
	numpy.polynomial.laguerre.lagvander3d(x, y, z, deg)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees deg and sample points (x, y, z). If l, m, n are the given
degrees in x, y, z, then The pseudo-Vandermonde matrix is defined by

\[ V[\ldots, (m+1)(n+1)i + (n+1)j + k] = L_i(x) * L_j(y) * L_k(z), \]

where \(0 \leq i \leq l, 0 \leq j \leq m, \) and \(0 \leq j \leq n.\) The leading indices of \(V\) index the points (x, y, z) and the
last index encodes the degrees of the Laguerre polynomials.

If \(V = \text{lagvander3d}(x, y, z, [xdeg, ydeg, zdeg])\), then the columns of \(V\) correspond to the
elements of a 3-D coefficient array \(c\) of shape (xdeg + 1, ydeg + 1, zdeg + 1) in the order

\[ c_{000}, c_{001}, c_{002}, \ldots, c_{010}, c_{011}, c_{012}, \ldots \]

and np.dot(V, c.flat) and lagval3d(x, y, z, c) will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D Laguerre series of
the same degrees and sample points.

Parameters

x, y, z : array_like

Arrays of point coordinates, all of the same shape. The dtypes will be converted to
either float64 or complex128 depending on whether any of the elements are complex.
Scalars are converted to 1-D arrays.

deg : list of ints

List of maximum degrees of the form [x_deg, y_deg, z_deg].

Returns

vander3d : ndarray

The shape of the returned matrix is x.shape + (order,), where order =
\((deg[0] + 1) * (deg[1] + 1) * (deg[2] + 1).\) The dtype will be the same as the con-
verted x, y, and z.

See also:

lagvander, lagvander3d, lagval3d

Notes

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Calculus
	numpy.polynomial.laguerre.lagder(c, m=1, scl=1, axis=0)

Differentiate a Laguerre series.

Returns the Laguerre series coefficients \(c\) differentiated \(m\) times along \(axis\). At each iteration the result is mul-
tiplied by \(scl\) (the scaling factor is for use in a linear change of variable). The argument \(c\) is an array of coeffi-
cients from low to high degree along each axis, e.g., \([1,2,3]\) represents the series \(1*\text{L}_0 + 2*\text{L}_1 + 3*\text{L}_2\)
while \([[[1,2], [1,2]]]\) represents \(1*\text{L}_0(x) + 2*\text{L}_0(y) + 1*\text{L}_1(x) + 1*\text{L}_0(y) + 2*\text{L}_0(x) + 2*\text{L}_0(y)\)
if axis=0 is \(x\) and axis=1 is \(y\).

Parameters
c : array_like
    Array of Laguerre series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m : int, optional
    Number of derivatives taken, must be non-negative. (Default: 1)

scl : scalar, optional
    Each differentiation is multiplied by scl. The end result is multiplication by scl**m. This is for use in a linear change of variable. (Default: 1)

axis : int, optional
    Axis over which the derivative is taken. (Default: 0).

New in version 1.7.0.

Returns
---

der : ndarray
    Laguerre series of the derivative.

See also:
---

lagint

Notes
---

In general, the result of differentiating a Laguerre series does not resemble the same operation on a power series. Thus the result of this function may be “unintuitive,” albeit correct; see Examples section below.

Examples
---

```python
>>> from numpy.polynomial.laguerre import lagder
>>> lagder([ 1., 1., 1., -3.])
array([ 1., 2., 3.])
>>> lagder([ 1., 0., 0., -4., 3.], m=2)
array([ 1., 2., 3.])
```

numpy.polynomial.laguerre.**lagint** *(c, m=1, k=[], lbnd=0, scl=1, axis=0)*

Integrate a Laguerre series.

Returns the Laguerre series coefficients c integrated m times from lbnd along axis. At each iteration the resulting series is multiplied by scl and an integration constant, k, is added. The scaling factor is for use in a linear change of variable. (“Buyer beware”: note that, depending on what one is doing, one may want scl to be the reciprocal of what one might expect; for more information, see the Notes section below.) The argument c is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series \( L_0(x) + 2L_1(x) + 3L_2(x) \) while [1.2][1.2] represents \( 1L_0(x)L_0(y) + 1L_1(x)L_0(y) + 2L_0(x)L_1(y) + 2L_1(x)L_1(y) \) if axis=0 is x and axis=1 is y.

Parameters
---

c : array_like
    Array of Laguerre series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m : int, optional
    Order of integration, must be positive. (Default: 1)
k : [:[], list, scalar], optional
Integration constant(s). The value of the first integral at lbnd is the first value in the list, the value of the second integral at lbnd is the second value, etc. If k == [] (the default), all constants are set to zero. If m == 1, a single scalar can be given instead of a list.

lbnd : scalar, optional
The lower bound of the integral. (Default: 0)

scl : scalar, optional
Following each integration the result is multiplied by scl before the integration constant is added. (Default: 1)

axis : int, optional
Axis over which the integral is taken. (Default: 0).

New in version 1.7.0.

Returns
S : ndarray
Laguerre series coefficients of the integral.

Raises
ValueError
If m < 0, len(k) > m, np.isscalar(lbnd) == False, or np.isscalar(scl) == False.

See also:
lagder

Notes
Note that the result of each integration is multiplied by scl. Why is this important to note? Say one is making a linear change of variable \( u = ax + b \) in an integral relative to \( x \). Then .. math:: dx = du/a, so one will need to set scl equal to \( 1/a \) - perhaps not what one would have first thought.

Also note that, in general, the result of integrating a C-series needs to be “reprojected” onto the C-series basis set. Thus, typically, the result of this function is “unintuitive,” albeit correct; see Examples section below.

Examples
>>> from numpy.polynomial.laguerre import lagint
>>> lagint([1,2,3])
array([ 1., 1., 1., -3.])
>>> lagint([1,2,3], m=2)
array([ 1., 0., 0., -4., 3.])
>>> lagint([1,2,3], k=1)
array([ 2., 1., 1., -3.])
>>> lagint([1,2,3], lbnd=-1)
array([ 11.5, 1. , 1. , -3. ])
>>> lagint([1,2], m=2, k=[1,2], lbnd=-1)
array([ 11.16666667, -5. , -3. , 2. ])

lagadd(c1, c2) Add one Laguerre series to another. Continued on next page
Table 3.151 – continued from previous page

- `lagsub(c1, c2)` Subtract one Laguerre series from another.
- `lagmul(c1, c2)` Multiply one Laguerre series by another.
- `lagmulx(c)` Multiply a Laguerre series by x.
- `lagdiv(c1, c2)` Divide one Laguerre series by another.
- `lagpow(c, pow[, maxpower])` Raise a Laguerre series to a power.

### Algebra

#### `numpy.polynomial.laguerre.lagadd(c1, c2)`

Add one Laguerre series to another.

Returns the sum of two Laguerre series $c1 + c2$. The arguments are sequences of coefficients ordered from lowest order term to highest, i.e., $[1,2,3]$ represents the series $P_0 + 2*P_1 + 3*P_2$.

**Parameters**
- `c1, c2`: array_like
  1-D arrays of Laguerre series coefficients ordered from low to high.

**Returns**
- `out`: ndarray
  Array representing the Laguerre series of their sum.

**See also:**
- `lagsub`, `lagmul`, `lagdiv`, `lagpow`

#### Notes

Unlike multiplication, division, etc., the sum of two Laguerre series is a Laguerre series (without having to “re-project” the result onto the basis set) so addition, just like that of “standard” polynomials, is simply “component-wise.”

#### Examples

```python
>>> from numpy.polynomial.laguerre import lagadd
>>> lagadd([1, 2, 3], [1, 2, 3, 4])
array([ 2., 4., 6., 4.])
```

#### `numpy.polynomial.laguerre.lagsub(c1, c2)`

Subtract one Laguerre series from another.

Returns the difference of two Laguerre series $c1 - c2$. The sequences of coefficients are from lowest order term to highest, i.e., $[1,2,3]$ represents the series $P_0 + 2*P_1 + 3*P_2$.

**Parameters**
- `c1, c2`: array_like
  1-D arrays of Laguerre series coefficients ordered from low to high.

**Returns**
- `out`: ndarray
  Of Laguerre series coefficients representing their difference.

**See also:**
- `lagadd`, `lagmul`, `lagdiv`, `lagpow`
Notes

Unlike multiplication, division, etc., the difference of two Laguerre series is a Laguerre series (without having to "reproject" the result onto the basis set) so subtraction, just like that of "standard" polynomials, is simply "component-wise."

Examples

```python
>>> from numpy.polynomial.laguerre import lagsub
>>> lagsub([1, 2, 3, 4], [1, 2, 3])
array([ 0., 0., 0., 4.])
```

```
numpy.polynomial.laguerre.lagmul(c1,c2)

Multiply one Laguerre series by another.

Returns

1-D arrays of Laguerre series coefficients ordered from low to high.
```

See also:

lagadd, lagsub, lagdiv, lagpow

Notes

In general, the (polynomial) product of two C-series results in terms that are not in the Laguerre polynomial basis set. Thus, to express the product as a Laguerre series, it is necessary to “reproject” the product onto said basis set, which may produce “unintuitive” (but correct) results; see Examples section below.

Examples

```python
>>> from numpy.polynomial.laguerre import lagmul
>>> lagmul([1, 2, 3], [0, 1, 2])
array([ 8., -13., 38., -51., 36.])
```

```
numpy.polynomial.laguerre.lagmulx(c)

Multiply the Laguerre series c by x.

Parameters

- c : array_like

1-D array of Laguerre series coefficients ordered from low to high.

Returns

out : ndarray

Array representing the result of the multiplication.
```

Notes

The multiplication uses the recursion relationship for Laguerre polynomials in the form

\[ xP_i(x) = (-(i + 1)P_{i + 1}(x) + (2i + 1)P_i(x) - iP_{i - 1}(x)) \]
Examples

```python
>>> from numpy.polynomial.laguerre import lagmulx
>>> lagmulx([1, 2, 3])
array([-1., -1., 11., -9.])
```

def lagdiv(c1, c2)
    Divide one Laguerre series by another.

    Returns the quotient-with-remainder of two Laguerre series \( c_1 / c_2 \). The arguments are sequences of coefficients from lowest order “term” to highest, e.g., \([1,2,3]\) represents the series \( P_0 + 2P_1 + 3P_2 \).

    Parameters
    c1, c2 : array_like
        1-D arrays of Laguerre series coefficients ordered from low to high.

    Returns
    [quo, rem] : ndarrays
        Of Laguerre series coefficients representing the quotient and remainder.

See also:
lagadd, lagsub, lagmul, lagpow

Notes
In general, the (polynomial) division of one Laguerre series by another results in quotient and remainder terms that are not in the Laguerre polynomial basis set. Thus, to express these results as a Laguerre series, it is necessary to “reproject” the results onto the Laguerre basis set, which may produce “unintuitive” (but correct) results; see Examples section below.

Examples

```python
>>> from numpy.polynomial.laguerre import lagdiv
>>> lagdiv([ 8., -13., 38., -51., 36.], [0, 1, 2])
(array([ 1., 2., 3.]), array([ 0.]))
>>> lagdiv([ 9., -12., 38., -51., 36.], [0, 1, 2])
(array([ 1., 2., 3.]), array([ 1., 1.]))
```

def lagpow(c, pow, maxpower=16)
    Raise a Laguerre series to a power.

    Returns the Laguerre series \( c \) raised to the power \( pow \). The argument \( c \) is a sequence of coefficients ordered from low to high. i.e., \([1,2,3]\) is the series \( P_0 + 2P_1 + 3P_2 \).

    Parameters
    c : array_like
        1-D array of Laguerre series coefficients ordered from low to high.

    pow : integer
        Power to which the series will be raised

    maxpower : integer, optional
        Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16

    Returns
    coef : ndarray
Laguerre series of power.

See also:
lagadd, lagsub, lagmul, lagdiv

Examples
>>> from numpy.polynomial.laguerre import lagpow
>>> lagpow([1, 2, 3], 2)
array([ 14., -16.,  56., -72.,  54.])

Gauss-Laguerre quadrature.

Computes the sample points and weights for Gauss-Laguerre quadrature. These sample points and weights will correctly integrate polynomials of degree $2 \ast \text{deg} - 1$ or less over the interval $[0, \infty]$ with the weight function $f(x) = \exp(-x)$.

Parameters
deg : int
    Number of sample points and weights. It must be $\geq 1$.

Returns
x : ndarray
    1-D ndarray containing the sample points.
y : ndarray
    1-D ndarray containing the weights.

Notes
The results have only been tested up to degree 100 higher degrees may be problematic. The weights are determined by using the fact that

\[ w_k = c / (L'_n(x_k) \ast L_{n-1}(x_k)) \]

where $c$ is a constant independent of $k$ and $x_k$ is the $k$'th root of $L_n$, and then scaling the results to get the right value when integrating 1.

Weight function of the Laguerre polynomials.

The weight function is $\exp(-x)$ and the interval of integration is $[0, \infty]$. The Laguerre polynomials are orthogonal, but not normalized, with respect to this weight function.

Parameters
x : array_like
    Values at which the weight function will be computed.

Returns
w : ndarray
    The weight function at $x$. 
Notes

`lagcompanion(c)`  Return the companion matrix of c.

Miscellaneous

numpy.polynomial.laguerre.

`lagcompanion(c)`  Return the companion matrix of c.

The usual companion matrix of the Laguerre polynomials is already symmetric when c is a basis Laguerre polynomial, so no scaling is applied.

Parameters

c : array_like

1-D array of Laguerre series coefficients ordered from low to high degree.

Returns

mat : ndarray

Companion matrix of dimensions (deg, deg).

Notes

numpy.polynomial.laguerre.

`lagdomain = array([0, 1])`

numpy.polynomial.laguerre.

`lagzero = array([0])`

numpy.polynomial.laguerre.

`lagone = array([1])`

numpy.polynomial.laguerre.

`lagx = array([ 1, -1])`

numpy.polynomial.laguerre.

`lagtrim(c, tol=0)`  Remove “small” “trailing” coefficients from a polynomial.

“Small” means “small in absolute value” and is controlled by the parameter tol; “trailing” means highest order coefficient(s), e.g., in [0, 1, 1, 0, 0] (which represents 0 + x + x**2 + 0*x**3 + 0*x**4) both the 3-rd and 4-th order coefficients would be “trimmed.”

Parameters

c : array_like

1-d array of coefficients, ordered from lowest order to highest.

tol : number, optional

Trailing (i.e., highest order) elements with absolute value less than or equal to tol (default value is zero) are removed.

Returns

trimmed : ndarray
1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

Raises

ValueError

If \( tol < 0 \)

See also:

trimseq

Examples

```python
>>> from numpy import polynomial as P
>>> P.trimcoef((0,0,3,0,5,0,0))
array([ 0., 0., 3., 0., 5.])
>>> P.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3) # item == tol is trimmed
array([ 0.])
```

numpy.polynomial.laguerre.lagline(off, scl)

Laguerre series whose graph is a straight line.

Parameters

off, scl : scalars

The specified line is given by \( off + scl \cdot x \).

Returns

y : ndarray

This module’s representation of the Laguerre series for \( off + scl \cdot x \).

See also:

dpolyline, chebline

Examples

```python
>>> from numpy.polynomial.laguerre import lagline, lagval
>>> lagval(0,lagline(3, 2))
3.0
>>> lagval(1,lagline(3, 2))
5.0
```

numpy.polynomial.laguerre.lag2poly(c)

Convert a Laguerre series to a polynomial.

Convert an array representing the coefficients of a Laguerre series, ordered from lowest degree to highest, to an array of the coefficients of the equivalent polynomial (relative to the “standard” basis) ordered from lowest to highest degree.

Parameters

\( c \) : array_like

1-D array containing the Laguerre series coefficients, ordered from lowest order term to highest.

Returns

\( pol \) : ndarray
1-D array containing the coefficients of the equivalent polynomial (relative to the “standard” basis) ordered from lowest order term to highest.

See also:
poly2lag

Notes
The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```python
>>> from numpy.polynomial.laguerre import lag2poly
>>> lag2poly([ 23., -63., 58., -18.])
array([ 0., 1., 2., 3.])
```

```
numpy.polynomial.laguerre.poly2lag(pol)
Convert a polynomial to a Laguerre series.

Convert an array representing the coefficients of a polynomial (relative to the “standard” basis) ordered from lowest degree to highest, to an array of the coefficients of the equivalent Laguerre series, ordered from lowest to highest degree.

Parameters
pol : array_like
    1-D array containing the polynomial coefficients

Returns
c : ndarray
    1-D array containing the coefficients of the equivalent Laguerre series.

See also:
lag2poly
```

Notes
The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```python
>>> from numpy.polynomial.laguerre import poly2lag
>>> poly2lag(np.arange(4))
array([ 23., -63., 58., -18.])
```

Hermite Module, “Physicists” (numpy.polynomial.hermite)

New in version 1.6.0.

This module provides a number of objects (mostly functions) useful for dealing with Hermite series, including a Hermite class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with such polynomials is in the docstring for its “parent” sub-package, numpy.polynomial).

```
Hermite(coef[, domain, window]) An Hermite series class.
```

Hermite Class
class numpy.polynomial.hermite.Hermite(coef, domain=None, window=None)
An Hermite series class.

The Hermite class provides the standard Python numerical methods ‘+’, ‘-’, ‘*’, ‘/’, ‘%’, ‘divmod’, ‘**’, and ‘()’ as well as the attributes and methods listed in the `ABCPolyBase` documentation.

**Parameters**

- **coef**: array_like
  Laguerre coefficients in order of increasing degree, i.e, \((1, 2, 3)\) gives \(1H_0(x) + 2H_1(X) + 3H_2(x)\).

- **domain**: (2,) array_like, optional
  Domain to use. The interval \([\text{domain}[0], \text{domain}[1]]\) is mapped to the interval \([\text{window}[0], \text{window}[1]]\) by shifting and scaling. The default value is \([-1, 1]\).

- **window**: (2,) array_like, optional
  Window, see domain for its use. The default value is \([-1, 1]\).
  New in version 1.6.0.

**Methods**

__call__(arg)

```
Hermite(basis(deg[, domain, window]))
```

Series basis polynomial of degree \(deg\).

```
Hermite.cast(series[, domain, window])
```

Convert series to series of this class.

```
Hermite.convert([domain, kind, window])
```

Convert series to a different kind and/or domain and/or window.

```
Hermite.copy()
```

Return a copy.

```
Hermite.cutdeg(deg)
```

Truncate series to the given degree.

```
Hermite.degree()
```

The degree of the series.

```
Hermite.deriv([m])
```

Differentiate.

```
Hermite.fit(x, y, deg[, domain, rcond, full, w, window])
```

Least squares fit to data.

```
Hermite.fromroots(roots[, domain, window])
```

Return series instance that has the specified roots.

```
Hermite.has_samecoef(other)
```

Check if coefficients match.

```
Hermite.has_samedomain(other)
```

Check if domains match.

```
Hermite.has_sametype(other)
```

Check if types match.

```
Hermite.has_samewindow(other)
```

Check if windows match.

```
Hermite.identity([domain, window])
```

Identity function.

```
Hermite.integ([m, k, lbnd])
```

Integrate.

```
Hermite.linspace([n, domain])
```

Return x, y values at equally spaced points in domain.

```
Hermite.mapparms()
```

Return the mapping parameters.

```
Hermite.roots()
```

Return the roots of the series polynomial.

```
Hermite.trim([tol])
```

Remove trailing coefficients. Remove trailing coefficients until a coefficient is reached whose absolute value is greater than \(\text{tol}\). Remove trailing coefficients until a coefficient is reached whose absolute value is less than \(\text{tol}\).

```
Hermite.truncate(size)
```

Truncate series to length \(size\).

**Hermite.__call__(arg)**

**classmethod**

```
Hermite.basis(deg, domain=None, window=None)
```

Series basis polynomial of degree \(deg\).

Returns the series representing the basis polynomial of degree \(deg\).

New in version 1.7.0.

**Parameters**

- **deg**: int
  Degree of the basis polynomial for the series. Must be \(\geq 0\).
domain : [None, array_like], optional

If given, the array must be of the form \([\text{beg, end}]\), where \text{beg} and \text{end} are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window : [None, array_like], optional

If given, the resulting array must be if the form \([\text{beg, end}]\), where \text{beg} and \text{end} are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series : series

A series with the coefficient of the \text{deg} term set to one and all others zero.

classmethod Hermite.cast (series, domain=None, window=None)

Convert series to series of this class.

The \text{series} is expected to be an instance of some polynomial series of one of the types supported by by the numpy.polynomial module, but could be some other class that supports the convert method.

New in version 1.7.0.

Parameters

series : series

The series instance to be converted.

domain : [None, array_like], optional

If given, the array must be of the form \([\text{beg, end}]\), where \text{beg} and \text{end} are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window : [None, array_like], optional

If given, the resulting array must be if the form \([\text{beg, end}]\), where \text{beg} and \text{end} are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series : series

A series of the same kind as the calling class and equal to \text{series} when evaluated.

See also:

cast

similar instance method

Hermite.convert (domain=None, kind=None, window=None)

Convert series to a different kind and/or domain and/or window.

Parameters

domain : array_like, optional

The domain of the converted series. If the value is None, the default domain of \text{kind} is used.

kind : class, optional
The polynomial series type class to which the current instance should be converted. If kind is None, then the class of the current instance is used.

window : array_like, optional

The window of the converted series. If the value is None, the default window of kind is used.

Returns
new_series : series

The returned class can be of different type than the current instance and/or have a different domain and/or different window.

Notes
Conversion between domains and class types can result in numerically ill defined series.

Hermite.copy()

Return a copy.

Returns
new_series : series

Copy of self.

Hermite.cutdeg(deg)

Truncate series to the given degree.

Reduce the degree of the series to deg by discarding the high order terms. If deg is greater than the current degree a copy of the current series is returned. This can be useful in least squares where the coefficients of the high degree terms may be very small.

New in version 1.5.0.

Parameters
deg : non-negative int

The series is reduced to degree deg by discarding the high order terms. The value of deg must be a non-negative integer.

Returns
new_series : series

New instance of series with reduced degree.

Hermite.degree()

The degree of the series.

New in version 1.5.0.

Returns
degree : int

Degree of the series, one less than the number of coefficients.

Hermite.deriv(m=1)

Differentiate.

Return a series instance of that is the derivative of the current series.

Parameters
m : non-negative int

The number of integrations to perform.
Returns

new_series : series

A new series representing the derivative. The domain is the same as the domain of the differentiated series.

classmethod Hermite.fit(x, y, deg, domain=None, rcond=None, full=False, w=None, window=None)

Least squares fit to data.

Return a series instance that is the least squares fit to the data y sampled at x. The domain of the returned instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

Parameters

x : array_like, shape (M,)

x-coordinates of the M sample points (x[i], y[i]).

y : array_like, shape (M,) or (M, K)

y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

deg : int

Degree of the fitting polynomial.

domain : {None, [beg, end], []}, optional

Domain to use for the returned series. If None, then a minimal domain that covers the points x is chosen. If [] the class domain is used. The default value was the class domain in NumPy 1.4 and None in later versions. The [] option was added in numpy 1.5.0.

rcond : float, optional

Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

full : bool, optional

Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w : array_like, shape (M,), optional

Weights. If not None the contribution of each point (x[i], y[i]) to the fit is weighted by w[i]. Ideally the weights are chosen so that the errors of the products w[i]*y[i] all have the same variance. The default value is None.

New in version 1.5.0.

window : [{beg, end}], optional

Window to use for the returned series. The default value is the default class domain

New in version 1.6.0.

Returns

new_series : series

A series that represents the least squares fit to the data and has the domain specified in the call.
[resid, rank, sv, rcond] : list

These values are only returned if full = True

resid – sum of squared residuals of the least squares fit rank – the numerical rank of the scaled Vandermonde matrix sv – singular values of the scaled Vandermonde matrix rcond – value of rcond.

For more details, see linalg.lstsq.

classmethod Hermite.fromroots(roots, domain=[], window=None)

Return series instance that has the specified roots.

Returns a series representing the product \((x - r[0])*(x - r[1])*...*(x - r[n-1])\), where \(r\) is a list of roots.

Parameters

roots : array_like

List of roots.

domain : [ ], None, array_like, optional

Domain for the resulting series. If None the domain is the interval from the smallest root to the largest. If [ ] the domain is the class domain. The default is [ ].

window : {None, array_like}, optional

Window for the returned series. If None the class window is used. The default is None.

Returns

new_series : series

Series with the specified roots.

Hermite.has_samecoef(other)

Check if coefficients match.

New in version 1.6.0.

Parameters

other : class instance

The other class must have the coef attribute.

Returns

bool : boolean

True if the coefficients are the same, False otherwise.

Hermite.has_samedomain(other)

Check if domains match.

New in version 1.6.0.

Parameters

other : class instance

The other class must have the domain attribute.

Returns

bool : boolean

True if the domains are the same, False otherwise.
Hermite has_same_type (other)
Check if types match.
New in version 1.7.0.

Parameters
other : object

Class instance.

Returns
bool : boolean
True if other is same class as self.

Hermite has_same_window (other)
Check if windows match.
New in version 1.6.0.

Parameters
other : class instance
The other class must have the window attribute.

Returns
bool : boolean
True if the windows are the same, False otherwise.

classmethod Hermite identity (domain=None, window=None)
Identity function.
If p is the returned series, then p (x) == x for all values of x.

Parameters
domain : {None, array_like}, optional
If given, the array must be of the form [beg, end], where beg and end are the
endpoints of the domain. If None is given then the class domain is used. The default is
None.

window : {None, array_like}, optional
If given, the resulting array must be if the form [beg, end], where beg and end are the
endpoints of the window. If None is given then the class window is used. The default is None.

Returns
new_series : series
Series of representing the identity.

Hermite integ (m=1, k=[], lbnd=None)
Integrate.
Return a series instance that is the definite integral of the current series.

Parameters
m : non-negative int
The number of integrations to perform.
k : array_like
Integration constants. The first constant is applied to the first integration, the second to
the second, and so on. The list of values must less than or equal to \( m \) in length and any
missing values are set to zero.

\textbf{lbnd} : Scalar

The lower bound of the definite integral.

**Returns**

\textbf{new\_series} : series

A new series representing the integral. The domain is the same as the domain of the
integrated series.

\texttt{Hermite.linspace} \((n=100,\ domain=None)\)

Return \( x, y \) values at equally spaced points in domain.

Returns the \( x, y \) values at \( n \) linearly spaced points across the domain. Here \( y \) is the value of the polynomial
at the points \( x \). By default the domain is the same as that of the series instance. This method is intended
mostly as a plotting aid.

New in version 1.5.0.

**Parameters**

\textbf{n} : int, optional

Number of point pairs to return. The default value is 100.

\textbf{domain} : [None, array_like], optional

If not None, the specified domain is used instead of that of the calling instance. It should
be of the form \([\text{beg}, \text{end}]\). The default is None which case the class domain is used.

**Returns**

\( x, y \) : ndarray

\( x \) is equal to linspace(self.domain[0], self.domain[1], n) and \( y \) is the series evaluated at
element of \( x \).

\texttt{Hermite.mapparms}()

Return the mapping parameters.

The returned values define a linear map \( \text{off} + \text{scl}*x \) that is applied to the input arguments before
the series is evaluated. The map depends on the \text{domain} and \text{window}; if the current \text{domain} is equal
to the \text{window} the resulting map is the identity. If the coefficients of the series instance are to be used
by themselves outside this class, then the linear function must be substituted for the \( x \) in the standard
representation of the base polynomials.

**Returns**

\( \text{off}, \text{scl} \) : float or complex

The mapping function is defined by \( \text{off} + \text{scl}*x \).

**Notes**

If the current domain is the interval \([l1, r1]\) and the window is \([l2, r2]\), then the linear mapping function \( L \) is defined by the equations:

\[
L(l1) = l2 \\
L(r1) = r2
\]

\texttt{Hermite.roots}()

Return the roots of the series polynomial.
Compute the roots for the series. Note that the accuracy of the roots decrease the further outside the domain they lie.

**Returns**
- **roots**: ndarray
  Array containing the roots of the series.

**Hermite.trim(tol=0)**
Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than tol or the beginning of the series is reached. If all the coefficients would be removed the series is set to [0]. A new series instance is returned with the new coefficients. The current instance remains unchanged.

**Parameters**
- **tol**: non-negative number.
  All trailing coefficients less than tol will be removed.

**Returns**
- **new_series**: series
  Contains the new set of coefficients.

**Hermite.truncate(size)**
Truncate series to length size.

Reduce the series to length size by discarding the high degree terms. The value of size must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

**Parameters**
- **size**: positive int
  The series is reduced to length size by discarding the high degree terms. The value of size must be a positive integer.

**Returns**
- **new_series**: series
  New instance of series with truncated coefficients.

---

**hermval(x, c[, tensor])**
Evaluate an Hermite series at points x.

If c is of length n + 1, this function returns the value:

\[ p(x) = c_0 \cdot H_0(x) + c_1 \cdot H_1(x) + ... + c_n \cdot H_n(x) \]

The parameter x is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In
either case, either \( x \) or its elements must support multiplication and addition both with themselves and with the elements of \( c \).

If \( c \) is a 1-D array, then \( p(x) \) will have the same shape as \( x \). If \( c \) is multidimensional, then the shape of the result depends on the value of \( \text{tensor} \). If \( \text{tensor} \) is true the shape will be \( c\text{.shape}[1:] + x\text{.shape} \). If \( \text{tensor} \) is false the shape will be \( c\text{.shape}[1:] \). Note that scalars have shape \((,)\).

Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

**Parameters**

\( x \): array_like, compatible object

If \( x \) is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, \( x \) or its elements must support addition and multiplication with with themselves and with the elements of \( c \).

\( c \): array_like

Array of coefficients ordered so that the coefficients for terms of degree \( n \) are contained in \( c[n] \). If \( c \) is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of \( c \).

\( \text{tensor} \): boolean, optional

If True, the shape of the coefficient array is extended with ones on the right, one for each dimension of \( x \). Scalars have dimension 0 for this action. The result is that every column of coefficients in \( c \) is evaluated for every element of \( x \). If False, \( x \) is broadcast over the columns of \( c \) for the evaluation. This keyword is useful when \( c \) is multidimensional. The default value is True.

New in version 1.7.0.

**Returns**

\( \text{values} \): ndarray, algebra_like

The shape of the return value is described above.

**See also:**

hermval2d, hermgrid2d, hermval3d, hermgrid3d

**Notes**

The evaluation uses Clenshaw recursion, aka synthetic division.

**Examples**

```python
>>> from numpy.polynomial.hermite import hermval
>>> coef = [1,2,3]
>>> hermval(1, coef)
11.0
>>> hermval([[1,2],[3,4]], coef)
array([[11., 51.],
       [115., 203.]])
```

numpy.polynomial.hermite.\texttt{hermval2d}(x, y, c)

Evaluate a 2-D Hermite series at points \((x, y)\).

This function returns the values:

\[
p(x, y) = \sum_{i,j} c_{i,j} * H_i(x) * H_j(y)
\]
The parameters $x$ and $y$ are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either $x$ and $y$ or their elements must support multiplication and addition both with themselves and with the elements of $c$.

If $c$ is a 1-D array a one is implicitly appended to its shape to make it 2-D. The shape of the result will be $c.shape[2:] + x.shape$.

**Parameters**

$x, y$ : array_like, compatible objects

The two dimensional series is evaluated at the points $(x, y)$, where $x$ and $y$ must have the same shape. If $x$ or $y$ is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn’t an ndarray it is treated as a scalar.

$c$ : array_like

Array of coefficients ordered so that the coefficient of the term of multi-degree $i,j$ is contained in $c[i, j]$. If $c$ has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

**Returns**

$values$ : ndarray, compatible object

The values of the two dimensional polynomial at points formed with pairs of corresponding values from $x$ and $y$.

**See also:**

`hermval`, `hermgrid2d`, `hermval3d`, `hermgrid3d`

**Notes**

`numpy.polynomial.hermite.hermval3d(x, y, z, c)`

Evaluate a 3-D Hermite series at points $(x, y, z)$.

This function returns the values:

\[
p(x, y, z) = \sum_{i,j,k} c_{i,j,k} * H_i(x) * H_j(y) * H_k(z)
\]

The parameters $x$, $y$, and $z$ are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either $x$, $y$, and $z$ or their elements must support multiplication and addition both with themselves and with the elements of $c$.

If $c$ has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be $c.shape[3:] + x.shape$.

**Parameters**

$x, y, z$ : array_like, compatible object

The three dimensional series is evaluated at the points $(x, y, z)$, where $x$, $y$, and $z$ must have the same shape. If any of $x$, $y$, or $z$ is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn’t an ndarray it is treated as a scalar.

$c$ : array_like

Array of coefficients ordered so that the coefficient of the term of multi-degree $i,j,k$ is contained in $c[i, j, k]$. If $c$ has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

**Returns**

$values$ : ndarray, compatible object
The values of the multidimensional polynomial on points formed with triples of corresponding values from x, y, and z.

See also:

hermval, hermval2d, hermgrid2d, hermgrid3d

Notes

numpy.polynomial.hermite.hermgrid2d(x, y, c)
Evaluate a 2-D Hermite series on the Cartesian product of x and y.

This function returns the values:

\[ p(a, b) = \sum_{i,j} c_{i,j} \cdot H_i(a) \cdot H_j(b) \]

where the points \((a, b)\) consist of all pairs formed by taking \(a\) from \(x\) and \(b\) from \(y\). The resulting points form a grid with \(x\) in the first dimension and \(y\) in the second.

The parameters \(x\) and \(y\) are converted to arrays only if they are tuples or a lists, otherwise they are treated as scalars. In either case, either \(x\) and \(y\) or their elements must support multiplication and addition both with themselves and with the elements of \(c\).

If \(c\) has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be \(c.shape[2:] + x.shape\).

Parameters

- **x, y**: array_like, compatible objects
  The two dimensional series is evaluated at the points in the Cartesian product of \(x\) and \(y\). If \(x\) or \(y\) is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.

- **c**: array_like
  Array of coefficients ordered so that the coefficients for terms of degree \(i,j\) are contained in \(c[i,j]\). If \(c\) has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

- **values**: ndarray, compatible object
  The values of the two dimensional polynomial at points in the Cartesian product of \(x\) and \(y\).

See also:

hermval, hermval2d, hermval3d, hermgrid3d

Notes

numpy.polynomial.hermite.hermgrid3d(x, y, z, c)
Evaluate a 3-D Hermite series on the Cartesian product of \(x\), \(y\), and \(z\).

This function returns the values:

\[ p(a, b, c) = \sum_{i,j,k} c_{i,j,k} \cdot H_i(a) \cdot H_j(b) \cdot H_k(c) \]

where the points \((a, b, c)\) consist of all triples formed by taking \(a\) from \(x\), \(b\) from \(y\), and \(c\) from \(z\). The resulting points form a grid with \(x\) in the first dimension, \(y\) in the second, and \(z\) in the third.
The parameters \( x, y, \) and \( z \) are converted to arrays only if they are tuples or a lists, otherwise they are treated as scalars. In either case, either \( x, y, \) and \( z \) or their elements must support multiplication and addition both with themselves and with the elements of \( c \).

If \( c \) has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be \( \text{c.shape[3:]} + \text{x.shape} + \text{y.shape} + \text{z.shape} \).

**Parameters**

\( x, y, z : \) array_like, compatible objects

The three dimensional series is evaluated at the points in the Cartesian product of \( x, y, \) and \( z \). If \( x, y, \) or \( z \) is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.

\( c : \) array_like

Array of coefficients ordered so that the coefficients for terms of degree \( i,j \) are contained in \( c[i,j] \). If \( c \) has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

**Returns**

\( \text{values} : \) ndarray, compatible object

The values of the two dimensional polynomial at points in the Cartesian product of \( x \) and \( y \).

**See also:**

hermval, hermval2d, hermgrid2d, hermval3d

**Notes**

numpy.polynomial.hermite.hermroots \( c \)

Compute the roots of a Hermite series.

Return the roots (a.k.a. “zeros”) of the polynomial

\[
p(x) = \sum_i c[i] \cdot H_i(x).
\]

**Parameters**

\( c : \) 1-D array_like

1-D array of coefficients.

**Returns**

\( \text{out} : \) ndarray

Array of the roots of the series. If all the roots are real, then \( \text{out} \) is also real, otherwise it is complex.

**See also:**

polyroots, legroots, lagroots, chebroots, hermeroots

**Notes**

The root estimates are obtained as the eigenvalues of the companion matrix. Roots far from the origin of the complex plane may have large errors due to the numerical instability of the series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton’s method.

The Hermite series basis polynomials aren’t powers of \( x \) so the results of this function may seem unintuitive.
```python
>>> from numpy.polynomial.hermite import hermroots, hermfromroots
>>> coef = hermfromroots([-1, 0, 1])
>>> coef
array([ 0. , 0.25 , 0. , 0.125])
>>> hermroots(coef)
array([-1.00000000e+00, -1.38777878e-17, 1.00000000e+00])
```

```{={

**numpy.polynomial.hermite.hermfromroots** *(roots)*

Generate a Hermite series with given roots.

The function returns the coefficients of the polynomial

\[ p(x) = (x - r_0) * (x - r_1) * ... * (x - r_n), \]

in Hermite form, where the \( r_n \) are the roots specified in *roots*. If a zero has multiplicity \( n \), then it must appear in *roots* \( n \) times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then *roots* looks something like \([2, 2, 2, 3, 3]\). The roots can appear in any order.

If the returned coefficients are \( c \), then

\[ p(x) = c_0 + c_1 * H_1(x) + ... + c_n * H_n(x) \]

The coefficient of the last term is not generally 1 for monic polynomials in Hermite form.

**Parameters**

- **roots** : array_like
  Sequence containing the roots.

**Returns**

- **out** : ndarray
  1-D array of coefficients. If all roots are real then *out* is a real array, if some of the roots are complex, then *out* is complex even if all the coefficients in the result are real (see Examples below).

**See also:**

- polyfromroots, legfromroots, lagfromroots, chebfromroots, hermefromroots.

**Examples**

```python
>>> from numpy.polynomial.hermite import hermfromroots, hermval
>>> coef = hermfromroots((-1, 0, 1))
>>> hermval((-1, 0, 1), coef)
array([ 0., 0., 0.])
>>> coef = hermfromroots((-1j, 1j))
>>> hermval((-1j, 1j), coef)
array([ 0.+0.j, 0.+0.j])
```

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**Fitting**

```python
numpy.polynomial.hermite.hermfit(x, y, deg[, rcond, full, w])
```

1100 Chapter 3. Routines
Least squares fit of Hermite series to data.

Return the coefficients of a Hermite series of degree deg that is the least squares fit to the data values y given at points x. If y is 1-D the returned coefficients will also be 1-D. If y is 2-D multiple fits are done, one for each column of y, and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

\[ p(x) = c_0 + c_1 * H_1(x) + ... + c_n * H_n(x), \]

where \( n \) is deg.

Parameters

- **x**: array_like, shape (M,)
  - x-coordinates of the M sample points \((x[i], y[i])\).

- **y**: array_like, shape (M,) or (M, K)
  - y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

- **deg**: int
  - Degree of the fitting polynomial

- **rcond**: float, optional
  - Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

- **full**: bool, optional
  - Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

- **w**: array_like, shape (M,), optional
  - Weights. If not None, the contribution of each point \((x[i], y[i])\) to the fit is weighted by \(w[i]\). Ideally the weights are chosen so that the errors of the products \(w[i]*y[i]\) all have the same variance. The default value is None.

Returns

- **coef**: ndarray, shape (M,) or (M, K)
  - Hermite coefficients ordered from low to high. If y was 2-D, the coefficients for the data in column k of y are in column k.

- **[residuals, rank, singular_values, rcond]**: list
  - These values are only returned if full = True

  resid – sum of squared residuals of the least squares fit
  rank – the numerical rank of the scaled Vandermonde matrix sv – singular values of the scaled Vandermonde matrix
  rcond – value of rcond.

  For more details, see linalg.lstsq.

Warns

- **RankWarning**
  - The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if full = False. The warnings can be turned off by
>>> import warnings
>>> warnings.simplefilter('ignore', RankWarning)

See also:
chebfit, legfit, lagfit, polyfit, hermefit

hermval
Evaluates a Hermite series.

hermvander
Vandermonde matrix of Hermite series.

hermweight
Hermite weight function

linalg.lstsq
Computes a least-squares fit from the matrix.

scipy.interpolate.UnivariateSpline
Computes spline fits.

Notes
The solution is the coefficients of the Hermite series \( p \) that minimizes the sum of the weighted squared errors

\[
E = \sum_j w_j^2 \cdot |y_j - p(x_j)|^2,
\]

where the \( w_j \) are the weights. This problem is solved by setting up the (typically) overdetermined matrix equation

\[
V(x) \cdot c = w \cdot y,
\]

where \( V \) is the weighted pseudo Vandermonde matrix of \( x \), \( c \) are the coefficients to be solved for, \( w \) are the weights, \( y \) are the observed values. This equation is then solved using the singular value decomposition of \( V \).

If some of the singular values of \( V \) are so small that they are neglected, then a \texttt{RankWarning} will be issued. This means that the coefficient values may be poorly determined. Using a lower order fit will usually get rid of the warning. The \texttt{rcond} parameter can also be set to a value smaller than its default, but the resulting fit may be spurious and have large contributions from roundoff error.

Fits using Hermite series are probably most useful when the data can be approximated by \( \sqrt{w(x)} \cdot p(x) \), where \( w(x) \) is the Hermite weight. In that case the weight \( \sqrt{w(x[i])} \) should be used together with data values \( y[i]/\sqrt{w(x[i])} \). The weight function is available as \texttt{hermweight}.

References
[R61]

Examples

```python
>>> from numpy.polynomial.hermite import hermfit, hermval
>>> x = np.linspace(-10, 10)
>>> err = np.random.randn(len(x))/10
>>> y = hermval(x, [1, 2, 3]) + err
>>> hermfit(x, y, 2)
array([ 0.97902637, 1.99849131, 3.00006 ,])
```
numpy.polynomial.hermite.hermvander (x, deg)

Pseudo-Vandermonde matrix of given degree.

Returns the pseudo-Vandermonde matrix of degree deg and sample points x. The pseudo-Vandermonde matrix is defined by

\[ V[\ldots, i] = H_i(x), \]

where \( 0 \leq i \leq \text{deg} \). The leading indices of V index the elements of x and the last index is the degree of the Hermite polynomial.

If c is a 1-D array of coefficients of length \( n + 1 \) and V is the array \( V = \text{hermvander}(x, n) \), then \( \text{np.dot}(V, c) \) and \( \text{hermval}(x, c) \) are the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of Hermite series of the same degree and sample points.

Parameters
- x : array_like
  Array of points. The dtype is converted to float64 or complex128 depending on whether any of the elements are complex. If x is scalar it is converted to a 1-D array.
- deg : int
  Degree of the resulting matrix.

Returns
- vander : ndarray
  The pseudo-Vandermonde matrix. The shape of the returned matrix is \( x.\text{shape} + \text{(deg + 1,) \ldots} \), where The last index is the degree of the corresponding Hermite polynomial. The dtype will be the same as the converted x.

Examples

```python
>>> from numpy.polynomial.hermite import hermvander
>>> x = np.array([-1, 0, 1])
>>> hermvander(x, 3)
array([[ 1., -2.,  2.,  4.],
       [ 1.,  0., -2., -0.],
       [ 1.,  2.,  2., -4.]])
```

numpy.polynomial.hermite.hermvander2d (x, y, deg)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees deg and sample points \((x, y)\). The pseudo-Vandermonde matrix is defined by

\[ V[\ldots, \text{deg}[1] \star i + j] = H_i(x) \star H_j(y), \]

where \( 0 \leq i \leq \text{deg}[0] \) and \( 0 \leq j \leq \text{deg}[1] \). The leading indices of V index the points \((x, y)\) and the last index encodes the degrees of the Hermite polynomials.

If \( V = \text{hermvander2d}(x, y, [x\text{deg}, y\text{deg}]) \), then the columns of V correspond to the elements of a 2-D coefficient array c of shape \((x\text{deg} + 1, y\text{deg} + 1)\) in the order

\[ c_00, c_{01}, c_{02}, \ldots, c_{10}, c_{11}, c_{12}, \ldots \]

and \( \text{np.dot}(V, c.\text{flat}) \) and \( \text{hermval2d}(x, y, c) \) will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D Hermite series of the same degrees and sample points.
Parameters

x, y : array_like

Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg : list of ints

List of maximum degrees of the form [x_deg, y_deg].

Returns

vander2d : ndarray

The shape of the returned matrix is x.shape + (order,), where order = (deg[0] + 1) * (deg[1] + 1). The dtype will be the same as the converted x and y.

See also:

hermvander, hermvander3d, hermval3d

Notes

numpy.polynomial.hermite.hermvander3d(x, y, z, deg)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees deg and sample points (x, y, z). If l, m, n are the given degrees in x, y, z, then The pseudo-Vandermonde matrix is defined by

\[ V[\ldots, (m+1)(n+1)i + (n+1)j + k] = H_i(x) * H_j(y) * H_k(z), \]

where 0 <= i <= l, 0 <= j <= m, and 0 <= j <= n. The leading indices of V index the points (x, y, z) and the last index encodes the degrees of the Hermite polynomials.

If V = hermvander3d(x, y, z, [xdeg, ydeg, zdeg]), then the columns of V correspond to the elements of a 3-D coefficient array c of shape (xdeg + 1, ydeg + 1, zdeg + 1) in the order

\[ c_{000}, c_{001}, c_{002}, \ldots, c_{010}, c_{011}, c_{012}, \ldots \]

and np.dot(V, c.flat) and hermval3d(x, y, z, c) will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D Hermite series of the same degrees and sample points.

Parameters

x, y, z : array_like

Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg : list of ints

List of maximum degrees of the form [x_deg, y_deg, z_deg].

Returns

vander3d : ndarray

The shape of the returned matrix is x.shape + (order,), where order = (deg[0] + 1) * (deg[1] + 1) * (deg[2] + 1). The dtype will be the same as the converted x, y, and z.

See also:

hermvander, hermvander3d, hermval3d
Notes

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</table>

Calculus

numpy.polynomial.hermite.hermder(c, m=1, scl=1, axis=0)

Differentiate a Hermite series.

Returns the Hermite series coefficients c differentiated m times along axis. At each iteration the result is multiplied by scl (the scaling factor is for use in a linear change of variable). The argument c is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series 1*H_0 + 2*H_1 + 3*H_2 while [[1,2],[1,2]] represents 1*H_0(x)*H_0(y) + 1*H_1(x)*H_0(y) + 2*H_0(x)*H_1(y) + 2*H_1(x)*H_1(y) if axis=0 is x and axis=1 is y.

Parameters

- **c**: array_like
  Array of Hermite series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.
- **m**: int, optional
  Number of derivatives taken, must be non-negative. (Default: 1)
- **scl**: scalar, optional
  Each differentiation is multiplied by scl. The end result is multiplication by scl**m. This is for use in a linear change of variable. (Default: 1)
- **axis**: int, optional
  Axis over which the derivative is taken. (Default: 0).

New in version 1.7.0.

Returns

- **der**: ndarray
  Hermite series of the derivative.

See also:

hemit

Notes

In general, the result of differentiating a Hermite series does not resemble the same operation on a power series. Thus the result of this function may be “unintuitive,” albeit correct; see Examples section below.

Examples

```python
>>> from numpy.polynomial.hermite import hermder
>>> hermder([ 1. , 0.5, 0.5, 0.5])
array([ 1., 2., 3.])
>>> hermder([-0.5, 1./2., 1./8., 1./12., 1./16.], m=2)
array([-0.25, 1.25, 1.25, 1.25, 1.25])
```

numpy.polynomial.hermite.hermint(c, m=1, k=[], lbnd=0, scl=1, axis=0)

Integrate a Hermite series.

3.24. Polynomials
Returns the Hermite series coefficients \( c \) integrated \( m \) times from \( lbnd \) along \( axis \). At each iteration the resulting series is multiplied by \( scl \) and an integration constant, \( k \), is added. The scaling factor is for use in a linear change of variable. (“Buyer beware”: note that, depending on what one is doing, one may want \( scl \) to be the reciprocal of what one might expect; for more information, see the Notes section below.) The argument \( c \) is an array of coefficients from low to high degree along each axis, e.g., \([1,2,3]\) represents the series \( H_0 + 2*H_1 + 3*H_2 \) while \([[[1,2],[1,2]]]\) represents \( 1*H_0(x)*H_0(y) + 1*H_1(x)*H_0(y) + 2*H_0(x)*H_1(y) + 2*H_1(x)*H_1(y) \) if \( \text{axis}=0 \) is \( x \) and \( \text{axis}=1 \) is \( y \).

**Parameters**

- **c**: array_like
  - Array of Hermite series coefficients. If \( c \) is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

- **m**: int, optional
  - Order of integration, must be positive. (Default: 1)

- **k**: list, scalar, optional
  - Integration constant(s). The value of the first integral at \( lbnd \) is the first value in the list, the value of the second integral at \( lbnd \) is the second value, etc. If \( k == [] \) (the default), all constants are set to zero. If \( m == 1 \), a single scalar can be given instead of a list.

- **lbnd**: scalar, optional
  - The lower bound of the integral. (Default: 0)

- **scl**: scalar, optional
  - Following each integration the result is multiplied by \( scl \) before the integration constant is added. (Default: 1)

- **axis**: int, optional
  - Axis over which the integral is taken. (Default: 0).

**Returns**

- **S**: ndarray
  - Hermite series coefficients of the integral.

**Raises**

- **ValueError**
  - If \( m < 0 \), \( \text{len(k)} > m \), \( \text{np.isscalar(lbnd)} == \text{False} \), or \( \text{np.isscalar(scl)} == \text{False} \).

**See also:**

- **hermderv**

**Notes**

Note that the result of each integration is multiplied by \( scl \). Why is this important to note? Say one is making a linear change of variable \( u = ax + b \) in an integral relative to \( x \). Then .. math:: dx = du/a, so one will need to set \( scl \) equal to \( 1/a \) - perhaps not what one would have first thought.

Also note that, in general, the result of integrating a C-series needs to be “reprojected” onto the C-series basis set. Thus, typically, the result of this function is “unintuitive,” albeit correct; see Examples section below.
Examples

```python
>>> from numpy.polynomial.hermite import hermint
>>> hermint([1,2,3]) # integrate once, value 0 at 0.
array([ 1. , 0.5, 0.5, 0.5])
>>> hermint([1,2,3], m=2) # integrate twice, value & deriv 0 at 0
array([-0.5 , 0.5 , 0.125 , 0.08333333, 0.0625 ])
>>> hermint([1,2,3], k=1) # integrate once, value 1 at 0.
array([ 2. , 0.5, 0.5, 0.5])
>>> hermint([1,2,3], lbnd=-1) # integrate once, value 0 at -1
array([-2. , 0.5, 0.5, 0.5])
>>> hermint([1,2,3], m=2, k=[1,2], lbnd=-1)
array([ 1.66666667, -0.5 , 0.125 , 0.08333333, 0.0625 ])
```

hermadd(c1, c2) Add one Hermite series to another.
hermsub(c1, c2) Subtract one Hermite series from another.
hermmul(c1, c2) Multiply one Hermite series by another.
hermupx(c) Multiply a Hermite series by x.
hermdiv(c1, c2) Divide one Hermite series by another.
hermpow(c, pow[, maxpower]) Raise a Hermite series to a power.

Algebra

```
numpy.polynomial.hermite.hermadd(c1, c2)
Add one Hermite series to another.
```

Returns the sum of two Hermite series \( c1 + c2 \). The arguments are sequences of coefficients ordered from lowest order term to highest, i.e., \([1,2,3]\) represents the series \( P_0 + 2*P_1 + 3*P_2 \).

Parameters

\( c1, c2 \) : array_like

1-D arrays of Hermite series coefficients ordered from low to high.

Returns

out : ndarray

Array representing the Hermite series of their sum.

See also:

hermsub, hermmul, hermdiv, hermpow

Notes

Unlike multiplication, division, etc., the sum of two Hermite series is a Hermite series (without having to “re-project” the result onto the basis set) so addition, just like that of “standard” polynomials, is simply “component-wise.”

Examples

```
>>> from numpy.polynomial.hermite import hermadd
>>> hermadd([1, 2, 3], [1, 2, 3, 4])
array([ 2., 4., 6., 4.])
```

```
numpy.polynomial.hermite.hermsub(c1, c2)
Subtract one Hermite series from another.
```

Returns the difference of two Hermite series \( c1 - c2 \). The sequences of coefficients are from lowest order term to highest, i.e., \([1,2,3]\) represents the series \( P_0 + 2*P_1 + 3*P_2 \).
Parameters
   c1, c2 : array_like
     1-D arrays of Hermite series coefficients ordered from low to high.

Returns
   out : ndarray
     Of Hermite series coefficients representing their difference.

See also:
   hermadd, hermmul, hermdiv, hermpow

Notes
Unlike multiplication, division, etc., the difference of two Hermite series is a Hermite series (without having
to “reproject” the result onto the basis set) so subtraction, just like that of “standard” polynomials, is simply
“component-wise.”

Examples
>>> from numpy.polynomial.hermite import hermsub
>>> hermsub([1, 2, 3, 4], [1, 2, 3])
array([ 0., 0., 0., 4.])

numpy.polynomial.hermite.hermmul(c1, c2)
Multiply one Hermite series by another.

Parameters
   c1, c2 : array_like
     1-D arrays of Hermite series coefficients ordered from low to high.

Returns
   out : ndarray
     Of Hermite series coefficients representing their product.

See also:
   hermadd, hermsub, hermdiv, hermpow

Notes
In general, the (polynomial) product of two C-series results in terms that are not in the Hermite polynomial basis set. Thus, to express the product as a Hermite series, it is necessary to “reproject” the product onto said basis set, which may produce “unintuitive” (but correct) results; see Examples section below.

Examples
>>> from numpy.polynomial.hermite import hermmul
>>> hermmul([1, 2, 3], [0, 1, 2])
array([ 52., 29., 52., 7., 6.])

numpy.polynomial.hermite.hermmulx(c)
Multiply a Hermite series by x.

Multiply the Hermite series c by x, where x is the independent variable.
Parameters

- **c**: array_like
  1-D array of Hermite series coefficients ordered from low to high.

Returns

- **out**: ndarray
  Array representing the result of the multiplication.

Notes

The multiplication uses the recursion relationship for Hermite polynomials in the form

\[ xP_i(x) = \frac{P_{i+1}(x)}{2} + iP_{i-1}(x) \]

Examples

```python
>>> from numpy.polynomial.hermite import hermmulx
>>> hermmulx([1, 2, 3])
array([ 2., 6.5, 1., 1.5])
```

**numpy.polynomial.hermite**

- **hermdiv**: divide one Hermite series by another.

  ```python
def hermdiv(c1, c2):
    return [quo, rem]
  ```

  Divide one Hermite series by another.

  Returns the quotient-with-remainder of two Hermite series \( c1 / c2 \). The arguments are sequences of coefficients from lowest order “term” to highest, e.g., \([1,2,3]\) represents the series \( P_0 + 2P_1 + 3P_2 \).

Parameters

- **c1, c2**: array_like
  1-D arrays of Hermite series coefficients ordered from low to high.

Returns

- **[quo, rem]**: ndarrays
  Of Hermite series coefficients representing the quotient and remainder.

See also:

- **hermadd**, **hermsub**, **hermmul**, **hermpow**

Notes

In general, the (polynomial) division of one Hermite series by another results in quotient and remainder terms that are not in the Hermite polynomial basis set. Thus, to express these results as a Hermite series, it is necessary to "reproject" the results onto the Hermite basis set, which may produce "unintuitive" (but correct) results; see Examples section below.

Examples

```python
>>> from numpy.polynomial.hermite import hermdiv
>>> hermdiv([ 52., 29., 52., 7., 6.], [0, 1, 2])
(array([ 1., 2., 3.]), array([ 0.]))
>>> hermdiv([ 54., 31., 52., 7., 6.], [0, 1, 2])
(array([ 1., 2., 3.]), array([ 2., 2.]))
>>> hermdiv([ 53., 30., 52., 7., 6.], [0, 1, 2])
(array([ 1., 2., 3.]), array([ 1., 1.]))
```

**numpy.polynomial.hermite**

- **hermpow**: raise a Hermite series to a power.

  ```python
def hermpow(c, pow, maxpower=16):
    return
  ```

  Raise a Hermite series to a power.
Returns the Hermite series $c$ raised to the power $\text{pow}$. The argument $c$ is a sequence of coefficients ordered from low to high. i.e., $[1,2,3]$ is the series $P_0 + 2*P_1 + 3*P_2$.

**Parameters**
- $c$ : array_like
  1-D array of Hermite series coefficients ordered from low to high.
- $\text{pow}$ : integer
  Power to which the series will be raised
- $\text{maxpower}$ : integer, optional
  Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16

**Returns**
- $\text{coef}$ : ndarray
  Hermite series of power.

**See also:**
- hermadd, hermsub, hermmul, hermdiv

**Examples**
```python
>>> from numpy.polynomial.hermite import hermpow
>>> hermpow([1, 2, 3], 2)
array([ 81., 52., 82., 12., 9.])
```

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**Quadrature**

Gauss-Hermite quadrature.

Computes the sample points and weights for Gauss-Hermite quadrature. These sample points and weights will correctly integrate polynomials of degree $2*deg - 1$ or less over the interval $[-\infty, \infty]$ with the weight function $f(x) = \exp(-x^2)$.

**Parameters**
- $\text{deg}$ : int
  Number of sample points and weights. It must be $\geq 1$.

**Returns**
- $x$ : ndarray
  1-D ndarray containing the sample points.
- $y$ : ndarray
  1-D ndarray containing the weights.
Notes

The results have only been tested up to degree 100, higher degrees may be problematic. The weights are determined by using the fact that

\[ w_k = c/(H'_n(x_k) \ast H_{n-1}(x_k)) \]

where \( c \) is a constant independent of \( k \) and \( x_k \) is the \( k \)'th root of \( H_n \), and then scaling the results to get the right value when integrating 1.

numpy.polynomial.hermite.hermweight(x)

Weight function of the Hermite polynomials.

The weight function is \( \exp(-x^2) \) and the interval of integration is \([-\infty, \infty]\). The Hermite polynomials are orthogonal, but not normalized, with respect to this weight function.

Parameters

\( x \) : array_like

Values at which the weight function will be computed.

Returns

\( w \) : ndarray

The weight function at \( x \).

Notes

hermcompanion(c)  
Return the scaled companion matrix of \( c \).

hermdomain
hermzero
hermone
hermx
hermtrim(c[, tol])  
Remove “small” “trailing” coefficients from a polynomial.

hermline(off, scl)  
Hermite series whose graph is a straight line.

herm2poly(c)  
Convert a Hermite series to a polynomial.

poly2herm(pol)  
Convert a polynomial to a Hermite series.

**Miscellaneous**

numpy.polynomial.hermite.hermcompanion(c)

Return the scaled companion matrix of \( c \).

The basis polynomials are scaled so that the companion matrix is symmetric when \( c \) is an Hermite basis polynomial. This provides better eigenvalue estimates than the unscaled case and for basis polynomials the eigenvalues are guaranteed to be real if \( \text{numpy.linalg.eigvalsh} \) is used to obtain them.

Parameters

\( c \) : array_like

1-D array of Hermite series coefficients ordered from low to high degree.

Returns

\( \text{mat} \) : ndarray

Scaled companion matrix of dimensions (deg, deg).

Notes

numpy.polynomial.hermite.hermdomain = array([-1, 1])
numpy.polynomial.hermite.hermzero = array([0])

numpy.polynomial.hermite.hermone = array([1])

numpy.polynomial.hermite.hermx = array([ 0. , 0.5])

numpy.polynomial.hermite.hermtrim(c, tol=0)

Remove “small” “trailing” coefficients from a polynomial.

“Small” means “small in absolute value” and is controlled by the parameter tol; “trailing” means highest order coefficient(s), e.g., in [0, 1, 1, 0, 0] (which represents 0 + x + x**2 + 0*x**3 + 0*x**4) both the 3-rd and 4-th order coefficients would be “trimmed.”

Parameters

c : array_like
    1-d array of coefficients, ordered from lowest order to highest.

tol : number, optional
    Trailing (i.e., highest order) elements with absolute value less than or equal to tol (default value is zero) are removed.

Returns

trimmed : ndarray
    1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

Raises

ValueError

If tol < 0

See also:

trimseq

Examples

>>> from numpy import polynomial as P
>>> P.trimcoef((0,0,3,0,5,0,0))
array([ 0., 0., 3., 0., 5.])
>>> P.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3) # item == tol is trimmed
array([ 0.])
>>> i = complex(0,1) # works for complex
>>> P.trimcoef((3e-4,1e-3*1j,-5e-4,2e-5*(-1+1j)), 1e-3)
array([ 0.0003+0.j , 0.0010-0.001j])

numpy.polynomial.hermite.hermline(off, scl)

Hermite series whose graph is a straight line.

Parameters

off, scl : scalars
    The specified line is given by off + scl*x.

Returns

y : ndarray
    This module’s representation of the Hermite series for off + scl*x.
See also:
polyline, chebline

Examples

```python
>>> from numpy.polynomial.hermite import hermline, hermval
>>> hermval(0,hermline(3, 2))
3.0
>>> hermval(1,hermline(3, 2))
5.0
```

```python
numpy.polynomial.hermite.herm2poly(c)
Convert a Hermite series to a polynomial.

Convert an array representing the coefficients of a Hermite series, ordered from lowest degree to highest, to an array of the coefficients of the equivalent polynomial (relative to the “standard” basis) ordered from lowest to highest degree.

Parameters
c : array_like
   1-D array containing the Hermite series coefficients, ordered from lowest order term to highest.

Returns
pol : ndarray
   1-D array containing the coefficients of the equivalent polynomial (relative to the “standard” basis) ordered from lowest order term to highest.

See also:
poly2herm

Notes
The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```python
>>> from numpy.polynomial.hermite import herm2poly
>>> herm2poly([ 1. , 2.75 , 0.5 , 0.375])
array([ 0., 1., 2., 3.])
```

```python
numpy.polynomial.hermite.poly2herm(pol)
Convert a polynomial to a Hermite series.

Convert an array representing the coefficients of a polynomial (relative to the “standard” basis) ordered from lowest degree to highest, to an array of the coefficients of the equivalent Hermite series, ordered from lowest to highest degree.

Parameters
pol : array_like
   1-D array containing the polynomial coefficients.

Returns
c : ndarray
   1-D array containing the coefficients of the equivalent Hermite series.
See also:

herm2poly

Notes
The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```python
>>> from numpy.polynomial.hermite import poly2herm
>>> poly2herm(np.arange(4))
array([ 1. ,  2.75 ,  0.5 ,  0.375])
```

HermiteE Module, “Probabilists” (numpy.polynomial.hermite_e)

New in version 1.6.0.

This module provides a number of objects (mostly functions) useful for dealing with HermiteE series, including a `HermiteE` class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with such polynomials is in the docstring for its “parent” sub-package, `numpy.polynomial`).

```python
HermiteE(coef[, domain, window]) An HermiteE series class.
```

HermiteE Class

class numpy.polynomial.hermite_e.HermiteE (coef, domain=None, window=None)
An HermiteE series class.

The HermiteE class provides the standard Python numerical methods ‘+’, ‘-’, ‘*’, ‘/’, ‘%’, ‘divmod’, ‘**’, and ‘()` as well as the attributes and methods listed in the ABCPolyBase documentation.

Parameters

- **coef** : array_like
  Laguerre coefficients in order of increasing degree, i.e, \((1, 2, 3)\) gives \(1*He_0(x) + 2*He_1(x) + 3*He_2(x)\).
- **domain** : (2,) array_like, optional
  Domain to use. The interval \([domain[0], domain[1]]\) is mapped to the interval \([window[0], window[1]]\) by shifting and scaling. The default value is \([-1, 1]\).
- **window** : (2,) array_like, optional
  Window, see domain for its use. The default value is \([-1, 1]\).

New in version 1.6.0.

Methods

- **__call__(arg)**
  Series basis polynomial of degree \(deg\).
- **basis(deg[, domain, window])**
  Convert series to series of this class.
- **cast(series[, domain, window])**
  Convert series to different kind and/or domain and/or window.
- **copy()**
  Return a copy.
- **cutdeg(deg)**
  Truncate series to the given degree.
- **degree()**
  The degree of the series.
- **deriv([m])**
  Differentiate.
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<td>Least squares fit to data.</td>
</tr>
<tr>
<td>fromroots(roots[, domain, window])</td>
<td>Return series instance that has the specified roots.</td>
</tr>
<tr>
<td>has_samecoef(other)</td>
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<tr>
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<tr>
<td>identity([domain, window])</td>
<td>Identity function.</td>
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<tr>
<td>integ([m, k, lbnd])</td>
<td>Integrate.</td>
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<tr>
<td>linspace([n, domain])</td>
<td>Return x, y values at equally spaced points in domain.</td>
</tr>
<tr>
<td>mapparms()</td>
<td>Return the mapping parameters.</td>
</tr>
<tr>
<td>roots()</td>
<td>Return the roots of the series polynomial.</td>
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<tr>
<td>trim([tol])</td>
<td>Remove trailing coefficients Remove trailing coefficients until a coefficient is reached.</td>
</tr>
<tr>
<td>truncate(size)</td>
<td>Truncate series to length size.</td>
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</table>

HermiteE.__call__(arg)

**classmethod** HermiteE.basis(deg, domain=None, window=None)

Series basis polynomial of degree deg.

Returns the series representing the basis polynomial of degree deg.

New in version 1.7.0.

**Parameters**

- **deg**: int
  
  Degree of the basis polynomial for the series. Must be >= 0.

- **domain**: {None, array_like}, optional
  
  If given, the array must be of the form [beg, end], where beg and end are the endpoints of the domain. If None is given then the class domain is used. The default is None.

- **window**: {None, array_like}, optional
  
  If given, the resulting array must be if the form [beg, end], where beg and end are the endpoints of the window. If None is given then the class window is used. The default is None.

**Returns**

- **new_series**: series
  
  A series with the coefficient of the deg term set to one and all others zero.

**classmethod** HermiteE.cast(series, domain=None, window=None)

Convert series to series of this class.

The series is expected to be an instance of some polynomial series of one of the types supported by the numpy.polynomial module, but could be some other class that supports the convert method.

New in version 1.7.0.

**Parameters**

- **series**: series
  
  The series instance to be converted.

- **domain**: {None, array_like}, optional

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If given, the array must be of the form \([\text{beg}, \text{end}]\), where \(\text{beg}\) and \(\text{end}\) are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window : {None, array_like}, optional

If given, the resulting array must be of the form \([\text{beg}, \text{end}]\), where \(\text{beg}\) and \(\text{end}\) are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series : series

A series of the same kind as the calling class and equal to \(\text{series}\) when evaluated.

See also:

convert

similar instance method

**HermiteE.convert** *(domain=None, kind=None, window=None)*

Convert series to a different kind and/or domain and/or window.

Parameters

domain : array_like, optional

The domain of the converted series. If the value is None, the default domain of \(\text{kind}\) is used.

kind : class, optional

The polynomial series type class to which the current instance should be converted. If kind is None, then the class of the current instance is used.

window : array_like, optional

The window of the converted series. If the value is None, the default window of \(\text{kind}\) is used.

Returns

new_series : series

The returned class can be of different type than the current instance and/or have a different domain and/or different window.

Notes

Conversion between domains and class types can result in numerically ill defined series.

**HermiteE.copy** ()

Return a copy.

Returns

new_series : series

Copy of self.

**HermiteE.cutdeg**(deg)

Truncate series to the given degree.

Reduce the degree of the series to \(\text{deg}\) by discarding the high order terms. If \(\text{deg}\) is greater than the current degree a copy of the current series is returned. This can be useful in least squares where the coefficients of the high degree terms may be very small.
New in version 1.5.0.

**Parameters**

- **deg**: non-negative int
  
The series is reduced to degree `deg` by discarding the high order terms. The value of `deg` must be a non-negative integer.

**Returns**

- **new_series**: series
  
  New instance of series with reduced degree.

**HermiteE.degree()**

The degree of the series.

New in version 1.5.0.

**Returns**

- **degree**: int
  
  Degree of the series, one less than the number of coefficients.

**HermiteE.deriv(m=1)**

Differentiate.

Return a series instance of that is the derivative of the current series.

**Parameters**

- **m**: non-negative int
  
  The number of integrations to perform.

**Returns**

- **new_series**: series
  
  A new series representing the derivative. The domain is the same as the domain of the differentiated series.

**classmethod HermiteE.fit(x, y, deg, domain=None, rcond=None, full=False, w=None, window=None)**

Least squares fit to data.

Return a series instance that is the least squares fit to the data `y` sampled at `x`. The domain of the returned instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

**Parameters**

- **x**: array_like, shape (M,)
  
  x-coordinates of the M sample points (x[i], y[i]).

- **y**: array_like, shape (M,) or (M, K)
  
  y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

- **deg**: int
  
  Degree of the fitting polynomial.

- **domain**: [None, [beg, end], []], optional
  
  Domain to use for the returned series. If `None`, then a minimal domain that covers the points `x` is chosen. If `[ ]` the class domain is used. The default value was the class
domain in NumPy 1.4 and None in later versions. The [] option was added in numpy 1.5.0.

**rcond** : float, optional

Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

**full** : bool, optional

Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

**w** : array_like, shape (M,), optional

Weights. If not None the contribution of each point \((x[i], y[i])\) to the fit is weighted by \(w[i]\). Ideally the weights are chosen so that the errors of the products \(w[i]*y[i]\) all have the same variance. The default value is None.

New in version 1.5.0.

**window** : {{beg, end}}, optional

Window to use for the returned series. The default value is the default class domain

New in version 1.6.0.

**Returns**

**new_series** : series

A series that represents the least squares fit to the data and has the domain specified in the call.

**[resid, rank, sv, rcond]** : list

These values are only returned if full = True

resid – sum of squared residuals of the least squares fit rank – the numerical rank of the scaled Vandermonde matrix sv – singular values of the scaled Vandermonde matrix rcond – value of rcond.

For more details, see linalg.lstsq.

**classmethod** HermiteE.fromroots (roots, domain=[], window=None)

Return series instance that has the specified roots.

Returns a series representing the product \((x - r[0])*(x - r[1])*...*(x - r[n-1])\), where \(r\) is a list of roots.

**Parameters**

**roots** : array_like

List of roots.

**domain** : {[]}, None, array_like}, optional

Domain for the resulting series. If None the domain is the interval from the smallest root to the largest. If [] the domain is the class domain. The default is [].

**window** : {None, array_like}, optional

Window for the returned series. If None the class window is used. The default is None.
Returns

new_series : series
Series with the specified roots.

HermiteE().has_samecoef(other)
Check if coefficients match.
New in version 1.6.0.
Parameters

other : class instance
The other class must have the coef attribute.

Returns

bool : boolean
True if the coefficients are the same, False otherwise.

HermiteE().has_samedomain(other)
Check if domains match.
New in version 1.6.0.
Parameters

other : class instance
The other class must have the domain attribute.

Returns

bool : boolean
True if the domains are the same, False otherwise.

HermiteE().has_sametype(other)
Check if types match.
New in version 1.7.0.
Parameters

other : object
Class instance.

Returns

bool : boolean
True if other is same class as self

HermiteE().has_samewindow(other)
Check if windows match.
New in version 1.6.0.
Parameters

other : class instance
The other class must have the window attribute.

Returns

bool : boolean
True if the windows are the same, False otherwise.
classmethod HermiteE.identity (domain=None, window=None)
Identity function.
If p is the returned series, then p(x) == x for all values of x.

Parameters
  domain : [None, array_like], optional
    If given, the array must be of the form [beg, end], where beg and end are the
    endpoints of the domain. If None is given then the class domain is used. The default is
    None.
  window : [None, array_like], optional
    If given, the resulting array must be if the form [beg, end], where beg and end are the
    endpoints of the window. If None is given then the class window is used. The default is None.

Returns
  new_series : series
    Series of representing the identity.

HermiteE.integ (m=1, k=[], lbnd=None)
Integrate.
Return a series instance that is the definite integral of the current series.

Parameters
  m : non-negative int
    The number of integrations to perform.
  k : array_like
    Integration constants. The first constant is applied to the first integration, the second to
    the second, and so on. The list of values must less than or equal to m in length and any
    missing values are set to zero.
  lbnd : Scalar
    The lower bound of the definite integral.

Returns
  new_series : series
    A new series representing the integral. The domain is the same as the domain of the
    integrated series.

HermiteE.linspace (n=100, domain=None)
Return x, y values at equally spaced points in domain.
Returns the x, y values at n linearly spaced points across the domain. Here y is the value of the polynomial
at the points x. By default the domain is the same as that of the series instance. This method is intended
mostly as a plotting aid.
New in version 1.5.0.

Parameters
  n : int, optional
    Number of point pairs to return. The default value is 100.
  domain : [None, array_like], optional
If not None, the specified domain is used instead of that of the calling instance. It should be of the form \([\text{beg}, \text{end}]\). The default is None which case the class domain is used.

**Returns**

\(x, y\) : ndarray

\(x\) is equal to \(\text{linspace}(self.\text{domain}[0], self.\text{domain}[1], n)\) and \(y\) is the series evaluated at element of \(x\).

**HermiteE.mapparms()**

Return the mapping parameters.

The returned values define a linear map \(\text{off} + \text{scl}*x\) that is applied to the input arguments before the series is evaluated. The map depends on the domain and window; if the current domain is equal to the window the resulting map is the identity. If the coefficients of the series instance are to be used by themselves outside this class, then the linear function must be substituted for the \(x\) in the standard representation of the base polynomials.

**Returns**

\(\text{off, scl}\) : float or complex

The mapping function is defined by \(\text{off} + \text{scl}*x\).

**Notes**

If the current domain is the interval \([l1, r1]\) and the window is \([l2, r2]\), then the linear mapping function \(L\) is defined by the equations:

\[
L(l1) = l2 \\
L(r1) = r2
\]

**HermiteE.roots()**

Return the roots of the series polynomial.

Compute the roots for the series. Note that the accuracy of the roots decrease the further outside the domain they lie.

**Returns**

\(\text{roots}\) : ndarray

Array containing the roots of the series.

**HermiteE.trim(tol=0)**

Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than \(tol\) or the beginning of the series is reached. If all the coefficients would be removed the series is set to \([0]\). A new series instance is returned with the new coefficients. The current instance remains unchanged.

**Parameters**

\(tol\) : non-negative number.

All trailing coefficients less than \(tol\) will be removed.

**Returns**

\(\text{new\_series}\) : series

Contains the new set of coefficients.

**HermiteE.truncate(size)**

Truncate series to length \(size\).
Reduce the series to length `size` by discarding the high degree terms. The value of `size` must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

**Parameters**
- **size**: positive int
  The series is reduced to length `size` by discarding the high degree terms. The value of `size` must be a positive integer.

**Returns**
- **new_series**: series
  New instance of series with truncated coefficients.

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**Basics**

numpy.polynomial.hermite_e

`hermeval(x, c, tensor=True)`

Evaluate an HermiteE series at points x.

If `c` is of length `n + 1`, this function returns the value:

```
p(x) = c_0 * H_0(x) + c_1 * H_1(x) + ... + c_n * H_n(x)
```

The parameter `x` is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either `x` or its elements must support multiplication and addition both with themselves and with the elements of `c`.

If `c` is a 1-D array, then `p(x)` will have the same shape as `x`. If `c` is multidimensional, then the shape of the result depends on the value of `tensor`. If `tensor` is true the shape will be `c.shape[1:] + x.shape`. If `tensor` is false the shape will be `c.shape[1:]`. Note that scalars have shape `(,)`.

Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

**Parameters**
- **x**: array_like, compatible object
  If `x` is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, `x` or its elements must support addition and multiplication with with themselves and with the elements of `c`.

- **c**: array_like
  Array of coefficients ordered so that the coefficients for terms of degree `n` are contained in `c[n]`. If `c` is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of `c`.

- **tensor**: boolean, optional
If True, the shape of the coefficient array is extended with ones on the right, one for each dimension of \( x \). Scalars have dimension 0 for this action. The result is that every column of coefficients in \( c \) is evaluated for every element of \( x \). If False, \( x \) is broadcast over the columns of \( c \) for the evaluation. This keyword is useful when \( c \) is multidimensional. The default value is True.

New in version 1.7.0.

Returns
values : ndarray, algebra_like

The shape of the return value is described above.

See also:
hermeval2d, hermegrid2d, hermeval3d, hermegrid3d

Notes
The evaluation uses Clenshaw recursion, aka synthetic division.

Examples

```python
>>> from numpy.polynomial.hermite_e import hermeval
>>> coef = [1, 2, 3]
>>> hermeval(1, coef)
3.0
>>> hermeval([[1, 2], [3, 4]], coef)
array([[ 3., 14.],
       [31., 54.]])
```

numpy.polynomial.hermite_e.hermeval2d(x, y, c)

Evaluate a 2-D HermiteE series at points \((x, y)\).

This function returns the values:

\[
p(x, y) = \sum_{i,j} c_{i,j} * H_i(x) * H_j(y)
\]

The parameters \( x \) and \( y \) are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either \( x \) and \( y \) or their elements must support multiplication and addition both with themselves and with the elements of \( c \).

If \( c \) is a 1-D array a one is implicitly appended to its shape to make it 2-D. The shape of the result will be \( c.shape[2:] + x.shape \).

Parameters
x, y : array_like, compatible objects

The two dimensional series is evaluated at the points \((x, y)\), where \( x \) and \( y \) must have the same shape. If \( x \) or \( y \) is a list or tuple, it is first converted to an \( \text{ndarray} \), otherwise it is left unchanged and if it isn’t an \( \text{ndarray} \) it is treated as a scalar.

c : array_like

Array of coefficients ordered so that the coefficient of the term of multi-degree \( i,j \) is contained in \( c[i,j] \). If \( c \) has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns
values : ndarray, compatible object

The values of the two dimensional polynomial at points formed with pairs of corresponding values from \( x \) and \( y \).
numpy.polynomial.hermite_e.

hermeval3d(x, y, z, c)

Evaluate a 3-D Hermite_e series at points (x, y, z).

This function returns the values:

\[ p(x, y, z) = \sum_{i,j,k} c_{i,j,k} \times H_i(x) \times H_j(y) \times H_k(z) \]

The parameters x, y, and z are converted to arrays only if they are tuples or lists, otherwise they are treated as scalars and they must have the same shape after conversion. In either case, either x, y, and z or their elements must support multiplication and addition both with themselves and with the elements of c.

If c has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape.

Parameters

- x, y, z : array_like, compatible object
  The three dimensional series is evaluated at the points (x, y, z), where x, y, and z must have the same shape. If any of x, y, or z is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn’t an ndarray it is treated as a scalar.
- c : array_like
  Array of coefficients ordered so that the coefficient of the term of multi-degree i,j,k is contained in c[i, j, k]. If c has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

Returns

- values : ndarray, compatible object
  The values of the multidimensional polynomial on points formed with triples of corresponding values from x, y, and z.

See also:

hermeval, hermeval2d, hermegrid2d, hermeval3d, hermegrid3d

Notes

numpy.polynomial.hermite_e.

hermegrid2d(x, y, c)

Evaluate a 2-D HermiteE series on the Cartesian product of x and y.

This function returns the values:

\[ p(a, b) = \sum_{i,j} c_{i,j} \times H_i(a) \times H_j(b) \]

where the points (a, b) consist of all pairs formed by taking a from x and b from y. The resulting points form a grid with x in the first dimension and y in the second.

The parameters x and y are converted to arrays only if they are tuples or lists, otherwise they are treated as scalars. In either case, either x and y or their elements must support multiplication and addition both with themselves and with the elements of c.

If c has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape.
Parameters

\( x, y : \text{array_like, compatible objects} \)

The two dimensional series is evaluated at the points in the Cartesian product of \( x \) and \( y \). If \( x \) or \( y \) is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.

\( c : \text{array_like} \)

Array of coefficients ordered so that the coefficients for terms of degree \( i,j \) are contained in \( c[i,j] \). If \( c \) has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

\( \text{values : ndarray, compatible object} \)

The values of the two dimensional polynomial at points in the Cartesian product of \( x \) and \( y \).

See also:

\text{hermeval}, \text{hermeval2d}, \text{hermeval3d}, \text{hermegrid3d}

Notes

\text{numpy.polynomial.hermite_e.hermegrid3d}(x, y, z, c)

Evaluate a 3-D HermiteE series on the Cartesian product of \( x \), \( y \), and \( z \).

This function returns the values:

\[
p(a, b, c) = \sum_{i,j,k} c_{i,j,k} \cdot He_i(a) \cdot He_j(b) \cdot He_k(c)
\]

where the points \((a, b, c)\) consist of all triples formed by taking \( a \) from \( x \), \( b \) from \( y \), and \( c \) from \( z \). The resulting points form a grid with \( x \) in the first dimension, \( y \) in the second, and \( z \) in the third.

The parameters \( x \), \( y \), and \( z \) are converted to arrays only if they are tuples or a lists, otherwise they are treated as scalars. In either case, either \( x \), \( y \), and \( z \) or their elements must support multiplication and addition both with themselves and with the elements of \( c \).

If \( c \) has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be \( c.\text{shape}[3:] + x.\text{shape} + y.\text{shape} + z.\text{shape} \).

Parameters

\( x, y, z : \text{array_like, compatible objects} \)

The three dimensional series is evaluated at the points in the Cartesian product of \( x \), \( y \), and \( z \). If \( x, y, \) or \( z \) is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn’t an ndarray, it is treated as a scalar.

\( c : \text{array_like} \)

Array of coefficients ordered so that the coefficients for terms of degree \( i,j \) are contained in \( c[i,j] \). If \( c \) has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

\( \text{values : ndarray, compatible object} \)

The values of the two dimensional polynomial at points in the Cartesian product of \( x \) and \( y \).

See also:

\text{hermeval}, \text{hermeval2d}, \text{hermegrid2d}, \text{hermeval3d}
numpy.polynomial.hermite_e.hermeroots(c)
Compute the roots of a HermiteE series.

Return the roots (a.k.a. “zeros”) of the polynomial

\[ p(x) = \sum_i c[i] \times H_i(x). \]

Parameters
  c : 1-D array_like
    1-D array of coefficients.

Returns
  out : ndarray
    Array of the roots of the series. If all the roots are real, then out is also real, otherwise it is complex.

See also:
polyroots, legroots, lagroots, hermroots, chebroots

Notes
The root estimates are obtained as the eigenvalues of the companion matrix, Roots far from the origin of the complex plane may have large errors due to the numerical instability of the series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton’s method.

The HermiteE series basis polynomials aren’t powers of \( x \) so the results of this function may seem unintuitive.

Examples

```python
generate a HermiteE series with given roots.
The function returns the coefficients of the polynomial

\[ p(x) = (x - r_0) \times (x - r_1) \times ... \times (x - r_n), \]

in HermiteE form, where the \( r_n \) are the roots specified in roots. If a zero has multiplicity \( n \), then it must appear in roots \( n \) times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then roots looks something like [2, 2, 2, 3, 3]. The roots can appear in any order.

If the returned coefficients are \( c \), then

\[ p(x) = c_0 + c_1 \times H_1(x) + ... + c_n \times H_n(x) \]

The coefficient of the last term is not generally 1 for monic polynomials in HermiteE form.

Parameters
  roots : array_like
Sequence containing the roots.

Returns

out : ndarray

1-D array of coefficients. If all roots are real then out is a real array, if some of the roots are complex, then out is complex even if all the coefficients in the result are real (see Examples below).

See also:

polyfromroots, legfromroots, lagfromroots, hermfromroots, chebfromroots.

Examples

```python
>>> from numpy.polynomial.hermite_e import hermefromroots, hermeval
>>> coef = hermefromroots((-1, 0, 1))
>>> hermeval((-1, 0, 1), coef)
array([ 0., 0., 0.])
>>> coef = hermefromroots((-1j, 1j))
>>> hermeval((-1j, 1j), coef)
array([ 0.+0.j, 0.+0.j])
```

Fitting

```
numpy.polynomial.hermite_e.hermefit (x, y, deg[, rcond, full, w])
```

Least squares fit of Hermite series to data.

Return the coefficients of a HermiteE series of degree deg that is the least squares fit to the data values y given at points x. If y is 1-D the returned coefficients will also be 1-D. If y is 2-D multiple fits are done, one for each column of y, and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

\[ p(x) = c_0 + c_1 \cdot H_1(x) + \ldots + c_n \cdot H_n(x), \]

where \( n \) is \( \text{deg} \).

Parameters

- **x** : array_like, shape (M,)
  
  x-coordinates of the M sample points \((x[i], y[i])\).

- **y** : array_like, shape (M,) or (M, K)
  
  y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

- **deg** : int
  
  Degree of the fitting polynomial

- **rcond** : float, optional
  
  Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is \( \text{len(x)} \cdot \text{eps} \), where \( \text{eps} \) is the relative precision of the float type, about 2e-16 in most cases.
full : bool, optional

Switch determining nature of return value. When it is False (the default) just the coef-
ficients are returned, when True diagnostic information from the singular value decom-
position is also returned.

w : array_like, shape (M,), optional

Weights. If not None, the contribution of each point \((x[i], y[i])\) to the fit is
weighted by \(w[i]\). Ideally the weights are chosen so that the errors of the products
\(w[i]*y[i]\) all have the same variance. The default value is None.

Returns

coef : ndarray, shape (M,) or (M, K)

Hermite coefficients ordered from low to high. If \(y\) was 2-D, the coefficients for the data
in column \(k\) of \(y\) are in column \(k\).

[residuals, rank, singular_values, rcond] : list

These values are only returned if full = True

resid – sum of squared residuals of the least squares fit
rank – the numerical rank of the scaled Vandermonde matrix
sv – singular values of the scaled Vandermonde matrix
rcond – value of \(\text{rcond}\).

For more details, see \texttt{linalg.lstsq}.

Warns

RankWarning

The rank of the coefficient matrix in the least-squares fit is deficient. The warning is
only raised if full = False. The warnings can be turned off by

    >>> import warnings
    >>> warnings.simplefilter('ignore', RankWarning)

See also:

chebfit, legfit, polyfit, hermfit, polyfit

hermeval

Evaluates a Hermite series.

hermevander

pseudo Vandermonde matrix of Hermite series.

hermeweight

HermiteE weight function.

linalg.lstsq

Computes a least-squares fit from the matrix.

scipy.interpolate.UnivariateSpline

Computes spline fits.

Notes

The solution is the coefficients of the HermiteE series \(p\) that minimizes the sum of the weighted squared errors

\[
E = \sum_j w_j^2 * |y_j - p(x_j)|^2,
\]
where the $w_j$ are the weights. This problem is solved by setting up the (typically) overdetermined matrix equation

$$V(x) \cdot c = w \cdot y,$$

where $V$ is the pseudo Vandermonde matrix of $x$, the elements of $c$ are the coefficients to be solved for, and the elements of $y$ are the observed values. This equation is then solved using the singular value decomposition of $V$.

If some of the singular values of $V$ are so small that they are neglected, then a RankWarning will be issued. This means that the coefficient values may be poorly determined. Using a lower order fit will usually get rid of the warning. The $rcond$ parameter can also be set to a value smaller than its default, but the resulting fit may be spurious and have large contributions from roundoff error.

Fits using HermiteE series are probably most useful when the data can be approximated by $\sqrt{w(x)} \cdot p(x)$, where $w(x)$ is the HermiteE weight. In that case the weight $\sqrt{w(x[i])}$ should be used together with data values $y[i]/\sqrt{w(x[i])}$. The weight function is available as hermeweight.

References

[R62]

Examples

```python
>>> from numpy.polynomial.hermite_e import hermefit, hermeval
>>> x = np.linspace(-10, 10)
>>> err = np.random.randn(len(x))/10
>>> y = hermeval(x, [1, 2, 3]) + err
>>> hermefit(x, y, 2)
array([1.01690445, 1.99951418, 2.99948696])
```

numpy.polynomial.hermite_e.hermevander(x, deg)

Pseudo-Vandermonde matrix of given degree.

Returns the pseudo-Vandermonde matrix of degree $deg$ and sample points $x$. The pseudo-Vandermonde matrix is defined by

$$V[\ldots, i] = H_e_i(x),$$

where $0 <= i <= deg$. The leading indices of $V$ index the elements of $x$ and the last index is the degree of the HermiteE polynomial.

If $c$ is a 1-D array of coefficients of length $n + 1$ and $V$ is the array $V = \text{hermevander}(x, n)$, then $\text{np.dot}(V, c)$ and $\text{hermeval}(x, c)$ are the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of HermiteE series of the same degree and sample points.

Parameters

- $x$: array_like
  - Array of points. The dtype is converted to float64 or complex128 depending on whether any of the elements are complex. If $x$ is scalar it is converted to a 1-D array.

- $deg$: int
  - Degree of the resulting matrix.

Returns

- $vander$: ndarray
  - The pseudo-Vandermonde matrix. The shape of the returned matrix is $x$.shape + (deg + 1,), where The last index is the degree of the corresponding HermiteE polynomial. The dtype will be the same as the converted $x$.  

3.24. Polynomials
Examples

```python
>>> from numpy.polynomial.hermite_e import hermevander
>>> x = np.array([-1, 0, 1])
>>> hermevander(x, 3)
array([[ 1., -1., 0., 2.],
       [ 1., 0., -1., -0.],
       [ 1., 1., 0., -2.]])
```

numpy.polynomial.hermite_e.hermevander2d(x, y, deg)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees `deg` and sample points `(x, y)`. The pseudo-Vandermonde matrix is defined by

\[ V[..., deg[1] \cdot i + j] = He_i(x) \cdot He_j(y), \]

where \(0 <= i <= \text{deg}[0]\) and \(0 <= j <= \text{deg}[1]\). The leading indices of \(V\) index the points \((x, y)\) and the last index encodes the degrees of the HermiteE polynomials.

If \(V = \text{hermevander2d}(x, y, [\text{xdeg}, \text{ydeg}])\), then the columns of \(V\) correspond to the elements of a 2-D coefficient array \(c\) of shape \((\text{xdeg} + 1, \text{ydeg} + 1)\) in the order

\[ c_{00}, c_{01}, c_{02}, ..., c_{10}, c_{11}, c_{12}, ... \]

and \(\text{np.dot}(V, c\text{.flat})\) and \(\text{hermeval2d}(x, y, c)\) will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D HermiteE series of the same degrees and sample points.

Parameters

- `x, y`: array_like
  Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

- `deg`: list of ints
  List of maximum degrees of the form `[x_deg, y_deg]`.

Returns

- `vander2d`: ndarray
  The shape of the returned matrix is `x.shape + (order,)`, where \(\text{order} = (\text{deg}[0] + 1) \cdot (\text{deg}[1] + 1)\). The dtype will be the same as the converted `x` and `y`.

See also:

- hermevander, hermevander3d, hermeval3d

Notes

numpy.polynomial.hermite_e.hermevander3d(x, y, z, deg)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees `deg` and sample points `(x, y, z)`. If \(l, m, n\) are the given degrees in \(x, y, z\), then Hehe pseudo-Vandermonde matrix is defined by

\[ V[...,(m + 1)(n + 1)i + (n + 1)j + k] = He_i(x) \cdot He_j(y) \cdot He_k(z), \]

where \(0 <= i <= l\), \(0 <= j <= m\), and \(0 <= j <= n\). The leading indices of \(V\) index the points \((x, y, z)\) and the last index encodes the degrees of the HermiteE polynomials.
If $V = \text{hermevander3d}(x, y, z, [x\text{deg}, y\text{deg}, z\text{deg}])$, then the columns of $V$ correspond to the elements of a 3-D coefficient array $c$ of shape $(x\text{deg} + 1, y\text{deg} + 1, z\text{deg} + 1)$ in the order

$$c_{000}, c_{001}, c_{002}, ..., c_{010}, c_{011}, c_{012}, ...$$

and $\text{np.dot}(V, c\text{.flat})$ and $\text{hermeval3d}(x, y, z, c)$ will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D HermiteE series of the same degrees and sample points.

**Parameters**

- $x, y, z$ : array_like
  
  Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

- $\text{deg}$ : list of ints
  
  List of maximum degrees of the form [$x\text{deg}, y\text{deg}, z\text{deg}$].

**Returns**

- $\text{vander3d}$ : ndarray
  
  The shape of the returned matrix is $x\.shape + (\text{order},)$, where $\text{order} = (\text{deg}[0] + 1) \times (\text{deg}[1] + 1) \times (\text{deg}[2] + 1)$. The dtype will be the same as the converted $x, y, z$.

**See also:**

- hermevander, hermevander3d, hermeval3d

**Notes**

- $\text{hermeder}(c[, m, scl, axis])$ Differentiate a Hermite_e series.
- $\text{hermeint}(c[, m, k, lbnd, scl, axis])$ Integrate a Hermite_e series.

**Calculus**

- **numpy.polynomial.hermite_e.** $\text{hermeder}(c, m=1, scl=1, axis=0)$
  
  Differentiate a Hermite_e series.

Returns the series coefficients $c$ differentiated $m$ times along $axis$. At each iteration the result is multiplied by $scl$ (the scaling factor is for use in a linear change of variable). The argument $c$ is an array of coefficients from low to high degree along each axis, e.g., $[1,2,3]$ represents the series $1*\text{He}_0 + 2*\text{He}_1 + 3*\text{He}_2$ while $[[1,2],[1,2]]$ represents $1*\text{He}_0(x)*\text{He}_0(y) + 1*\text{He}_1(x)*\text{He}_0(y) + 2*\text{He}_0(x)*\text{He}_1(y) + 2*\text{He}_1(x)*\text{He}_1(y)$ if $axis=0$ is $x$ and $axis=1$ is $y$.

**Parameters**

- $c$ : array_like
  
  Array of Hermite_e series coefficients. If $c$ is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

- $m$ : int, optional
  
  Number of derivatives taken, must be non-negative. (Default: 1)

- $scl$ : scalar, optional
  
  Each differentiation is multiplied by $scl$. The end result is multiplication by $scl^{**m}$. This is for use in a linear change of variable. (Default: 1)
axis : int, optional

   Axis over which the derivative is taken. (Default: 0).

New in version 1.7.0.

Returns
der : ndarray

   Hermite series of the derivative.

See also:

hermeint

Notes

In general, the result of differentiating a Hermite series does not resemble the same operation on a power series. Thus the result of this function may be “unintuitive,” albeit correct; see Examples section below.

Examples

>>> from numpy.polynomial.hermite_e import hermeder

>>> hermeder([1., 1., 1., 1.])
array([1., 2., 3.])

>>> hermeder([-0.25, 1., 1./2., 1./3., 1./4 ], m=2)
array([1., 2., 3.])

numpy.polynomial.hermite_e.hermint(c, m=1, k=[], lbnd=0, scl=1, axis=0)

Integrate a Hermite_e series.

Returns the Hermite_e series coefficients c integrated m times from lbnd along axis. At each iteration the resulting series is multiplied by scl and an integration constant, k, is added. The scaling factor is for use in a linear change of variable. (“Buyer beware”: note that, depending on what one is doing, one may want scl to be the reciprocal of what one might expect; for more information, see the Notes section below.) The argument c is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series \( H_0 + 2*H_1 + 3*H_2 \) while [[1,2],[1,2]] represents \( 1*H_0(x)*H_0(y) + 1*H_1(x)*H_0(y) + 2*H_0(x)*H_1(y) + 2*H_1(x)*H_1(y) \) if axis=0 is x and axis=1 is y.

Parameters
c : array_like

   Array of Hermite_e series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m : int, optional

   Order of integration, must be positive. (Default: 1)

k : {}, list, scalar), optional

   Integration constant(s). The value of the first integral at \( lbnd \) is the first value in the list, the value of the second integral at \( lbnd \) is the second value, etc. If \( k == [] \) (the default), all constants are set to zero. If \( m == 1 \), a single scalar can be given instead of a list.

lbnd : scalar, optional

   The lower bound of the integral. (Default: 0)

scl : scalar, optional

   Following each integration the result is multiplied by \( scl \) before the integration constant is added. (Default: 1)
axis : int, optional
    Axis over which the integral is taken. (Default: 0).
    New in version 1.7.0.

Returns
S : ndarray
    Hermite_e series coefficients of the integral.

Raises
ValueError
    If m < 0, len(k) > m, np.isscalar(lbnd) == False, or
    np.isscalar(scl) == False.

See also:
hermeder

Notes
Note that the result of each integration is multiplied by scl. Why is this important to note? Say one is making a
linear change of variable \( u = ax + b \) in an integral relative to \( x \). Then .. math:: dx = du/a, so one will need to set
\( scl \) equal to \(1/a \) - perhaps not what one would have first thought.

Also note that, in general, the result of integrating a C-series needs to be “reprojected” onto the C-series basis
set. Thus, typically, the result of this function is “unintuitive,” albeit correct; see Examples section below.

Examples
>>> from numpy.polynomial.hermite_e import hermeint
>>> hermeint([1, 2, 3])  # integrate once, value 0 at 0.
array([ 1., 1., 1., 1.])
>>> hermeint([1, 2, 3], m=2)  # integrate twice, value & deriv 0 at 0.
array([ 0.25 , 1. , 0.5 , 0.33333333, 0.25 ])
>>> hermeint([1, 2, 3], k=1)  # integrate once, value 1 at 0.
array([ 2., 1., 1., 1.])
>>> hermeint([1, 2, 3], lbnd=-1)  # integrate once, value 0 at -1
array([ 1.83333333, 0.5 , 0.33333333, 0.25 ])

hermeadd(c1, c2) Add one Hermite series to another.
hermesub(c1, c2) Subtract one Hermite series from another.
hermemul(c1, c2) Multiply one Hermite series by another.
hermemulx(c) Multiply a Hermite series by x.
hermediv(c1, c2) Divide one Hermite series by another.
hermepow(c, pow[, maxpower]) Raise a Hermite series to a power.

Algebra
numpy.polynomial.hermite_e.**hermeadd**(c1, c2)
Add one Hermite series to another.

Returns the sum of two Hermite series \( c1 + c2 \). The arguments are sequences of coefficients ordered from lowest
order term to highest, i.e., [1,2,3] represents the series \( P_0 + 2*P_1 + 3*P_2 \).

Parameters
c1, c2 : array_like
1-D arrays of Hermite series coefficients ordered from low to high.

Returns
out : ndarray
Array representing the Hermite series of their sum.

See also:
hermesub, hermemul, hermediv, hermepow

Notes
Unlike multiplication, division, etc., the sum of two Hermite series is a Hermite series (without having to “re-
project” the result onto the basis set) so addition, just like that of “standard” polynomials, is simply “component-
wise.”

Examples
>>> from numpy.polynomial.hermite_e import hermeadd
>>> hermeadd([1, 2, 3], [1, 2, 3, 4])
array([ 2., 4., 6., 4.])

numpy.polynomial.hermite_e.hermsub(c1, c2)
Subtract one Hermite series from another.

Returns the difference of two Hermite series c1 - c2. The sequences of coefficients are from lowest order term
to highest, i.e., [1,2,3] represents the series P_0 + 2*P_1 + 3*P_2.

Parameters
c1, c2 : array_like
1-D arrays of Hermite series coefficients ordered from low to high.

Returns
out : ndarray
Of Hermite series coefficients representing their difference.

See also:
hermeadd, hermemul, hermediv, hermepow

Notes
Unlike multiplication, division, etc., the difference of two Hermite series is a Hermite series (without having
to “reproject” the result onto the basis set) so subtraction, just like that of “standard” polynomials, is simply “component-wise.”

Examples
>>> from numpy.polynomial.hermite_e import hermesub
>>> hermesub([1, 2, 3, 4], [1, 2, 3])
array([ 0., 0., 0., 4.])

numpy.polynomial.hermite_e.hermmul(cl, c2)
Multiply one Hermite series by another.

Returns the product of two Hermite series cl * c2. The arguments are sequences of coefficients, from lowest
order “term” to highest, e.g., [1,2,3] represents the series P_0 + 2*P_1 + 3*P_2.
Parameters
   c1, c2 : array_like
   1-D arrays of Hermite series coefficients ordered from low to high.

Returns
   out : ndarray
   Of Hermite series coefficients representing their product.

See also:
   hermeadd, hermesub, hermediv, hermepow

Notes
In general, the (polynomial) product of two C-series results in terms that are not in the Hermite polynomial basis set. Thus, to express the product as a Hermite series, it is necessary to “reproject” the product onto said basis set, which may produce “unintuitive” (but correct) results; see Examples section below.

Examples
   >>> from numpy.polynomial.hermite_e import hermemul
   >>> hermemul([1, 2, 3], [0, 1, 2])
   array([ 14., 15., 28., 7., 6.])

numpy.polynomial.hermite_e.hermemulx(c)
Multiply a Hermite series by x.

Parameters
   c : array_like
   1-D array of Hermite series coefficients ordered from low to high.

Returns
   out : ndarray
   Array representing the result of the multiplication.

Notes
The multiplication uses the recursion relationship for Hermite polynomials in the form
   xP_i(x) = (P_{i + 1}(x) + iP_{i - 1}(x))

Examples
   >>> from numpy.polynomial.hermite_e import hermemulx
   >>> hermemulx([1, 2, 3])
   array([ 2., 7., 2., 3.])

numpy.polynomial.hermite_e.hermediv(cl, c2)
Divide one Hermite series by another.

Returns the quotient-with-remainder of two Hermite series cl / c2. The arguments are sequences of coefficients from lowest order “term” to highest, e.g., [1,2,3] represents the series P_0 + 2*P_1 + 3*P_2.

Parameters
   cl, c2 : array_like
   1-D arrays of Hermite series coefficients ordered from low to high.
Returns

[quo, rem] : ndarrays

Of Hermite series coefficients representing the quotient and remainder.

See also:

hermeadd, hermesub, hermemul, hermepow

Notes

In general, the (polynomial) division of one Hermite series by another results in quotient and remainder terms that are not in the Hermite polynomial basis set. Thus, to express these results as a Hermite series, it is necessary to “reproject” the results onto the Hermite basis set, which may produce “unintuitive” (but correct) results; see Examples section below.

Examples

```python
>>> from numpy.polynomial.hermite_e import hermediv
>>> hermediv([ 14., 15., 28., 7., 6.], [0, 1, 2])
(array([ 1., 2., 3.]), array([ 0.]))
>>> hermediv([ 15., 17., 28., 7., 6.], [0, 1, 2])
(array([ 1., 2., 3.]), array([ 1., 2.]))
```

numpy.polynomial.hermite_e.hermepow(c, pow, maxpower=16)

Raise a Hermite series to a power.

Returns the Hermite series c raised to the power pow. The argument c is a sequence of coefficients ordered from low to high. i.e., [1,2,3] is the series \( P_0 + 2*P_1 + 3*P_2 \).

Parameters

- c : array_like
  1-D array of Hermite series coefficients ordered from low to high.
- pow : integer
  Power to which the series will be raised
- maxpower : integer, optional
  Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16

Returns

- coef : ndarray
  Hermite series of power.

See also:

hermeadd, hermesub, hermemul, hermediv

Examples

```python
>>> from numpy.polynomial.hermite_e import hermepow
>>> hermepow([1, 2, 3], 2)
array([ 23., 28., 46., 12., 9.])
```

hermegauss(deg)  Gauss-Hermite\(_E\) quadrature.
hermeweight(x)  Weight function of the Hermite\(_E\) polynomials.
**Quadrature**

numpy.polynomial.hermite_e.hermegauss(deg)

Gauss-HermiteE quadrature.

Computes the sample points and weights for Gauss-HermiteE quadrature. These sample points and weights will correctly integrate polynomials of degree \(2 \times \text{deg} - 1\) or less over the interval \([-\infty, \infty]\) with the weight function \(f(x) = \exp(-x^2/2)\).

**Parameters**

- `deg`: int
  Number of sample points and weights. It must be \(\geq 1\).

**Returns**

- `x`: ndarray
  1-D ndarray containing the sample points.
- `y`: ndarray
  1-D ndarray containing the weights.

**Notes**

The results have only been tested up to degree 100, higher degrees may be problematic. The weights are determined by using the fact that

\[
  w_k = c / (H_e'(x_k) \times H_{e-1}(x_k))
\]

where \(c\) is a constant independent of \(k\) and \(x_k\) is the \(k\)th root of \(H_e\), and then scaling the results to get the right value when integrating 1.

**numpy.polynomial.hermite_e.hermeweight(x)**

Weight function of the Hermite_e polynomials.

The weight function is \(\exp(-x^2/2)\) and the interval of integration is \([-\infty, \infty]\). the HermiteE polynomials are orthogonal, but not normalized, with respect to this weight function.

**Parameters**

- `x`: array_like
  Values at which the weight function will be computed.

**Returns**

- `w`: ndarray
  The weight function at \(x\).

**Notes**

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**Miscellaneous**

3.24. Polynomials
numpy.polynomial.hermite_e.hermecompanion(c)

Return the scaled companion matrix of c.

The basis polynomials are scaled so that the companion matrix is symmetric when c is an HermiteE basis polynomial. This provides better eigenvalue estimates than the unscaled case and for basis polynomials the eigenvalues are guaranteed to be real if numpy.linalg.eigvalsh is used to obtain them.

Parameters
  c : array_like
    1-D array of HermiteE series coefficients ordered from low to high degree.

Returns
  mat : ndarray
    Scaled companion matrix of dimensions (deg, deg).

Notes
numpy.polynomial.hermite_e.hermedomain = array([-1, 1])
numpy.polynomial.hermite_e.hermezero = array([0])
numpy.polynomial.hermite_e.hermeone = array([1])
numpy.polynomial.hermite_e.hermex = array([0, 1])
numpy.polynomial.hermite_e.hermestrtrim(c, tol=0)

Remove “small” “trailing” coefficients from a polynomial.

“Small” means “small in absolute value” and is controlled by the parameter tol; “trailing” means highest order coefficient(s), e.g., in [0, 1, 1, 0, 0] (which represents 0 + x + x**2 + 0*x**3 + 0*x**4) both the 3-rd and 4-th order coefficients would be “trimmed.”

Parameters
  c : array_like
    1-d array of coefficients, ordered from lowest order to highest.
  tol : number, optional
    Trailing (i.e., highest order) elements with absolute value less than or equal to tol (default value is zero) are removed.

Returns
  trimmed : ndarray
    1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

Raises
  ValueError
    If tol < 0

See also:
trimseq
**Examples**

```python
>>> from numpy import polynomial as P
>>> P.trimcoef((0, 0, 3, 0, 5, 0, 0))
array([ 0., 0., 3., 0., 5.])
>>> P.trimcoef((0, 0, 1e-3, 0, 1e-5, 0, 0), 1e-3) # item == tol is trimmed
array([ 0.])
>>> i = complex(0, 1) # works for complex
>>> P.trimcoef((3e-4, 1e-3*(1-i), 5e-4, 2e-5*(1+i)), 1e-3)
array([ 0.0003+0.j, 0.0010-0.001j])
```

```
numpy.polynomial.hermite_e.hermeline(off, scl)
Hermite series whose graph is a straight line.

Parameters
----------
off, scl : scalars
    The specified line is given by off + scl*x.

Returns
-------
y : ndarray
    This module’s representation of the Hermite series for off + scl*x.

See also:
---------
polyline, chebline
```

**Examples**

```python
>>> from numpy.polynomial.hermite_e import hermeline
>>> from numpy.polynomial.hermite_e import hermeline, hermeval

>>> hermeval(0, hermeline(3, 2))
3.0
>>> hermeval(1, hermeline(3, 2))
5.0
```

```
numpy.polynomial.hermite_e.hermepoly(c)
Convert a Hermite series to a polynomial.

Convert an array representing the coefficients of a Hermite series, ordered from lowest degree to highest, to an array of the coefficients of the equivalent polynomial (relative to the “standard” basis) ordered from lowest to highest degree.

Parameters
----------
c : array_like
    1-D array containing the Hermite series coefficients, ordered from lowest order term to highest.

Returns
-------
pol : ndarray
    1-D array containing the coefficients of the equivalent polynomial (relative to the “standard” basis) ordered from lowest order term to highest.

See also:
---------
poly2herme
```

**Notes**

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.
Examples

```python
>>> from numpy.polynomial.hermite_e import herme2poly
>>> herme2poly([ 2., 10., 2., 3.])
array([ 0., 1., 2., 3.])
```

`numpy.polynomial.hermite_e.poly2herme(pol)`

Convert a polynomial to a Hermite series.

Convert an array representing the coefficients of a polynomial (relative to the “standard” basis) ordered from lowest degree to highest, to an array of the coefficients of the equivalent Hermite series, ordered from lowest to highest degree.

**Parameters**

- `pol`: array_like
  1-D array containing the polynomial coefficients

**Returns**

- `c`: ndarray
  1-D array containing the coefficients of the equivalent Hermite series.

**See also:**

`herme2poly`

**Notes**

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```python
>>> from numpy.polynomial.hermite_e import poly2herme
>>> poly2herme(np.arange(4))
array([ 2., 10., 2., 3.])
```

Poly1d

**Basics**

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<td>A one-dimensional polynomial class.</td>
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<td><code>polyval(p, x)</code></td>
<td>Evaluate a polynomial at specific values.</td>
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<td><code>poly(seq_of_zeros)</code></td>
<td>Find the coefficients of a polynomial with the given sequence of roots.</td>
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<td><code>roots(p)</code></td>
<td>Return the roots of a polynomial with coefficients given in p.</td>
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</table>

```python
class numpy.poly1d(c_or_r[, r=0, variable=None])
```

A one-dimensional polynomial class.

A convenience class, used to encapsulate “natural” operations on polynomials so that said operations may take on their customary form in code (see Examples).

**Parameters**

- `c_or_r`: array_like

  The polynomial’s coefficients, in decreasing powers, or if the value of the second parameter is True, the polynomial’s roots (values where the polynomial evaluates to 0). For example, `poly1d([1, 2, 3])` returns an object that represents \( x^2 + 2x + 3 \), whereas `poly1d([1, 2, 3], True)` returns one that represents \( (x - 1)(x - 2)(x - 3) = \)
\[ x^3 - 6x^2 + 11x - 6. \]

- **r**: bool, optional
  - If True, `c_or_r` specifies the polynomial’s roots; the default is False.

- **variable**: str, optional
  - Changes the variable used when printing \( p \) from \( x \) to `variable` (see Examples).

### Examples

Construct the polynomial \( x^2 + 2x + 3 \):

```python
>>> p = np.poly1d([1, 2, 3])
>>> print np.poly1d(p)
2
1 x + 2 x + 3
```

Evaluate the polynomial at \( x = 0.5 \):

```python
>>> p(0.5)
4.25
```

Find the roots:

```python
>>> p.r
array([-1.+1.41421356j, -1.-1.41421356j])
```

These numbers in the previous line represent \((0, 0)\) to machine precision.

Show the coefficients:

```python
>>> p.c
array([1, 2, 3])
```

Display the order (the leading zero-coefficients are removed):

```python
>>> p.order
2
```

Show the coefficient of the k-th power in the polynomial (which is equivalent to `p.c[-(i+1)]`):

```python
>>> p[1]
2
```

Polynomials can be added, subtracted, multiplied, and divided (returns quotient and remainder):

```python
>>> p * p
poly1d([ 1, 4, 10, 12, 9])
```

```python
>>> (p**3 + 4) / p
(poly1d([ 1., 4., 10., 12., 9.]), poly1d([ 4.]))
```

`asarray(p)` gives the coefficient array, so polynomials can be used in all functions that accept arrays:

```python
>>> np.square(p) # square of polynomial
poly1d([ 1, 4, 10, 12, 9])
```

```python
>>> np.square(p) # square of individual coefficients
array([1, 4, 9])
```
The variable used in the string representation of \( p \) can be modified, using the `variable` parameter:

```python
>>> p = np.poly1d([1,2,3], variable='z')
>>> print(p
2
1 z + 2 z + 3
```

Construct a polynomial from its roots:

```python
>>> np.poly1d([1, 2], True)
poly1d([ 1, -3, 2])
```

This is the same polynomial as obtained by:

```python
>>> np.poly1d([1, -1]) * np.poly1d([1, -2])
poly1d([ 1, -3, 2])
```

### Attributes

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### Methods

- `poly1d.__call__(val)`
- `poly1dderiv(m=1)` Return a derivative of this polynomial.
- `poly1d.integ(m=1, k=0)` Return an antiderivative (indefinite integral) of this polynomial.

`poly1d.__call__(val)`

`poly1d.deriv(m=1)`

Return a derivative of this polynomial.

Refer to `polyder` for full documentation.

See also:

- `polyder`
equivalent function

`poly1d.integ(m=1, k=0)`

Return an antiderivative (indefinite integral) of this polynomial.

Refer to `polyint` for full documentation.

See also:

- `polyint`
equivalent function

`numpy.polyval(p, x)`

Evaluate a polynomial at specific values.

If `p` is of length \( N \), this function returns the value:

\[
p[0]x^{N-1} + p[1]x^{N-2} + \ldots + p[N-2]x + p[N-1]
\]
If \( x \) is a sequence, then \( p(x) \) is returned for each element of \( x \). If \( x \) is another polynomial then the composite polynomial \( p(x(t)) \) is returned.

**Parameters**

- \( p \): array_like or poly1d object
  
  1D array of polynomial coefficients (including coefficients equal to zero) from highest degree to the constant term, or an instance of poly1d.

- \( x \): array_like or poly1d object
  
  A number, a 1D array of numbers, or an instance of poly1d, “at” which to evaluate \( p \).

**Returns**

- \( \text{values} \): ndarray or poly1d
  
  If \( x \) is a poly1d instance, the result is the composition of the two polynomials, i.e., \( x \) is “substituted” in \( p \) and the simplified result is returned. In addition, the type of \( x \) - array_like or poly1d - governs the type of the output: \( x \) array_like \( \Rightarrow \) \( \text{values} \) array_like, \( x \) a poly1d object \( \Rightarrow \) \( \text{values} \) is also.

**See also:**

- poly1d
  
  A polynomial class.

**Notes**

Horner’s scheme [R65] is used to evaluate the polynomial. Even so, for polynomials of high degree the values may be inaccurate due to rounding errors. Use carefully.

**References**

[R65]

**Examples**

```python
>>> np.polyval([3,0,1], 5)  # 3 * 5**2 + 0 * 5**1 + 1
76
>>> np.polyval([3,0,1], np.poly1d(5))
poly1d([ 76.])
>>> np.polyval(np.poly1d([3,0,1]), 5)
76
>>> np.polyval(np.poly1d([3,0,1]), np.poly1d(5))
poly1d([ 76.])
```

**numpy.poly** (\( \text{seq\_of\_zeros} \))

Find the coefficients of a polynomial with the given sequence of roots.

Returns the coefficients of the polynomial whose leading coefficient is one for the given sequence of zeros (multiple roots must be included in the sequence as many times as their multiplicity; see Examples). A square matrix (or array, which will be treated as a matrix) can also be given, in which case the coefficients of the characteristic polynomial of the matrix are returned.

**Parameters**

- \( \text{seq\_of\_zeros} \): array_like, shape (\( N \)) or (\( N, N \))
  
  A sequence of polynomial roots, or a square array or matrix object.

**Returns**

- \( c \): ndarray
1D array of polynomial coefficients from highest to lowest degree:
\[ c[0] \times x^N + c[1] \times x^{N-1} + \ldots + c[N-1] \times x + c[N] \]
where \( c[0] \) always equals 1.

**Raises**

**ValueError**

If input is the wrong shape (the input must be a 1-D or square 2-D array).

**See also:**

- `polyval`
  Evaluate a polynomial at a point.
- `roots`
  Return the roots of a polynomial.
- `polyfit`
  Least squares polynomial fit.
- `poly1d`
  A one-dimensional polynomial class.

**Notes**

Specifying the roots of a polynomial still leaves one degree of freedom, typically represented by an undetermined leading coefficient. [R56] In the case of this function, that coefficient - the first one in the returned array - is always taken as one. (If for some reason you have one other point, the only automatic way presently to leverage that information is to use `polyfit`.)

The characteristic polynomial, \( p_a(t) \), of an \( n \)-by-\( n \) matrix \( A \) is given by
\[
p_a(t) = \det(tI - A),
\]
where \( I \) is the \( n \)-by-\( n \) identity matrix. [R57]

**References**

[R56], [R57]

**Examples**

Given a sequence of a polynomial’s zeros:

```python
>>> np.poly((0, 0, 0)) # Multiple root example
array([1, 0, 0, 0])
```

The line above represents \( z^3 + 0*z^2 + 0*z + 0 \).

```python
>>> np.poly((-1./2, 0, 1./2))
array([ 1. , 0. , -0.25, 0. ])
```

The line above represents \( z^3 - z/4 \)

```python
>>> np.poly((np.random.random(1.)[0], 0, np.random.random(1.)[0]))
array([ 1. , -0.77086955, 0.08618131, 0. ])
```

Given a square array object:

```python
>>> P = np.array([[0, 1./3], [-1./2, 0]])
>>> np.poly(P)
array([ 1. , 0. , 0.16666667])
```
Or a square matrix object:

```python
>>> np.poly(np.matrix(P))
array([[ 1. , 0. , 0.16666667]])
```

Note how in all cases the leading coefficient is always 1.

**numpy.roots(p)**

Return the roots of a polynomial with coefficients given in p.

The values in the rank-1 array `p` are coefficients of a polynomial. If the length of `p` is n+1 then the polynomial is described by:

\[
p[0] \times x^n + p[1] \times x^{n-1} + \ldots + p[n-1] \times x + p[n]
\]

**Parameters**

- `p`: array_like
  - Rank-1 array of polynomial coefficients.

**Returns**

- `out`: ndarray
  - An array containing the complex roots of the polynomial.

**Raises**

- `ValueError`
  - When `p` cannot be converted to a rank-1 array.

**See also:**

- **poly**
  - Find the coefficients of a polynomial with a given sequence of roots.

- **polyval**
  - Evaluate a polynomial at a point.

- **polyfit**
  - Least squares polynomial fit.

- **poly1d**
  - A one-dimensional polynomial class.

**Notes**

The algorithm relies on computing the eigenvalues of the companion matrix [R243].

**References**

[R243]

**Examples**

```python
>>> coeff = [3.2, 2, 1]
>>> np.roots(coeff)
array([-0.3125+0.46351241j, -0.3125-0.46351241j])
```
Fitting

\texttt{numpy.polyfit}(x, y, deg[, rcond, full, w, cov]) Least squares polynomial fit.

**Synopsis**

Fit a polynomial \( p(x) = p[0] \times x^{\text{deg}} + \ldots + p[\text{deg}] \) of degree \( \text{deg} \) to points \((x, y)\). Returns a vector of coefficients \( p \) that minimises the squared error.

**Parameters**

- \textit{x} : array_like, shape (M,)
  - x-coordinates of the M sample points \((x[i], y[i])\).

- \textit{y} : array_like, shape (M,) or (M, K)
  - y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

- \textit{deg} : int
  - Degree of the fitting polynomial

- \textit{rcond} : float, optional
  - Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is \( \text{len}(x) \times \text{eps} \), where \( \text{eps} \) is the relative precision of the float type, about 2e-16 in most cases.

- \textit{full} : bool, optional
  - Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

- \textit{w} : array_like, shape (M,), optional
  - Weights to apply to the y-coordinates of the sample points.

- \textit{cov} : bool, optional
  - Return the estimate and the covariance matrix of the estimate. If full is True, then cov is not returned.

**Returns**

- \textit{p} : ndarray, shape (M,) or (M, K)
  - Polynomial coefficients, highest power first. If \( y \) was 2-D, the coefficients for \( k \)-th data set are in \( p[:,k] \).

- \text{residuals}, \text{rank}, \text{singular_values}, \text{rcond} :
  - Present only if \textit{full} = True. Residuals of the least-squares fit, the effective rank of the scaled Vandermonde coefficient matrix, its singular values, and the specified value of \textit{rcond}. For more details, see \texttt{lin alg}.\texttt{lstsq}.

- \textit{V} : ndarray, shape (M,M) or (M,M,K)
Present only if `full = False and cov' = True. The covariance matrix of the polynomial coefficient estimates. The diagonal of this matrix are the variance estimates for each coefficient. If `y` is a 2-D array, then the covariance matrix for the `k`-th data set are in `V[:,:,k]`.

Warns

**RankWarning**

The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if `full = False`.

The warnings can be turned off by

```python
>>> import warnings
>>> warnings.simplefilter('ignore', np.RankWarning)
```

See also:

- **polyval**
  - Computes polynomial values.

- **linalg.lstsq**
  - Computes a least-squares fit.

- **scipy.interpolate.UnivariateSpline**
  - Computes spline fits.

Notes

The solution minimizes the squared error

$$E = \sum_{j=0}^{k} |p(x_j) - y_j|^2$$

in the equations:

$$x[0]^{*n} * p[0] + \ldots + x[0] * p[n-1] + p[n] = y[0]$$
$$\ldots$$
$$x[k]^{*n} * p[0] + \ldots + x[k] * p[n-1] + p[n] = y[k]$$

The coefficient matrix of the coefficients `p` is a Vandermonde matrix.

**polyfit** issues a **RankWarning** when the least-squares fit is badly conditioned. This implies that the best fit is not well-defined due to numerical error. The results may be improved by lowering the polynomial degree or by replacing `x` by `x - x.mean()`. The `rcond` parameter can also be set to a value smaller than its default, but the resulting fit may be spurious: including contributions from the small singular values can add numerical noise to the result.

Note that fitting polynomial coefficients is inherently badly conditioned when the degree of the polynomial is large or the interval of sample points is badly centered. The quality of the fit should always be checked in these cases. When polynomial fits are not satisfactory, splines may be a good alternative.

References

[R58], [R59]
Examples

```python
>>> x = np.array([0.0, 1.0, 2.0, 3.0, 4.0, 5.0])
>>> y = np.array([0.0, 0.8, 0.9, 0.1, -0.8, -1.0])
>>> z = np.polyfit(x, y, 3)
>>> z
array([ 0.08703704, -0.81349206, 1.69312169, -0.03968254])
```

It is convenient to use `poly1d` objects for dealing with polynomials:

```python
>>> p = np.poly1d(z)
>>> p(0.5)
0.6143849206349179
>>> p(3.5)
-0.34732142857143039
>>> p(10)
22.579365079365115
```

High-order polynomials may oscillate wildly:

```python
>>> p30 = np.poly1d(np.polyfit(x, y, 30))
/... RankWarning: Polyfit may be poorly conditioned...
>>> p30(4)
-0.80000000000000204
>>> p30(5)
-0.99999999999999445
>>> p30(4.5)
-0.10547061179440398
```

Illustration:

```python
>>> import matplotlib.pyplot as plt
>>> xp = np.linspace(-2, 6, 100)
>>> _ = plt.plot(x, y, '.', xp, p(xp), '-', xp, p30(xp), '--')
>>> plt.ylim(-2,2)
(-2, 2)
>>> plt.show()
```

Calculus
numpy.polyder ($p, m=1$)
Return the derivative of the specified order of a polynomial.

**Parameters**
- $p$: poly1d or sequence
  Polynomial to differentiate. A sequence is interpreted as polynomial coefficients, see poly1d.
- $m$: int, optional
  Order of differentiation (default: 1)

**Returns**
- $der$: poly1d
  A new polynomial representing the derivative.

**See also:**
- polyint
  Anti-derivative of a polynomial.
- poly1d
  Class for one-dimensional polynomials.

**Examples**
The derivative of the polynomial $x^3 + x^2 + x^1 + 1$ is:

```python
>>> p = np.poly1d([1,1,1,1])
>>> p2 = np.polyder(p)
>>> p2
poly1d([3, 2, 1])
```
which evaluates to:

```python
>>> p2(2.)
17.0
```
We can verify this, approximating the derivative with $(f(x + h) - f(x))/h$:

```python
>>> (p(2. + 0.001) - p(2.)) / 0.001
17.007000999997857
```
The fourth-order derivative of a 3rd-order polynomial is zero:

```python
>>> np.polyder(p, 2)
poly1d([6, 2])
>>> np.polyder(p, 3)
poly1d([6])
>>> np.polyder(p, 4)
poly1d([0.])
```

numpy.polyint ($p, m=1, k=None$)
Return an antiderivative (indefinite integral) of a polynomial.
The returned order $m$ antiderivative $P$ of polynomial $p$ satisfies $\frac{d^m}{dx^m} P(x) = p(x)$ and is defined up to $m - 1$ integration constants $k$. The constants determine the low-order polynomial part

$$k_{m-1} x^0 + \ldots + \frac{k_0}{(m-1)!} x^{m-1}$$

of $P$ so that $P^{(j)}(0) = k_{m-j-1}$.

**Parameters**

- **p**: {array_like, poly1d}
  Polynomial to differentiate. A sequence is interpreted as polynomial coefficients, see `poly1d`.

- **m**: int, optional
  Order of the antiderivative. (Default: 1)

- **k**: {None, list of $m$ scalars, scalar}, optional
  Integration constants. They are given in the order of integration: those corresponding to highest-order terms come first.
  
  If None (default), all constants are assumed to be zero. If $m = 1$, a single scalar can be given instead of a list.

**See also:**

- `polyder`
  derivative of a polynomial

- `poly1d.integ`
  equivalent method

**Examples**

The defining property of the antiderivative:

```python
>>> p = np.poly1d([1,1,1])
>>> P = np.polyint(p)
>>> P
poly1d([ 0.33333333, 0.5 , 1. , 0. ])
>>> np.polyder(P) == p
True
```

The integration constants default to zero, but can be specified:

```python
>>> P = np.polyint(p, 3)
>>> P(0)
0.0
>>> np.polyder(P)(0)
0.0
>>> np.polyder(P, 2)(0)
0.0
>>> P = np.polyint(p, 3, k=[6,5,3])
>>> P
poly1d([ 0.01666667, 0.04166667, 0.16666667, 3. , 5. , 3. ])
```

Note that $3 = 6 / 2!$, and that the constants are given in the order of integrations. Constant of the highest-order polynomial term comes first:
```python
>>> np.polyder(P, 2)(0)
6.0
>>> np.polyder(P, 1)(0)
5.0
>>> P(0)
3.0
```

### Arithmetic

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**numpy.polyadd(a1, a2)**

Find the sum of two polynomials.

Returns the polynomial resulting from the sum of two input polynomials. Each input must be either a `poly1d` object or a 1D sequence of polynomial coefficients, from highest to lowest degree.

**Parameters**

- `a1, a2`: array_like or `poly1d` object
  - Input polynomials.

**Returns**

- `out`: ndarray or `poly1d` object
  - The sum of the inputs. If either input is a `poly1d` object, then the output is also a `poly1d` object. Otherwise, it is a 1D array of polynomial coefficients from highest to lowest degree.

**See also:**

- `poly1d`  
  - A one-dimensional polynomial class.

**Examples**

```python
>>> np.polyadd([1, 2], [9, 5, 4])
array([9, 6, 6])
```

Using `poly1d` objects:

```python
>>> p1 = np.poly1d([1, 2])
>>> p2 = np.poly1d([9, 5, 4])
>>> print p1
1 x + 2
>>> print p2
2
9 x + 5 x + 4
>>> print np.polyadd(p1, p2)
2
9 x + 6 x + 6
```
numpy.polydiv(u, v)
Returns the quotient and remainder of polynomial division.

The input arrays are the coefficients (including any coefficients equal to zero) of the “numerator” (dividend) and “denominator” (divisor) polynomials, respectively.

Parameters
u : array_like or poly1d
Dividend polynomial’s coefficients.
v : array_like or poly1d
Divisor polynomial’s coefficients.

Returns
q : ndarray
Coefficients, including those equal to zero, of the quotient.
r : ndarray
Coefficients, including those equal to zero, of the remainder.

See also:
poly, polyadd, polyder, polydiv, polyfit, polyint, polymul, polysub, polyval

Notes
Both u and v must be 0-d or 1-d (ndim = 0 or 1), but u.ndim need not equal v.ndim. In other words, all four possible combinations - u.ndim = v.ndim = 0, u.ndim = v.ndim = 1, u.ndim = 0, and v.ndim = 0, v.ndim = 1 - work.

Examples
\[
\frac{3x^2 + 5x + 2}{2x + 1} = 1.5x + 1.75, \text{remainder 0.25}
\]

>>> x = np.array([3.0, 5.0, 2.0])
>>> y = np.array([2.0, 1.0])
>>> np.polydiv(x, y)
(array([ 1.5 , 1.75]), array([ 0.25]))

numpy.polymul(a1, a2)
Find the product of two polynomials.

Finds the polynomial resulting from the multiplication of the two input polynomials. Each input must be either a poly1d object or a 1D sequence of polynomial coefficients, from highest to lowest degree.

Parameters
a1, a2 : array_like or poly1d object
Input polynomials.

Returns
out : ndarray or poly1d object
The polynomial resulting from the multiplication of the inputs. If either inputs is a poly1d object, then the output is also a poly1d object. Otherwise, it is a 1D array of polynomial coefficients from highest to lowest degree.

See also:
**poly1d**

A one-dimensional polynomial class.

**poly, polyadd, polyder, polydiv, polyfit, polyint, polysub, polyval**

**convolve**

Array convolution. Same output as polymul, but has parameter for overlap mode.

**Examples**

```python
>>> np.polymul([1, 2, 3], [9, 5, 1])
array([ 9, 23, 38, 17, 3])
```

Using `poly1d` objects:

```python
>>> p1 = np.poly1d([1, 2, 3])
>>> p2 = np.poly1d([9, 5, 1])
>>> print p1
 2
1 x + 2 x + 3
>>> print p2
 2
9 x + 5 x + 1
>>> print np.polymul(p1, p2)
 4 3 2
9 x + 23 x + 38 x + 17 x + 3
```

**numpy.polysub(a1, a2)**

Difference (subtraction) of two polynomials.

Given two polynomials `a1` and `a2`, returns `a1 - a2`. `a1` and `a2` can be either array_like sequences of the polynomials’ coefficients (including coefficients equal to zero), or `poly1d` objects.

**Parameters**

- `a1, a2` : array_like or poly1d
  Minuend and subtrahend polynomials, respectively.

**Returns**

- `out` : ndarray or poly1d
  Array or `poly1d` object of the difference polynomial’s coefficients.

**See also:**

- `polyval`, `polydiv`, `polymul`, `polyadd`

**Examples**

```
(2x^2 + 10x - 2) - (3x^2 + 10x - 4) = (-x^2 + 2)
```

```python
>>> np.polysub([2, 10, -2], [3, 10, -4])
array([-1,  0,  2])
```

**Warnings**

- `RankWarning` Issued by `polyfit` when the Vandermonde matrix is rank deficient.
exception numpy.RankWarning
   Issued by polyfit when the Vandermonde matrix is rank deficient.

   For more information, a way to suppress the warning, and an example of RankWarning being issued, see polyfit.

3.25 Random sampling (numpy.random)

3.25.1 Simple random data

numpy.random.rand(d0, d1, ..., dn)
   Random values in a given shape.

Create an array of the given shape and propagate it with random samples from a uniform distribution over [0, 1).

Parameters
   d0, d1, ..., dn : int, optional
      The dimensions of the returned array, should all be positive. If no argument is given a single Python float is returned.

Returns
   out : ndarray, shape (d0, d1, ..., dn)
      Random values.

See also:
   random

Notes
   This is a convenience function. If you want an interface that takes a shape-tuple as the first argument, refer to np.random.random_sample.

Examples

>>> np.random.rand(3,2)
array([[ 0.14022471, 0.96360618],
       [ 0.37601032, 0.25528411],
       [ 0.49313049, 0.94909878]]) #random

numpy.random.randn(d0, d1, ..., dn)
   Return a sample (or samples) from the “standard normal” distribution.
If positive, int_like or int-convertible arguments are provided, `randn` generates an array of shape \((d_0, d_1, \ldots, d_n)\), filled with random floats sampled from a univariate “normal” (Gaussian) distribution of mean 0 and variance 1 (if any of the \(d_i\) are floats, they are first converted to integers by truncation). A single float randomly sampled from the distribution is returned if no argument is provided.

This is a convenience function. If you want an interface that takes a tuple as the first argument, use `numpy.random.standard_normal` instead.

**Parameters**

\(d_0, d_1, \ldots, d_n\) : int, optional

The dimensions of the returned array, should be all positive. If no argument is given a single Python float is returned.

**Returns**

\(Z\) : ndarray or float

A \((d_0, d_1, \ldots, d_n)\)-shaped array of floating-point samples from the standard normal distribution, or a single such float if no parameters were supplied.

**See also:**

`random.standard_normal`

Similar, but takes a tuple as its argument.

**Notes**

For random samples from \(N(\mu, \sigma^2)\), use:

\[
\sigma \ast \text{np.random.randn}(\ldots) + \mu
\]

**Examples**

```python
>>> np.random.randn()
2.1923875335537315  #random
```

Two-by-four array of samples from N(3, 6.25):

```python
>>> 2.5 * np.random.randn(2, 4) + 3
array([[[-4.49401501, 4.00950034, -1.81814867, 7.29718677],
        [0.39924804, 4.68456316, 4.99394529, 4.84057254]])  #random
```

**numpy.random.randint** *(low, high=None, size=None)*

Return random integers from \(low\) (inclusive) to \(high\) (exclusive).

Return random integers from the “discrete uniform” distribution in the “half-open” interval \([low, high)\). If \(high\) is None (the default), then results are from \([0, low)\).

**Parameters**

\(low\) : int

Lowest (signed) integer to be drawn from the distribution (unless \(high=\text{None}\), in which case this parameter is the highest such integer).

\(high\) : int, optional

If provided, one above the largest (signed) integer to be drawn from the distribution (see above for behavior if \(high=\text{None}\)).

\(size\) : int or tuple of ints, optional

Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \ast n \ast k\) samples are drawn. Default is None, in which case a single value is returned.
Returns

out : int or ndarray of ints

size-shaped array of random integers from the appropriate distribution, or a single such random int if size not provided.

See also:

random.random_integers

similar to randint, only for the closed interval [low, high], and 1 is the lowest value if high is omitted. In particular, this other one is the one to use to generate uniformly distributed discrete non-integers.

Examples

>>> np.random.randint(2, size=10)
array([1, 0, 0, 0, 1, 1, 0, 0, 1, 0])

>>> np.random.randint(1, size=10)
array([0, 0, 0, 0, 0, 0, 0, 0, 0, 0])

Generate a 2 x 4 array of ints between 0 and 4, inclusive:

>>> np.random.randint(5, size=(2, 4))
array([[4, 0, 2, 1],
       [3, 2, 2, 0]])

numpy.random.random_integers(low, high=None, size=None)

Return random integers between low and high, inclusive.

Parameters

low : int

Lowest (signed) integer to be drawn from the distribution (unless high=None, in which case this parameter is the highest such integer).

high : int, optional

If provided, the largest (signed) integer to be drawn from the distribution (see above for behavior if high=None).

size : int or tuple of ints, optional

Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

Returns

out : int or ndarray of ints

size-shaped array of random integers from the appropriate distribution, or a single such random int if size not provided.

See also:

random.randint

Similar to random_integers, only for the half-open interval [low, high), and 0 is the lowest value if high is omitted.
Notes

To sample from N evenly spaced floating-point numbers between a and b, use:

\[ a + (b - a) \times (\text{np.random.random_integers}(N) - 1) / (N - 1.) \]

Examples

```python
>>> np.random.random_integers(5)
4
>>> type(np.random.random_integers(5))
<type 'int'>
>>> np.random.random_integers(5, size=(3,2.))
array([[5, 4],
       [3, 3],
       [4, 5]])
```

Choose five random numbers from the set of five evenly-spaced numbers between 0 and 2.5, inclusive (i.e., from the set 0, 5/8, 10/8, 15/8, 20/8):

```python
>>> 2.5 * (np.random.random_integers(5, size=(5,)) - 1) / 4.
array([ 0.625, 1.25 , 0.625, 0.625, 2.5 ])
```

Roll two six sided dice 1000 times and sum the results:

```python
>>> d1 = np.random.random_integers(1, 6, 1000)
>>> d2 = np.random.random_integers(1, 6, 1000)
>>> dsums = d1 + d2
```

Display results as a histogram:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(dsums, 11, normed=True)
>>> plt.show()
```

```
```

### numpy.random.random_sample (size=None)

Return random floats in the half-open interval [0.0, 1.0).

Results are from the “continuous uniform” distribution over the stated interval. To sample \( \text{Unif}[a,b], b > a \) multiply the output of `random_sample` by \((b-a)\) and add \(a\):
(b - a) * random_sample() + a

**Parameters**

- **size**: int or tuple of ints, optional

  Output shape. If the given shape is, e.g., (m, n, k), then \( m \times n \times k \) samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- **out**: float or ndarray of floats

  Array of random floats of shape size (unless size=None, in which case a single float is returned).

**Examples**

```python
>>> np.random.random_sample()
0.47108547995356098
```

```python
type(np.random.random_sample())
<type 'float'>
```

```python
>>> np.random.random_sample((5,))
array([ 0.30220482, 0.86820401, 0.1654503 , 0.11659149, 0.54323428])
```

Three-by-two array of random numbers from [-5, 0):

```python
>>> 5 * np.random.random_sample((3, 2)) - 5
array([[-3.99149989, -0.52338984],
       [-2.99091858, -0.79479508],
       [-1.23204345, -1.75224494]])
```

`numpy.random.random(size=None)`

Return random floats in the half-open interval \([0.0, 1.0)\).

Results are from the “continuous uniform” distribution over the stated interval. To sample \( Unif[a, b) \), \( b > a \) multiply the output of `random_sample` by \((b-a)\) and add \(a\):

\[
(b - a) \times \text{random_sample()} + a
\]

**Parameters**

- **size**: int or tuple of ints, optional

  Output shape. If the given shape is, e.g., (m, n, k), then \( m \times n \times k \) samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- **out**: float or ndarray of floats

  Array of random floats of shape size (unless size=None, in which case a single float is returned).

**Examples**

```python
>>> np.random.random_sample()
0.47108547995356098
```

```python
type(np.random.random_sample())
<type 'float'>
```

```python
>>> np.random.random_sample((5,))
array([ 0.30220482, 0.86820401, 0.1654503 , 0.11659149, 0.54323428])
```
Three-by-two array of random numbers from [-5, 0):

```
>>> 5 * np.random.random_sample((3, 2)) - 5
array([[-3.99149989, -0.52338984],
       [-2.99091858, -0.79479508],
       [-1.23204345, -1.75224494]])
```

```
numpy.random.ranf(size=None)
Return random floats in the half-open interval [0.0, 1.0).
Results are from the “continuous uniform” distribution over the stated interval. To sample \( U[nf[a, b], b > a \) multiply the output of random_sample by \( (b-a) \) and add \( a \):

\[
(b - a) \times \text{random_sample()} + a
\]

Parameters

- **size**: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \( (m, n, k) \), then \( m \times n \times k \) samples are drawn. Default is None, in which case a single value is returned.

Returns

- **out**: float or ndarray of floats
  - Array of random floats of shape size (unless size=None, in which case a single float is returned).

```
Examples
```
```
>>> np.random.random_sample()
0.47108547995356098
>>> type(np.random.random_sample())
<type 'float'>
>>> np.random.random_sample((5,))
array([ 0.30220482, 0.86820401, 0.1654503 , 0.11659149, 0.54323428])
```

Three-by-two array of random numbers from [-5, 0):

```
>>> 5 * np.random.random_sample((3, 2)) - 5
array([[-3.99149989, -0.52338984],
       [-2.99091858, -0.79479508],
       [-1.23204345, -1.75224494]])
```

```
numpy.random.sample(size=None)
Return random floats in the half-open interval [0.0, 1.0).
Results are from the “continuous uniform” distribution over the stated interval. To sample \( U[nf[a, b], b > a \) multiply the output of random_sample by \( (b-a) \) and add \( a \):

\[
(b - a) \times \text{random_sample()} + a
\]

Parameters

- **size**: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \( (m, n, k) \), then \( m \times n \times k \) samples are drawn. Default is None, in which case a single value is returned.

Returns

- **out**: float or ndarray of floats
  - Array of random floats of shape size (unless size=None, in which case a single float is returned).
Array of random floats of shape size (unless size=None, in which case a single float is returned).

Examples

```python
>>> np.random.random_sample()
0.47108547995356098
>>> type(np.random.random_sample())
type ‘float’
>>> np.random.random_sample((5,))
array([ 0.30220482, 0.86820401, 0.1654503 , 0.11659149, 0.54323428])
```

Three-by-two array of random numbers from [-5, 0):

```python
>>> 5 * np.random.random_sample((3, 2)) - 5
array([[-3.99149989, -0.52338984],
       [-2.99091858, -0.79479508],
       [-1.23204345, -1.75224494]])
```

numpy.random.choice(a, size=None, replace=True, p=None)
Generates a random sample from a given 1-D array

New in version 1.7.0.

Parameters

- **a**: 1-D array-like or int
  - If an ndarray, a random sample is generated from its elements. If an int, the random sample is generated as if a was np.arange(n)
- **size**: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.
- **replace**: boolean, optional
  - Whether the sample is with or without replacement
- **p**: 1-D array-like, optional
  - The probabilities associated with each entry in a. If not given the sample assumes a uniform distribution over all entries in a.

Returns

- **samples**: 1-D ndarray, shape (size,)
  - The generated random samples

Raises

- **ValueError**
  - If a is an int and less than zero, if a or p are not 1-dimensional, if a is an array-like of size 0, if p is not a vector of probabilities, if a and p have different lengths, or if replace=False and the sample size is greater than the population size

See also:

- randint, shuffle, permutation
Examples

Generate a uniform random sample from np.arange(5) of size 3:

```python
generate = np.random.choice(5, 3)
array([0, 3, 4])
# This is equivalent to np.random.randint(0,5,3)
```

Generate a non-uniform random sample from np.arange(5) of size 3:

```python
generate = np.random.choice(5, 3, p=[0.1, 0.3, 0.6, 0])
array([3, 3, 0])
```  

Generate a uniform random sample from np.arange(5) of size 3 without replacement:

```python
generate = np.random.choice(5, 3, replace=False)
array([3, 1, 0])
# This is equivalent to np.random.permutation(np.arange(5))[:3]
```

Generate a non-uniform random sample from np.arange(5) of size 3 without replacement:

```python
generate = np.random.choice(5, 3, replace=False, p=[0.1, 0.3, 0.6, 0])
array([2, 3, 0])
```

Any of the above can be repeated with an arbitrary array-like instead of just integers. For instance:

```python
aa_milne_arr = ['pooh', 'rabbit', 'piglet', 'Christopher']
gen = np.random.choice(aa_milne_arr, 5, p=[0.5, 0.1, 0.1, 0.3])
array(['pooh', 'pooh', 'pooh', 'Christopher', 'piglet'])
dtype='|S11')
```

```
3.25.2 Permutations

numpy.random.shuffle(x)  Modify a sequence in-place by shuffling its contents.

Parameters

x : array_like
```

```
3.25. Random sampling (numpy.random) 1161
```
The array or list to be shuffled.

Returns
None

Examples
>>> arr = np.arange(10)
>>> np.random.shuffle(arr)
>>> arr
[1 7 5 2 9 4 3 6 0 8]

This function only shuffles the array along the first index of a multi-dimensional array:

>>> arr = np.arange(9).reshape((3, 3))
>>> np.random.shuffle(arr)
>>> arr
array([[3, 4, 5],
       [6, 7, 8],
       [0, 1, 2]])

numpy.random.permutation(x)
Randomly permute a sequence, or return a permuted range.

If x is a multi-dimensional array, it is only shuffled along its first index.

Parameters
x : int or array_like
    If x is an integer, randomly permute np.arange(x). If x is an array, make a copy and shuffle the elements randomly.

Returns
out : ndarray
    Permuted sequence or array range.

Examples
>>> np.random.permutation(10)
array([1, 7, 4, 3, 0, 9, 2, 5, 8, 6])

>>> np.random.permutation([1, 4, 9, 12, 15])
array([15, 1, 9, 4, 12])

>>> arr = np.arange(9).reshape((3, 3))
>>> np.random.permutation(arr)
array([[6, 7, 8],
       [0, 1, 2],
       [3, 4, 5]])

3.25.3 Distributions

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<th>Description</th>
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<tr>
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<td>Draw samples from a binomial distribution.</td>
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<td>Draw samples from a chi-square distribution.</td>
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<table>
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<th>Function</th>
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<td>Draw samples from a F distribution.</td>
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<td><code>gamma(shape[, scale, size])</code></td>
<td>Draw samples from a Gamma distribution.</td>
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<td><code>geometric(p[, size])</code></td>
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</tr>
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<td><code>gumbel([loc, scale, size])</code></td>
<td>Gumbel distribution.</td>
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</tr>
<tr>
<td><code>logseries(p[, size])</code></td>
<td>Draw samples from a Logarithmic Series distribution.</td>
</tr>
<tr>
<td><code>multinomial(n, pvals[, size])</code></td>
<td>Draw samples from a multinomial distribution.</td>
</tr>
<tr>
<td><code>multivariate_normal(mean, cov[, size])</code></td>
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<tr>
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<tr>
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<tr>
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<td>Draw samples from the noncentral F distribution.</td>
</tr>
<tr>
<td><code>normal([loc, scale, size])</code></td>
<td>Draw samples from a normal (Gaussian) distribution.</td>
</tr>
<tr>
<td><code>pareto(a[, size])</code></td>
<td>Draw samples from a Pareto II or Lomax distribution with specified shape.</td>
</tr>
<tr>
<td><code>poisson([lam, size])</code></td>
<td>Draw samples from a Poisson distribution.</td>
</tr>
<tr>
<td><code>power(a[, size])</code></td>
<td>Draw samples in [0, 1] from a power distribution with positive exponent a - 1.</td>
</tr>
<tr>
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<td>Draw samples from a Rayleigh distribution.</td>
</tr>
<tr>
<td><code>standard_cauchy([size])</code></td>
<td>Standard Cauchy distribution with mode = 0.</td>
</tr>
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<td>Draw samples from the standard exponential distribution.</td>
</tr>
<tr>
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</tr>
<tr>
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<td>Returns samples from a Standard Normal distribution (mean=0, stdev=1).</td>
</tr>
<tr>
<td><code>triangular(left, mode, right[, size])</code></td>
<td>Standard Student’s t distribution with df degrees of freedom.</td>
</tr>
<tr>
<td><code>uniform(low, high, size)</code></td>
<td>Draw samples from a uniform distribution.</td>
</tr>
<tr>
<td><code>vonmises(mu, kappa[, size])</code></td>
<td>Draw samples from a von Mises distribution.</td>
</tr>
<tr>
<td><code>wald(mean, scale[, size])</code></td>
<td>Draw samples from a Wald, or Inverse Gaussian, distribution. Weibull distribution.</td>
</tr>
<tr>
<td><code>zipf(a[, size])</code></td>
<td>Draw samples from a Zipf distribution.</td>
</tr>
</tbody>
</table>

```
import numpy as np

np.random.beta(a, b, size=None)
```

The Beta distribution over [0, 1].

The Beta distribution is a special case of the Dirichlet distribution, and is related to the Gamma distribution. It has the probability distribution function

\[
f(x; a, b) = \frac{1}{B(a, b)} x^{a-1} (1 - x)^{b-1},
\]

where the normalisation, B, is the beta function,

\[
B(a, b) = \int_0^1 t^{a-1} (1 - t)^{b-1} dt.
\]

It is often seen in Bayesian inference and order statistics.

**Parameters**

- `a` : float
  Alpha, non-negative.

- `b` : float
  Beta, non-negative.

- `size` : int or tuple of ints, optional
Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

Returns

\textbf{out} : ndaray

Array of the given shape, containing values drawn from a Beta distribution.

\texttt{numpy.random.binomial}(n, p, size=None)

Draw samples from a binomial distribution.

Samples are drawn from a Binomial distribution with specified parameters, \(n\) trials and \(p\) probability of success where \(n\) an integer \(\geq 0\) and \(p\) is in the interval \([0,1]\). (\(n\) may be input as a float, but it is truncated to an integer in use)

Parameters

\(n\) : float (but truncated to an integer)

parameter, \(\geq 0\).

\(p\) : float

parameter, \(\geq 0\) and \(\leq 1\).

\texttt{size} : int or tuple of ints, optional

Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

Returns

\texttt{samples} : {ndarray, scalar}

where the values are all integers in \([0, n]\).

See also:

\texttt{scipy.stats.distributions.binom}

probability density function, distribution or cumulative density function, etc.

Notes

The probability density for the Binomial distribution is

\[
P(N) = \binom{n}{N} p^N (1 - p)^{n-N},
\]

where \(n\) is the number of trials, \(p\) is the probability of success, and \(N\) is the number of successes.

When estimating the standard error of a proportion in a population by using a random sample, the normal distribution works well unless the product \(p^*n \leq 5\), where \(p^*\) = population proportion estimate, and \(n\) = number of samples, in which case the binomial distribution is used instead. For example, a sample of 15 people shows 4 who are left handed, and 11 who are right handed. Then \(p = 4/15 = 27\%\). \(0.27^*15 = 4\), so the binomial distribution should be used in this case.

References

[R184], [R185], [R186], [R187], [R188]

Examples

Draw samples from the distribution:
A real world example. A company drills 9 wild-cat oil exploration wells, each with an estimated probability of success of 0.1. All nine wells fail. What is the probability of that happening?

Let’s do 20,000 trials of the model, and count the number that generate zero positive results.

```python
>>> sum(np.random.binomial(9,0.1,20000)==0)/20000.
answer = 0.38885, or 38%.
```

`numpy.random.chisquare(df, size=None)`

Draw samples from a chi-square distribution.

When `df` independent random variables, each with standard normal distributions (mean 0, variance 1), are squared and summed, the resulting distribution is chi-square (see Notes). This distribution is often used in hypothesis testing.

**Parameters**
- `df`: int
  Number of degrees of freedom.
- `size`: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

**Returns**
- `output`: ndarray
  Samples drawn from the distribution, packed in a `size`-shaped array.

**Raises**
- `ValueError`
  When `df` <= 0 or when an inappropriate `size` (e.g., `size=-1`) is given.

**Notes**

The variable obtained by summing the squares of `df` independent, standard normally distributed random variables:

\[ Q = \sum_{i=0}^{df} X_i^2 \]

is chi-square distributed, denoted

\[ Q \sim \chi^2_k. \]

The probability density function of the chi-squared distribution is

\[ p(x) = \frac{(1/2)^{k/2}}{\Gamma(k/2)} x^{k/2-1} e^{-x/2}, \]

where \( \Gamma \) is the gamma function,

\[ \Gamma(x) = \int_{0}^{-\infty} t^{x-1} e^{-t} dt. \]
References

NIST/SEMATECH e-Handbook of Statistical Methods

Examples

```python
>>> np.random.chisquare(2,4)
array([ 1.89920014,  9.00867716,  3.13710533,  5.62318272])
```

```python
numpy.random.dirichlet(alpha, size=None)

Draw samples from the Dirichlet distribution.

Draw size samples of dimension k from a Dirichlet distribution. A Dirichlet-distributed random variable can be seen as a multivariate generalization of the Beta distribution. Dirichlet pdf is the conjugate prior of a multinomial in Bayesian inference.

Parameters

- `alpha` : array
  Parameter of the distribution (k dimension for sample of dimension k).
- `size` : array
  Number of samples to draw.

Returns

- `samples` : ndarray,
  The drawn samples, of shape (alpha.ndim, size).

Notes

\[ X \approx \prod_{i=1}^{k} x_i^{\alpha_i - 1} \]

Uses the following property for computation: for each dimension, draw a random sample y_i from a standard gamma generator of shape `alpha_i`, then \[ X = \frac{1}{\sum_{i=1}^{k} y_i} (y_1, \ldots, y_n) \] is Dirichlet distributed.

References

[R189], [R190]

Examples

Taking an example cited in Wikipedia, this distribution can be used if one wanted to cut strings (each of initial length 1.0) into K pieces with different lengths, where each piece had, on average, a designated average length, but allowing some variation in the relative sizes of the pieces.

```python
>>> s = np.random.dirichlet((10, 5, 3), 20).transpose()

>>> plt.barh(range(20), s[0])
>>> plt.barh(range(20), s[1], left=s[0], color='g')
>>> plt.barh(range(20), s[2], left=s[0]+s[1], color='r')
>>> plt.title("Lengths of Strings")
```

```python
numpy.random.exponential(scale=1.0, size=None)

Exponential distribution.

Its probability density function is

\[ f(x; \frac{1}{\beta}) = \frac{1}{\beta} \exp(-\frac{x}{\beta}), \]
for \( x > 0 \) and 0 elsewhere. \( \beta \) is the scale parameter, which is the inverse of the rate parameter \( \lambda = 1/\beta \). The rate parameter is an alternative, widely used parameterization of the exponential distribution [R193].

The exponential distribution is a continuous analogue of the geometric distribution. It describes many common situations, such as the size of raindrops measured over many rainstorms [R191], or the time between page requests to Wikipedia [R192].

**Parameters**

- `scale`: float
  - The scale parameter, \( \beta = 1/\lambda \).

- `size`: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

**References**

[R191], [R192], [R193]

numpy.random.f(dfnum, dfden, size=None)

Draw samples from a F distribution.

Samples are drawn from an F distribution with specified parameters, \( dfnum \) (degrees of freedom in numerator) and \( dfden \) (degrees of freedom in denominator), where both parameters should be greater than zero.

The random variate of the F distribution (also known as the Fisher distribution) is a continuous probability distribution that arises in ANOVA tests, and is the ratio of two chi-square variates.

**Parameters**

- `dfnum`: float
  - Degrees of freedom in numerator. Should be greater than zero.

- `dfden`: float
  - Degrees of freedom in denominator. Should be greater than zero.

- `size`: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- `samples`: {ndarray, scalar}
  - Samples from the Fisher distribution.

See also:

scipy.stats.distributions.f

probability density function, distribution or cumulative density function, etc.

**Notes**

The F statistic is used to compare in-group variances to between-group variances. Calculating the distribution depends on the sampling, and so it is a function of the respective degrees of freedom in the problem. The variable \( dfnum \) is the number of samples minus one, the between-groups degrees of freedom, while \( dfden \) is the within-groups degrees of freedom, the sum of the number of samples in each group minus the number of groups.

**References**

[R194], [R195]
Examples

An example from Glantz[1], pp 47-40. Two groups, children of diabetics (25 people) and children from people without diabetes (25 controls). Fasting blood glucose was measured, case group had a mean value of 86.1, controls had a mean value of 82.2. Standard deviations were 2.09 and 2.49 respectively. Are these data consistent with the null hypothesis that the parents diabetic status does not affect their children’s blood glucose levels? Calculating the F statistic from the data gives a value of 36.01.

Draw samples from the distribution:

```python
>>> dfnum = 1. # between group degrees of freedom
>>> dfden = 48. # within groups degrees of freedom
>>> s = np.random.f(dfnum, dfden, 1000)
```

The lower bound for the top 1% of the samples is:

```python
>>> sort(s)[-10]
7.61988120985
```

So there is about a 1% chance that the F statistic will exceed 7.62, the measured value is 36, so the null hypothesis is rejected at the 1% level.

```
numpy.random.gamma(shape, scale=1.0, size=None)
```

draw samples from a Gamma distribution.

Samples are drawn from a Gamma distribution with specified parameters, shape (sometimes designated “k”) and scale (sometimes designated “theta”), where both parameters are > 0.

**Parameters**

- `shape`: scalar > 0
  The shape of the gamma distribution.

- `scale`: scalar > 0, optional
  The scale of the gamma distribution. Default is equal to 1.

- `size`: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- `out`: ndarray, float
  Returns one sample unless size parameter is specified.

**See also:**

`scipy.stats.distributions.gamma`

probability density function, distribution or cumulative density function, etc.

**Notes**

The probability density for the Gamma distribution is

\[ p(x) = x^{k-1} \frac{e^{-x/\theta}}{\theta^k \Gamma(k)}, \]

where \( k \) is the shape and \( \theta \) the scale, and \( \Gamma \) is the Gamma function.

The Gamma distribution is often used to model the times to failure of electronic components, and arises naturally in processes for which the waiting times between Poisson distributed events are relevant.
References

[R196], [R197]

Examples

Draw samples from the distribution:

```python
>>> shape, scale = 2., 2. # mean and dispersion
>>> s = np.random.gamma(shape, scale, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps

>>> count, bins, ignored = plt.hist(s, 50, normed=True)
>>> y = bins**(shape-1)*(np.exp(-bins/scale) /
...                  (sps.gamma(shape)*scale**shape))
>>> plt.plot(bins, y, linewidth=2, color='r')
>>> plt.show()
```

```
NumPy Reference, Release 1.9.2
References
[R196], [R197]

Examples

Draw samples from the geometric distribution.

Bernoulli trials are experiments with one of two outcomes: success or failure (an example of such an experiment is flipping a coin). The geometric distribution models the number of trials that must be run in order to achieve success. It is therefore supported on the positive integers, \( k = 1, 2, \ldots \).

The probability mass function of the geometric distribution is

\[
 f(k) = (1 - p)^{k-1} p
\]

where \( p \) is the probability of success of an individual trial.

Parameters

\( p \) : float

The probability of success of an individual trial.

\( \text{size} \) : int or tuple of ints, optional

Output shape. If the given shape is, e.g., (\( m \), \( n \), \( k \)), then \( m \times n \times k \) samples are drawn. Default is None, in which case a single value is returned.

Returns

\( \text{out} \) : ndarray

Samples from the geometric distribution, shaped according to \( \text{size} \).

Examples

Draw ten thousand values from the geometric distribution, with the probability of an individual success equal to 0.35:

```python
>>> z = np.random.geometric(p=0.35, size=10000)
```

How many trials succeeded after a single run?

```python
>>> (z == 1).sum() / 10000.
0.34889999999999999 #random
```

```
NumPy Reference, Release 1.9.2
References
[R196], [R197]

Examples

Draw samples from the geometric distribution.

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NumPy Reference, Release 1.9.2
References
[R196], [R197]

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 f(k) = (1 - p)^{k-1} p
\]

where \( p \) is the probability of success of an individual trial.

Parameters

\( p \) : float

The probability of success of an individual trial.

\( \text{size} \) : int or tuple of ints, optional

Output shape. If the given shape is, e.g., (\( m \), \( n \), \( k \)), then \( m \times n \times k \) samples are drawn. Default is None, in which case a single value is returned.

Returns

\( \text{out} \) : ndarray

Samples from the geometric distribution, shaped according to \( \text{size} \).

Examples

Draw ten thousand values from the geometric distribution, with the probability of an individual success equal to 0.35:

```python
>>> z = np.random.geometric(p=0.35, size=10000)
```

How many trials succeeded after a single run?

```python
>>> (z == 1).sum() / 10000.
0.34889999999999999 #random
```
Draw samples from a Gumbel distribution with specified location and scale. For more information on the Gumbel distribution, see Notes and References below.

**Parameters**

- **loc**: float
  The location of the mode of the distribution.

- **scale**: float
  The scale parameter of the distribution.

- **size**: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- **out**: ndarray
  The samples

**See also:**

- scipy.stats.gumbel_l
- scipy.stats.gumbel_r
- scipy.stats.genextreme

**Notes**

The Gumbel (or Smallest Extreme Value (SEV) or the Smallest Extreme Value Type I) distribution is one of a class of Generalized Extreme Value (GEV) distributions used in modeling extreme value problems. The Gumbel is a special case of the Extreme Value Type I distribution for maximums from distributions with “exponential-like” tails.

The probability density for the Gumbel distribution is

\[ p(x) = \frac{e^{-(x-\mu)/\beta}}{\beta} e^{-e^{-(x-\mu)/\beta}}, \]

where \( \mu \) is the mode, a location parameter, and \( \beta \) is the scale parameter.

The Gumbel (named for German mathematician Emil Julius Gumbel) was used very early in the hydrology literature, for modeling the occurrence of flood events. It is also used for modeling maximum wind speed and rainfall rates. It is a “fat-tailed” distribution - the probability of an event in the tail of the distribution is larger than if one used a Gaussian, hence the surprisingly frequent occurrence of 100-year floods. Floods were initially modeled as a Gaussian process, which underestimated the frequency of extreme events.

It is one of a class of extreme value distributions, the Generalized Extreme Value (GEV) distributions, which also includes the Weibull and Frechet.

The function has a mean of \( \mu + 0.57721/\beta \) and a variance of \( \frac{\pi^2}{6} \beta^2 \).

**References**


Examples

Draw samples from the distribution:

```python
>>> mu, beta = 0, 0.1 # location and scale
>>> s = np.random.gumbel(mu, beta, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, normed=True)
>>> plt.plot(bins, (1/beta)*np.exp(-(bins - mu)/beta)*np.exp(-np.exp(-(bins - mu)/beta)),
...          linewidth=2, color='r')
>>> plt.show()
```

Show how an extreme value distribution can arise from a Gaussian process and compare to a Gaussian:

```python
>>> means = []
>>> maxima = []
>>> for i in range(0,1000) :
...     a = np.random.normal(mu, beta, 1000)
...     means.append(a.mean())
...     maxima.append(a.max())
>>> count, bins, ignored = plt.hist(maxima, 30, normed=True)
>>> beta = np.std(maxima)*np.pi/np.sqrt(6)
>>> mu = np.mean(maxima) - 0.57721*beta
>>> plt.plot(bins, (1/beta)*np.exp(-(bins - mu)/beta)*np.exp(-np.exp(-(bins - mu)/beta)),
...          linewidth=2, color='r')
>>> plt.plot(bins, 1/(beta * np.sqrt(2 * np.pi))*np.exp(-(bins - mu)**2 / (2 * beta**2)),
...          linewidth=2, color='g')
>>> plt.show()
```
numpy.random.hypergeometric(ngood, nbad, nsample, size=None)

Draw samples from a Hypergeometric distribution.

Samples are drawn from a Hypergeometric distribution with specified parameters, ngood (ways to make a good selection), nbad (ways to make a bad selection), and nsample = number of items sampled, which is less than or equal to the sum ngood + nbad.

Parameters

ngood : int or array_like
    Number of ways to make a good selection. Must be nonnegative.

nbad : int or array_like
    Number of ways to make a bad selection. Must be nonnegative.

nsample : int or array_like
    Number of items sampled. Must be at least 1 and at most ngood + nbad.

size : int or tuple of ints, optional
    Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

Returns

samples : ndarray or scalar
    The values are all integers in [0, n].

See also:

scipy.stats.distributions.hypergeom

probability density function, distribution or cumulative density function, etc.

Notes

The probability density for the Hypergeometric distribution is

\[ P(x) = \binom{m}{x} \binom{N-m}{n-x} / \binom{N}{n}, \]
where \(0 \leq x \leq m\) and \(n + m - N \leq x \leq n\) for \(P(x)\) the probability of \(x\) successes, \(n = \text{ngood}\), \(m = \text{nbad}\), and \(N = \text{number of samples}\).

Consider an urn with black and white marbles in it, \(\text{ngood}\) of them black and \(\text{nbad}\) are white. If you draw \(\text{nsamp}\) balls without replacement, then the Hypergeometric distribution describes the distribution of black balls in the drawn sample.

Note that this distribution is very similar to the Binomial distribution, except that in this case, samples are drawn without replacement, whereas in the Binomial case samples are drawn with replacement (or the sample space is infinite). As the sample space becomes large, this distribution approaches the Binomial.

**References**

[R198], [R199], [R200]

**Examples**

Draw samples from the distribution:

```python
>>> ngood, nbad, nsamp = 100, 2, 10
# number of good, number of bad, and number of samples
>>> s = np.random.hypergeometric(ngood, nbad, nsamp, 1000)
>>> hist(s)
# note that it is very unlikely to grab both bad items
```

Suppose you have an urn with 15 white and 15 black marbles. If you pull 15 marbles at random, how likely is it that 12 or more of them are one color?

```python
>>> s = np.random.hypergeometric(15, 15, 15, 100000)
>>> sum(s>=12)/100000. + sum(s<=3)/100000.
# answer = 0.003 ... pretty unlikely!
```

**numpy.random.laplace**

Draw samples from the Laplace or double exponential distribution with specified location (or mean) and scale (decay).

The Laplace distribution is similar to the Gaussian/normal distribution, but is sharper at the peak and has fatter tails. It represents the difference between two independent, identically distributed exponential random variables.

**Parameters**

- **loc**: float
  The position, \(\mu\), of the distribution peak.

- **scale**: float
  \(\lambda\), the exponential decay.

- **size**: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

**Notes**

It has the probability density function

\[
f(x; \mu, \lambda) = \frac{1}{2\lambda} \exp\left(-\frac{|x - \mu|}{\lambda}\right).
\]

The first law of Laplace, from 1774, states that the frequency of an error can be expressed as an exponential function of the absolute magnitude of the error, which leads to the Laplace distribution. For many problems
in Economics and Health sciences, this distribution seems to model the data better than the standard Gaussian distribution.

References

[R201], [R202], [R203], [R204]

Examples

Draw samples from the distribution

```python
>>> loc, scale = 0., 1.
>>> s = np.random.laplace(loc, scale, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, normed=True)
>>> x = np.arange(-8., 8., .01)
>>> pdf = np.exp(-abs(x-loc)/scale)/(2.*scale)
>>> plt.plot(x, pdf)
```

Plot Gaussian for comparison:

```python
>>> g = (1/(scale * np.sqrt(2 * np.pi)) * 
... np.exp(-(x - loc)**2 / (2 * scale**2)))
>>> plt.plot(x, g)
```

```
```

```python
np.random.logistic(loc=0.0, scale=1.0, size=None)
```

Draw samples from a Logistic distribution.

Samples are drawn from a Logistic distribution with specified parameters, loc (location or mean, also median), and scale (>0).

**Parameters**

- `loc`: float
- `scale`: float > 0.
- `size`: int or tuple of ints, optional
Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

**Returns**

samples : {ndarray, scalar}

where the values are all integers in [0, n].

**See also:**

```python
scipy.stats.distributions.logistic
```

probability density function, distribution or cumulative density function, etc.

**Notes**

The probability density for the Logistic distribution is

\[
P(x) = \frac{e^{-(x-\mu)/s}}{s(1 + e^{-(x-\mu)/s})^2},
\]

where \(\mu\) = location and \(s\) = scale.

The Logistic distribution is used in Extreme Value problems where it can act as a mixture of Gumbel distributions, in Epidemiology, and by the World Chess Federation (FIDE) where it is used in the Elo ranking system, assuming the performance of each player is a logistically distributed random variable.

**References**

[R205], [R206], [R207]

**Examples**

Draw samples from the distribution:

```python
>>> loc, scale = 10, 1
>>> s = np.random.logistic(loc, scale, 10000)
>>> count, bins, ignored = plt.hist(s, bins=50)
```

# plot against distribution

```python
>>> def logist(x, loc, scale):
...     return exp((loc-x)/scale)/(scale*(1+exp((loc-x)/scale))**2)
>>> plt.plot(bins, logist(bins, loc, scale)*count.max()/
...     logist(bins, loc, scale).max())
>>> plt.show()
```

**numpy.random.lognormal**

(mean=0.0, sigma=1.0, size=None)

Return samples drawn from a log-normal distribution.

Draw samples from a log-normal distribution with specified mean, standard deviation, and array shape. Note that the mean and standard deviation are not the values for the distribution itself, but of the underlying normal distribution it is derived from.

**Parameters**

- mean : float
  Mean value of the underlying normal distribution

- sigma : float, > 0.
  Standard deviation of the underlying normal distribution

- size : int or tuple of ints, optional
Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

**Returns**

`samples`: ndarray or float

The desired samples. An array of the same shape as `size` if given, if `size` is None a float is returned.

**See also:**

`scipy.stats.lognorm`

probability density function, distribution, cumulative density function, etc.

**Notes**

A variable \(x\) has a log-normal distribution if \(\log(x)\) is normally distributed. The probability density function for the log-normal distribution is:

\[
p(x) = \frac{1}{\sigma x \sqrt{2\pi}} e^{\left(-\frac{(\ln(x) - \mu)^2}{2\sigma^2}\right)}
\]

where \(\mu\) is the mean and \(\sigma\) is the standard deviation of the normally distributed logarithm of the variable. A log-normal distribution results if a random variable is the product of a large number of independent, identically-distributed variables in the same way that a normal distribution results if the variable is the sum of a large number of independent, identically-distributed variables.

**References**


**Examples**

Draw samples from the distribution:

```python
>>> mu, sigma = 3., 1.  # mean and standard deviation
>>> s = np.random.lognormal(mu, sigma, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 100, normed=True, align='mid')

...  

>>> x = np.linspace(min(bins), max(bins), 10000)
>>> pdf = (np.exp(-(np.log(x) - mu)**2 / (2 * sigma**2))
        ...  / (x * sigma * np.sqrt(2 * np.pi)))

>>> plt.plot(x, pdf, linewidth=2, color='r')
>>> plt.axis('tight')
>>> plt.show()
```

Demonstrate that taking the products of random samples from a uniform distribution can be fit well by a log-normal probability density function.

```python
>>> # Generate a thousand samples: each is the product of 100 random
>>> # values, drawn from a normal distribution.
>>> b = []
>>> for i in range(1000):
```
... a = 10. + np.random.random(100)
... b.append(np.product(a))

>>> b = np.array(b) / np.min(b)  # scale values to be positive
>>> count, bins, ignored = plt.hist(b, 100, normed=True, align='center')
>>> sigma = np.std(np.log(b))
>>> mu = np.mean(np.log(b))

>>> x = np.linspace(min(bins), max(bins), 10000)
>>> pdf = (np.exp(-(np.log(x) - mu)**2 / (2 * sigma**2))
...       / (x * sigma * np.sqrt(2 * np.pi)))

>>> plt.plot(x, pdf, color='r', linewidth=2)
>>> plt.show()

numpy.random.logseries(p, size=None)
Draw samples from a Logarithmic Series distribution.

Samples are drawn from a Log Series distribution with specified parameter, p (probability, 0 < p < 1).

Parameters
loc : float
scale : float > 0.
size : int or tuple of ints, optional
Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

Returns
samples : {ndarray, scalar}
where the values are all integers in [0, n].

See also:
scipy.stats.distributions.logser
probability density function, distribution or cumulative density function, etc.

Notes
The probability density for the Log Series distribution is

\[ P(k) = \frac{-p^k}{k \ln(1 - p)}, \]

where p = probability.

The Log Series distribution is frequently used to represent species richness and occurrence, first proposed by Fisher, Corbet, and Williams in 1943 [2]. It may also be used to model the numbers of occupants seen in cars [3].

References
[R208], [R209], [R210], [R211]

Examples
Draw samples from the distribution:
```python
>>> a = .6
>>> s = np.random.logseries(a, 10000)
>>> count, bins, ignored = plt.hist(s)

# plot against distribution

>>> def logseries(k, p):
...     return -p**k/(k*log(1-p))
>>> plt.plot(bins, logseries(bins, a)*count.max()/
...           logseries(bins, a).max(), 'r')
>>> plt.show()
```

**numpy.random.multinomial**(*n*, *pvals*, *size=None*)

Draw samples from a multinomial distribution.

The multinomial distribution is a multivariate generalisation of the binomial distribution. Take an experiment with one of *p* possible outcomes. An example of such an experiment is throwing a dice, where the outcome can be 1 through 6. Each sample drawn from the distribution represents *n* such experiments. Its values, \(X_0, X_1, \ldots, X_p\), represent the number of times the outcome was *i*.

**Parameters**

- **n**: int
  Number of experiments.

- **pvals**: sequence of floats, length *p*
  Probabilities of each of the *p* different outcomes. These should sum to 1 (however, the last element is always assumed to account for the remaining probability, as long as \(\text{sum}(\text{pvals}[:-1]) \leq 1\)).

- **size**: tuple of ints
  Given a *size* of \((M, N, K)\), then \(M*N*K\) samples are drawn, and the output shape becomes \((M, N, K, p)\), since each sample has shape \((p,)\).

**Examples**

Throw a dice 20 times:

```python
>>> np.random.multinomial(20, [1/6.]*6, size=1)
aarray([[4, 1, 7, 5, 2, 1]])
```

It landed 4 times on 1, once on 2, etc.

Now, throw the dice 20 times, and 20 times again:

```python
>>> np.random.multinomial(20, [1/6.]*6, size=2)
aarray([[3, 4, 3, 3, 4, 3],
        [2, 4, 3, 4, 0, 7]])
```

For the first run, we threw 3 times 1, 4 times 2, etc. For the second, we threw 2 times 1, 4 times 2, etc.

A loaded dice is more likely to land on number 6:

```python
>>> np.random.multinomial(100, [1/7.]*5)
aarray([13, 16, 13, 16, 42])
```

**numpy.random.multivariate_normal**(*mean*, *cov*, *size*)

Draw random samples from a multivariate normal distribution.
The multivariate normal, multinormal or Gaussian distribution is a generalization of the one-dimensional normal distribution to higher dimensions. Such a distribution is specified by its mean and covariance matrix. These parameters are analogous to the mean (average or “center”) and variance (standard deviation, or “width,” squared) of the one-dimensional normal distribution.

**Parameters**

- **mean**: 1-D array_like, of length N
  
  Mean of the N-dimensional distribution.

- **cov**: 2-D array_like, of shape (N, N)
  
  Covariance matrix of the distribution. Must be symmetric and positive-semidefinite for “physically meaningful” results.

- **size**: int or tuple of ints, optional
  
  Given a shape of, for example, (m, n, k), m*n*k samples are generated, and packed in an m-by-n-by-k arrangement. Because each sample is N-dimensional, the output shape is (m, n, k, N). If no shape is specified, a single (N-D) sample is returned.

**Returns**

- **out**: ndarray
  
  The drawn samples, of shape size, if that was provided. If not, the shape is (N,).

In other words, each entry out[i,j,...,:] is an N-dimensional value drawn from the distribution.

**Notes**

The mean is a coordinate in N-dimensional space, which represents the location where samples are most likely to be generated. This is analogous to the peak of the bell curve for the one-dimensional or univariate normal distribution.

Covariance indicates the level to which two variables vary together. From the multivariate normal distribution, we draw N-dimensional samples, \( X = [x_1, x_2, ... x_N] \). The covariance matrix element \( C_{ij} \) is the covariance of \( x_i \) and \( x_j \). The element \( C_{ii} \) is the variance of \( x_i \) (i.e. its “spread”).

Instead of specifying the full covariance matrix, popular approximations include:

- Spherical covariance (cov is a multiple of the identity matrix)

- Diagonal covariance (cov has non-negative elements, and only on the diagonal)

This geometrical property can be seen in two dimensions by plotting generated data-points:

```python
>>> mean = [0,0]
>>> cov = [[1,0],[0,100]]  # diagonal covariance, points lie on x or y-axis

>>> import matplotlib.pyplot as plt
>>> x, y = np.random.multivariate_normal(mean, cov, 5000).T
>>> plt.plot(x,y,'x'); plt.axis('equal'); plt.show()
```

Note that the covariance matrix must be non-negative definite.

**References**


Examples

```python
>>> mean = (1,2)
>>> cov = [[1,0],[1,0]]
>>> x = np.random.multivariate_normal(mean,cov,(3,3))
>>> x.shape
(3, 3, 2)
```

The following is probably true, given that 0.6 is roughly twice the standard deviation:

```python
>>> print list( (x[0,0,:]-mean) < 0.6 )
[True, True]
```

```python
numpy.random.negative_binomial(n, p, size=None)
```

draw samples from a negative_binomial distribution.

Samples are drawn from a negative_Binomial distribution with specified parameters, $n$ trials and $p$ probability of success where $n$ is an integer $> 0$ and $p$ is in the interval $[0, 1]$.

Parameters

- **n**: int
  Parameter, $> 0$.

- **p**: float
  Parameter, $\geq 0$ and $\leq 1$.

- **size**: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., $(m, n, k)$, then $m* n * k$ samples are drawn. Default is None, in which case a single value is returned.

Returns

- **samples**: int or ndarray of ints
  Drawn samples.

Notes

The probability density for the Negative Binomial distribution is

$$P(N; n, p) = \binom{N+n-1}{n-1} p^n (1-p)^N,$$

where $n - 1$ is the number of successes, $p$ is the probability of success, and $N + n - 1$ is the number of trials.

The negative binomial distribution gives the probability of $n$-1 successes and $N$ failures in $N+n-1$ trials, and success on the $(N+n)$th trial.

If one throws a die repeatedly until the third time a “1” appears, then the probability distribution of the number of non-“1”s that appear before the third “1” is a negative binomial distribution.

References

[R212], [R213]

Examples

Draw samples from the distribution:

A real world example. A company drills wild-cat oil exploration wells, each with an estimated probability of success of 0.1. What is the probability of having one success for each successive well, that is what is the probability of a single success after drilling 5 wells, after 6 wells, etc.?
```python
>>> s = np.random.negative_binomial(1, 0.1, 100000)
>>> for i in range(1, 11):
...     probability = sum(s<i) / 100000.
...     print i, "wells drilled, probability of one success =", probability
```

```python
numpy.random.noncentral_chisquare(df, nonc, size=None)

Draw samples from a noncentral chi-square distribution.

The noncentral \(\chi^2\) distribution is a generalisation of the \(\chi^2\) distribution.

**Parameters**

- **df**: int
  
  Degrees of freedom, should be \(\geq 1\).

- **nonc**: float
  
  Non-centrality, should be \(> 0\).

- **size**: int or tuple of ints, optional
  
  Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

**Notes**

The probability density function for the noncentral Chi-square distribution is

\[
P(x; df, nonc) = \sum_{i=0}^{\infty} \frac{e^{-\frac{nonc}{2}}\left(\frac{nonc}{2}\right)^i}{i!} P_{Y_{df+2i}}(x),
\]

where \(Y_q\) is the Chi-square with \(q\) degrees of freedom.

In Delhi (2007), it is noted that the noncentral chi-square is useful in bombing and coverage problems, the probability of killing the point target given by the noncentral chi-squared distribution.

**References**

[R214], [R215]

**Examples**

Draw values from the distribution and plot the histogram

```python
>>> import matplotlib.pyplot as plt
>>> values = plt.hist(np.random.noncentral_chisquare(3, 20, 100000),
...                    bins=200, normed=True)
>>> plt.show()
```
Draw values from a noncentral chisquare with very small noncentrality, and compare to a chisquare.

```python
>>> plt.figure()
>>> values = plt.hist(np.random.noncentral_chisquare(3, .0000001, 100000),
...                    bins=np.arange(0., 25, .1), normed=True)
>>> values2 = plt.hist(np.random.chisquare(3, 100000),
...                    bins=np.arange(0., 25, .1), normed=True)
>>> plt.plot(values[1][0:-1], values[0]-values2[0], 'ob')
>>> plt.show()
```

Demonstrate how large values of non-centrality lead to a more symmetric distribution.

```python
>>> plt.figure()
>>> values = plt.hist(np.random.noncentral_chisquare(3, 20, 100000),
...                    bins=200, normed=True)
>>> plt.show()
```
numpy.random.noncentral_f (dfnum, dfden, nonc, size=None)

Draw samples from the noncentral F distribution.

Samples are drawn from an F distribution with specified parameters, \( dfnum \) (degrees of freedom in numerator) and \( dfden \) (degrees of freedom in denominator), where both parameters > 1. \( nonc \) is the non-centrality parameter.

**Parameters**

- **dfnum** : int
  - Parameter, should be > 1.

- **dfden** : int
  - Parameter, should be > 1.

- **nonc** : float
  - Parameter, should be >= 0.

- **size** : int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- **samples** : scalar or ndarray
  - Drawn samples.

**Notes**

When calculating the power of an experiment (power = probability of rejecting the null hypothesis when a specific alternative is true) the non-central F statistic becomes important. When the null hypothesis is true, the F statistic follows a central F distribution. When the null hypothesis is not true, then it follows a non-central F statistic.

**References**

Examples

In a study, testing for a specific alternative to the null hypothesis requires use of the Noncentral F distribution. We need to calculate the area in the tail of the distribution that exceeds the value of the F distribution for the null hypothesis. We’ll plot the two probability distributions for comparison.

```python
>>> dfnum = 3  # between group deg of freedom
>>> dfden = 20  # within groups degrees of freedom
>>> nonc = 3.0
>>> nc_vals = np.random.noncentral_f(dfnum, dfden, nonc, 1000000)
>>> NF = np.histogram(nc_vals, bins=50, normed=True)
>>> c_vals = np.random.f(dfnum, dfden, 1000000)
>>> F = np.histogram(c_vals, bins=50, normed=True)
>>> plt.plot(F[1][1:], F[0])
>>> plt.plot(NF[1][1:], NF[0])
>>> plt.show()
```

This is an example of how to use the `numpy.random.normal` function to draw random samples from a normal (Gaussian) distribution.

The probability density function of the normal distribution, first derived by De Moivre and 200 years later by both Gauss and Laplace independently [R217], is often called the bell curve because of its characteristic shape (see the example below).

The normal distributions occurs often in nature. For example, it describes the commonly occurring distribution of samples influenced by a large number of tiny, random disturbances, each with its own unique distribution [R217].

**Parameters**

- `loc`: float
  Mean (“centre”) of the distribution.

- `scale`: float
  Standard deviation (spread or “width”) of the distribution.

- `size`: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**See also:**

- `scipy.stats.distributions.norm`
  probability density function, distribution or cumulative density function, etc.

**Notes**

The probability density for the Gaussian distribution is

\[
p(x) = \frac{1}{\sqrt{2\pi}\sigma^2} e^{-\frac{(x-\mu)^2}{2\sigma^2}},
\]

where \( \mu \) is the mean and \( \sigma \) the standard deviation. The square of the standard deviation, \( \sigma^2 \), is called the variance.

The function has its peak at the mean, and its “spread” increases with the standard deviation (the function reaches 0.607 times its maximum at \( x + \sigma \) and \( x - \sigma \) [R217]). This implies that `numpy.random.normal` is more likely to return samples lying close to the mean, rather than those far away.
References

[R216], [R217]

Examples

Draw samples from the distribution:

```python
>>> mu, sigma = 0, 0.1 # mean and standard deviation
>>> s = np.random.normal(mu, sigma, 1000)
```

Verify the mean and the variance:

```python
>>> abs(mu - np.mean(s)) < 0.01
True

>>> abs(sigma - np.std(s, ddof=1)) < 0.01
True
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, normed=True)
>>> plt.plot(bins, 1/(sigma * np.sqrt(2 * np.pi)) *
... np.exp( - (bins - mu)**2 / (2 * sigma**2) ),
... linewidth=2, color='r')
>>> plt.show()
```

```
0.4
 0.3
 0.2
 0.1
 0.0
```

```
0
1
2
3
4
5
```

`numpy.random.pareto(a, size=None)`

Draw samples from a Pareto II or Lomax distribution with specified shape.

The Lomax or Pareto II distribution is a shifted Pareto distribution. The classical Pareto distribution can be obtained from the Lomax distribution by adding 1 and multiplying by the scale parameter $m$ (see Notes). The smallest value of the Lomax distribution is zero while for the classical Pareto distribution it is $\mu$, where the standard Pareto distribution has location $\mu = 1$. Lomax can also be considered as a simplified version of the Generalized Pareto distribution (available in SciPy), with the scale set to one and the location set to zero.

The Pareto distribution must be greater than zero, and is unbounded above. It is also known as the “80-20 rule”. In this distribution, 80 percent of the weights are in the lowest 20 percent of the range, while the other 20 percent fill the remaining 80 percent of the range.

3.25. Random sampling (`numpy.random`)
Parameters

- **shape**: float, > 0.
  Shape of the distribution.

- **size**: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

See also:

- **scipy.stats.distributions.lomax.pdf**
  probability density function, distribution or cumulative density function, etc.

- **scipy.stats.distributions.genpareto.pdf**
  probability density function, distribution or cumulative density function, etc.

Notes

The probability density for the Pareto distribution is

\[ p(x) = \frac{am^a}{x^{a+1}} \]

where \( a \) is the shape and \( m \) the scale.

The Pareto distribution, named after the Italian economist Vilfredo Pareto, is a power law probability distribution useful in many real world problems. Outside the field of economics it is generally referred to as the Bradford distribution. Pareto developed the distribution to describe the distribution of wealth in an economy. It has also found use in insurance, web page access statistics, oil field sizes, and many other problems, including the download frequency for projects in Sourceforge [R218]. It is one of the so-called “fat-tailed” distributions.

References

[R218], [R219], [R220], [R221]

Examples

Draw samples from the distribution:

```python
>>> a, m = 3., 2.  # shape and mode
>>> s = (np.random.pareto(a, 1000) + 1) * m
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(s, 100, normed=True)
>>> fit = a*m**a / bins**(a+1)
>>> plt.plot(bins, max(count)*fit/max(fit), linewidth=2, color='r')
>>> plt.show()
```
numpy.random.poisson(lam=1.0, size=None)

Draw samples from a Poisson distribution.

The Poisson distribution is the limit of the Binomial distribution for large \(N\).

Parameters

- `lam` : float or sequence of float
  Expectation of interval, should be \(\geq 0\). A sequence of expectation intervals must be broadcastable over the requested size.

- `size` : int or tuple of ints, optional
  Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

Notes

The Poisson distribution

\[
f(k; \lambda) = \frac{\lambda^k e^{-\lambda}}{k!}
\]

For events with an expected separation \(\lambda\) the Poisson distribution \(f(k; \lambda)\) describes the probability of \(k\) events occurring within the observed interval \(\lambda\).

Because the output is limited to the range of the C long type, a ValueError is raised when \(\text{lam}\) is within 10 sigma of the maximum representable value.

References

[R222], [R223]

Examples

Draw samples from the distribution:

```python
>>> import numpy as np
>>> s = np.random.poisson(5, 10000)
```

Display histogram of the sample:
```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 14, normed=True)
>>> plt.show()
```

Draw each 100 values for lambda 100 and 500:

```python
>>> s = np.random.poisson(lam=(100., 500.), size=(100, 2))
```

**`numpy.random.power(a, size=None)`**

Draws samples in [0, 1] from a power distribution with positive exponent a - 1.

Also known as the power function distribution.

**Parameters**

- `a` : float  
  parameter, > 0

- `size` : int or tuple of ints, optional  
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- `samples` : {ndarray, scalar}
  The returned samples lie in [0, 1].

**Raises**

- `ValueError`  
  If a<1.

**Notes**

The probability density function is

\[ P(x; a) = ax^{a-1}, 0 \leq x \leq 1, a > 0. \]

The power function distribution is just the inverse of the Pareto distribution. It may also be seen as a special case of the Beta distribution.

It is used, for example, in modeling the over-reporting of insurance claims.
References

[R224], [R225]

Examples

Draw samples from the distribution:

```python
>>> a = 5.  # shape
>>> samples = 1000
>>> s = np.random.power(a, samples)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt

>>> count, bins, ignored = plt.hist(s, bins=30)
>>> x = np.linspace(0, 1, 100)
>>> y = a*x**(a-1.)
>>> normed_y = samples*np.diff(bins)[0]*y
>>> plt.plot(x, normed_y)
>>> plt.show()
```

Compare the power function distribution to the inverse of the Pareto.

```python
>>> from scipy import stats

>>> rvs = np.random.power(5, 1000000)
>>> rvsp = np.random.pareto(5, 1000000)
>>> xx = np.linspace(0,1,100)
>>> powpdf = stats.powerlaw.pdf(xx,5)

>>> plt.figure()
>>> plt.hist(rvs, bins=50, normed=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('np.random.power(5)')

>>> plt.figure()
>>> plt.hist(1./(1.+rvsp), bins=50, normed=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('inverse of 1 + np.random.pareto(5)')

>>> plt.figure()
>>> plt.hist(1./(1.+rvsp), bins=50, normed=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('inverse of stats.pareto(5)')
```

```
numpy.random.rayleigh(scale=1.0, size=None)
```

Draw samples from a Rayleigh distribution.

The $\chi$ and Weibull distributions are generalizations of the Rayleigh.

**Parameters**

- `scale`: scalar
  
  Scale, also equals the mode. Should be $\geq 0$.

- `size`: int or tuple of ints, optional
  
  Output shape. If the given shape is, e.g., $(m, n, k)$, then $m \times n \times k$ samples are drawn. Default is None, in which case a single value is returned.
Notes

The probability density function for the Rayleigh distribution is

\[ P(x; \text{scale}) = \frac{x}{\text{scale}^2} e^{-\frac{x^2}{2 \cdot \text{scale}^2}} \]

The Rayleigh distribution arises if the wind speed and wind direction are both gaussian variables, then the vector wind velocity forms a Rayleigh distribution. The Rayleigh distribution is used to model the expected output from wind turbines.

References

[R226], [R227]

Examples

Draw values from the distribution and plot the histogram

```python
>>> values = hist(np.random.rayleigh(3, 100000), bins=200, normed=True)
```

Wave heights tend to follow a Rayleigh distribution. If the mean wave height is 1 meter, what fraction of waves are likely to be larger than 3 meters?

```python
>>> meanvalue = 1
>>> modevalue = np.sqrt(2 / np.pi) * meanvalue
>>> s = np.random.rayleigh(modevalue, 1000000)
```

The percentage of waves larger than 3 meters is:

```python
>>> 100.*sum(s>3)/1000000.
0.087300000000000003
```

numpy.random.standard_cauchy(size=None)

Standard Cauchy distribution with mode = 0.

Also known as the Lorentz distribution.

Parameters

- size : int or tuple of ints, optional
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

Returns

- samples : ndarray or scalar
  The drawn samples.

Notes

The probability density function for the full Cauchy distribution is

\[ P(x; x_0, \gamma) = \frac{1}{\pi \gamma [1 + (\frac{x - x_0}{\gamma})^2]} \]

and the Standard Cauchy distribution just sets \( x_0 = 0 \) and \( \gamma = 1 \)

The Cauchy distribution arises in the solution to the driven harmonic oscillator problem, and also describes spectral line broadening. It also describes the distribution of values at which a line tilted at a random angle will cut the x axis.

When studying hypothesis tests that assume normality, seeing how the tests perform on data from a Cauchy distribution is a good indicator of their sensitivity to a heavy-tailed distribution, since the Cauchy looks very much like a Gaussian distribution, but with heavier tails.
References

[R229], [R230], [R231]

Examples

Draw samples and plot the distribution:

```python
>>> s = np.random.standard_cauchy(1000000)
>>> s = s[(s>-25) & (s<25)]  # truncate distribution so it plots well
>>> plt.hist(s, bins=100)
>>> plt.show()
```

```
numpy.random.standard_exponential(size=None)
```

Draw samples from the standard exponential distribution.

`standard_exponential` is identical to the exponential distribution with a scale parameter of 1.

Parameters

- `size` : int or tuple of ints, optional
  
  Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

- `out` : float or ndarray
  
  Drawn samples.

Examples

Output a 3x8000 array:

```python
>>> n = np.random.standard_exponential((3, 8000))
```

```
numpy.random.standard_gamma(shape, size=None)
```

Draw samples from a Standard Gamma distribution.

Samples are drawn from a Gamma distribution with specified parameters, shape (sometimes designated “k”) and scale=1.

Parameters

- `shape` : float
  
  Parameter, should be > 0.

- `size` : int or tuple of ints, optional

  Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

- `samples` : ndarray or scalar
  
  The drawn samples.

See also:

```
scipy.stats.distributions.gamma
```

probability density function, distribution or cumulative density function, etc.
Notes
The probability density for the Gamma distribution is

\[ p(x) = x^{k-1} e^{-x/\theta} \frac{1}{\theta^k \Gamma(k)}, \]

where \( k \) is the shape and \( \theta \) the scale, and \( \Gamma \) is the Gamma function.

The Gamma distribution is often used to model the times to failure of electronic components, and arises naturally in processes for which the waiting times between Poisson distributed events are relevant.

References
[R232], [R233]

Examples
Draw samples from the distribution:

```python
>>> shape, scale = 2., 1.  # mean and width
>>> s = np.random.standard_gamma(shape, 1000000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps

>>> count, bins, ignored = plt.hist(s, 50, normed=True)
>>> y = bins**(shape-1) * ((np.exp(-bins/scale)) / 
... (sps.gamma(shape) * scale**shape))
>>> plt.plot(bins, y, linewidth=2, color='r')
>>> plt.show()
```

numpy.random.standard_normal(size=None)
Returns samples from a Standard Normal distribution (mean=0, stdev=1).

Parameters
- size : int or tuple of ints, optional
  Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

Returns
- out : float or ndarray
  Drawn samples.

Examples

```python
>>> s = np.random.standard_normal(8000)
```

numpy.random.standard_t(df, size=None)
Standard Student’s t distribution with \( df \) degrees of freedom.
A special case of the hyperbolic distribution. As \( df \) gets large, the result resembles that of the standard normal distribution (\texttt{standard_normal}).

**Parameters**
- \( df \) : int
  Degrees of freedom, should be > 0.
- \( size \) : int or tuple of ints, optional
  Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \ast n \ast k\) samples are drawn. Default is None, in which case a single value is returned.

**Returns**
- \( samples \) : ndarray or scalar
  Drawn samples.

**Notes**
The probability density function for the \( t \) distribution is

\[
P(x, df) = \frac{\Gamma\left(\frac{df+1}{2}\right)}{\sqrt{\pi df} \Gamma\left(\frac{df}{2}\right)} \left(1 + \frac{x^2}{df}\right)^{-(df+1)/2}
\]

The \( t \) test is based on an assumption that the data come from a Normal distribution. The \( t \) test provides a way to test whether the sample mean (that is the mean calculated from the data) is a good estimate of the true mean.

The derivation of the \( t \)-distribution was first published in 1908 by William Gisset while working for the Guinness Brewery in Dublin. Due to proprietary issues, he had to publish under a pseudonym, and so he used the name Student.

**References**
[R234], [R235]

**Examples**
From Dalgaard page 83 [R234], suppose the daily energy intake for 11 women in Kj is:

```python
>>> intake = np.array([5260., 5470, 5640, 6180, 6390, 6515, 6805, 7515, ... 7515, 8230, 8770])
```

Does their energy intake deviate systematically from the recommended value of 7725 kJ?

We have 10 degrees of freedom, so is the sample mean within 95% of the recommended value?

```python
>>> s = np.random.standard_t(10, size=10000)
```

```python
>>> np.mean(intake)
6753.636363636364
```

```python
>>> intake.std(ddof=1)
1142.1232221373727
```

Calculate the \( t \) statistic, setting the \texttt{ddof} parameter to the unbiased value so the divisor in the standard deviation will be degrees of freedom, N-1.

```python
>>> t = (np.mean(intake)-7725)/(intake.std(ddof=1))/np.sqrt(len(intake))
```

```python
import matplotlib.pyplot as plt
>>> h = plt.hist(s, bins=100, normed=True)
```

For a one-sided \( t \)-test, how far out in the distribution does the \( t \) statistic appear?
>>> >>> np.sum(s<t) / float(len(s))
0.0090699999999999999  #random

So the p-value is about 0.009, which says the null hypothesis has a probability of about 99% of being true.

```
numpy.random.triangular(left, mode, right, size=None)
```

Draw samples from the triangular distribution.

The triangular distribution is a continuous probability distribution with lower limit left, peak at mode, and upper limit right. Unlike the other distributions, these parameters directly define the shape of the pdf.

**Parameters**

- **left**: scalar
  - Lower limit.
- **mode**: scalar
  - The value where the peak of the distribution occurs. The value should fulfill the condition left <= mode <= right.
- **right**: scalar
  - Upper limit, should be larger than left.
- **size**: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- **samples**: ndarray or scalar
  - The returned samples all lie in the interval [left, right].

**Notes**

The probability density function for the Triangular distribution is

\[
P(x; l, m, r) = \begin{cases} 
\frac{2(x-l)}{(r-l)(m-l)} & \text{for } l \leq x \leq m, \\
\frac{2(m-x)}{(r-l)(r-m)} & \text{for } m \leq x \leq r, \\
0 & \text{otherwise.}
\end{cases}
\]

The triangular distribution is often used in ill-defined problems where the underlying distribution is not known, but some knowledge of the limits and mode exists. Often it is used in simulations.

**References**

[R236]

**Examples**

Draw values from the distribution and plot the histogram:

```python
>>> import matplotlib.pyplot as plt
>>> h = plt.hist(np.random.triangular(-3, 0, 8, 100000), bins=200,
...               normed=True)
>>> plt.show()
```
NumPy Reference, Release 1.9.2

numpy.random.uniform(low=0.0, high=1.0, size=None)

Draw samples from a uniform distribution.

Samples are uniformly distributed over the half-open interval [low, high) (includes low, but excludes high). In other words, any value within the given interval is equally likely to be drawn by uniform.

Parameters

- **low**: float, optional
  - Lower boundary of the output interval. All values generated will be greater than or equal to low. The default value is 0.

- **high**: float
  - Upper boundary of the output interval. All values generated will be less than high. The default value is 1.0.

- **size**: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

Returns

- **out**: ndarray
  - Drawn samples, with shape size.

See also:

- **randint**: Discrete uniform distribution, yielding integers.

- **random_integers**: Discrete uniform distribution over the closed interval [low, high].

- **random_sample**: Floats uniformly distributed over [0, 1).

- **random**: Alias for random_sample.
**rand**

Convenience function that accepts dimensions as input, e.g., `rand(2,2)` would generate a 2-by-2 array of floats, uniformly distributed over $[0, 1)$.

**Notes**

The probability density function of the uniform distribution is

$$p(x) = \frac{1}{b-a}$$

anywhere within the interval $[a, b)$, and zero elsewhere.

**Examples**

Draw samples from the distribution:

```python
>>> s = np.random.uniform(-1, 0, 1000)
```

All values are within the given interval:

```python
>>> np.all(s >= -1)
True
>>> np.all(s < 0)
True
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 15, normed=True)
>>> plt.plot(bins, np.ones_like(bins), linewidth=2, color='r')
>>> plt.show()
```

**numpy.random.vonmises**(mu, kappa, size=None)

Draw samples from a von Mises distribution.

Samples are drawn from a von Mises distribution with specified mode (mu) and dispersion (kappa), on the interval [-pi, pi].

The von Mises distribution (also known as the circular normal distribution) is a continuous probability distribution on the unit circle. It may be thought of as the circular analogue of the normal distribution.
**Parameters**

- **mu**: float
  Mode ("center") of the distribution.
- **kappa**: float
  Dispersion of the distribution, has to be >=0.
- **size**: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- **samples**: scalar or ndarray
  The returned samples, which are in the interval [-pi, pi].

**See also:**

- `scipy.stats.distributions.vonmises` probability density function, distribution, or cumulative density function, etc.

**Notes**

The probability density for the von Mises distribution is

\[ p(x) = \frac{e^{\kappa \cos(x-\mu)}}{2\pi I_0(\kappa)}, \]

where \( \mu \) is the mode and \( \kappa \) the dispersion, and \( I_0(\kappa) \) is the modified Bessel function of order 0.

The von Mises is named for Richard Edler von Mises, who was born in Austria-Hungary, in what is now the Ukraine. He fled to the United States in 1939 and became a professor at Harvard. He worked in probability theory, aerodynamics, fluid mechanics, and philosophy of science.

**References**


**Examples**

Draw samples from the distribution:

```python
>>> mu, kappa = 0.0, 4.0  # mean and dispersion
>>> s = np.random.vonmises(mu, kappa, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps
>>> count, bins, ignored = plt.hist(s, 50, normed=True)
>>> x = np.arange(-np.pi, np.pi, 2*np.pi/50.)
>>> y = -np.exp(kappa*np.cos(x-mu))/(2*np.pi*sps.jn(0,kappa))
>>> plt.plot(x, y/max(y), linewidth=2, color='r')
>>> plt.show()
```

**numpy.random.wald** (mean, scale, size=None)

- Draw samples from a Wald, or Inverse Gaussian, distribution.
As the scale approaches infinity, the distribution becomes more like a Gaussian.

Some references claim that the Wald is an Inverse Gaussian with mean=1, but this is by no means universal.

The Inverse Gaussian distribution was first studied in relationship to Brownian motion. In 1956 M.C.K. Tweedie used the name Inverse Gaussian because there is an inverse relationship between the time to cover a unit distance and distance covered in unit time.

**Parameters**
- **mean**: scalar
  - Distribution mean, should be > 0.
- **scale**: scalar
  - Scale parameter, should be >= 0.
- **size**: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**
- **samples**: ndarray or scalar
  - Drawn sample, all greater than zero.

**Notes**

The probability density function for the Wald distribution is

\[
P(x; \text{mean}, \text{scale}) = \sqrt{\frac{\text{scale}}{2\pi x^3}} \exp\left(-\frac{\text{scale}(x-\text{mean})^2}{2\text{mean}^2 x}\right)
\]

As noted above the Inverse Gaussian distribution first arise from attempts to model Brownian Motion. It is also a competitor to the Weibull for use in reliability modeling and modeling stock returns and interest rate processes.

**References**

[R237], [R238], [R239]

**Examples**

Draw values from the distribution and plot the histogram:

```python
>>> import matplotlib.pyplot as plt
>>> h = plt.hist(np.random.wald(3, 2, 100000), bins=200, normed=True)
>>> plt.show()
```
numpy.random.weibull(a, size=None)

Weibull distribution.

Draw samples from a 1-parameter Weibull distribution with the given shape parameter $a$.

$$X = (-\ln(U))^{1/a}$$

Here, $U$ is drawn from the uniform distribution over $(0,1]$.

The more common 2-parameter Weibull, including a scale parameter $\lambda$ is just $X = \lambda(-\ln(U))^{1/a}$.

**Parameters**

- **a** : float
  Shape of the distribution.

- **size** : int or tuple of ints, optional
  Output shape. If the given shape is, e.g., $(m, n, k)$, then $m \times n \times k$ samples are drawn. Default is None, in which case a single value is returned.

**See also:**

scipy.stats.distributions.weibull_max, scipy.stats.distributions.weibull_min, scipy.stats.distributions.genextreme, gumbel

**Notes**

The Weibull (or Type III asymptotic extreme value distribution for smallest values, SEV Type III, or Rosin-Rammler distribution) is one of a class of Generalized Extreme Value (GEV) distributions used in modeling extreme value problems. This class includes the Gumbel and Frechet distributions.

The probability density for the Weibull distribution is

$$p(x) = \frac{a}{\lambda} \left(\frac{x}{\lambda}\right)^{a-1} e^{-(x/\lambda)^a},$$

where $a$ is the shape and $\lambda$ the scale.

The function has its peak (the mode) at $\lambda(a-1)^{1/a}$.

When $a = 1$, the Weibull distribution reduces to the exponential distribution.
References

[R240], [R241], [R242]

Examples

Draw samples from the distribution:

```python
>>> a = 5.  # shape
>>> s = np.random.weibull(a, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> x = np.arange(1,100.)/50.
>>> def weib(x,n,a):
...     return (a / n) * (x / n)**(a - 1) * np.exp(-(x / n)**a)

>>> count, bins, ignored = plt.hist(np.random.weibull(5.,1000))
>>> x = np.arange(1,100.)/50.
>>> scale = count.max()/weib(x, 1., 5.).max()
>>> plt.plot(x, weib(x, 1., 5.)*scale)
>>> plt.show()
```

```
numpy.random.zipf(a, size=None)
```

Draw samples from a Zipf distribution.

Samples are drawn from a Zipf distribution with specified parameter $a > 1$.

The Zipf distribution (also known as the zeta distribution) is a continuous probability distribution that satisfies Zipf's law: the frequency of an item is inversely proportional to its rank in a frequency table.

Parameters

- **a**: float > 1
  Distribution parameter.

- **size**: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.
Returns

samples : scalar or ndarray

The returned samples are greater than or equal to one.

See also:

`scipy.stats.distributions.zipf`

probability density function, distribution, or cumulative density function, etc.

Notes

The probability density for the Zipf distribution is

\[ p(x) = \frac{x^{-a}}{\zeta(a)} \]

where \( \zeta \) is the Riemann Zeta function.

It is named for the American linguist George Kingsley Zipf, who noted that the frequency of any word in a sample of a language is inversely proportional to its rank in the frequency table.

References


Examples

Draw samples from the distribution:

```python
>>> a = 2. # parameter
>>> s = np.random.zipf(a, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps
>>> count, bins, ignored = plt.hist(s[s<50], 50, normed=True)
>>> x = np.arange(1., 50.)
>>> y = x**(-a)/sps.zetac(a)
>>> plt.plot(x, y/max(y), linewidth=2, color='r')
>>> plt.show()
```

3.25.4 Random generator

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**class** `numpy.random.RandomState`  
Container for the Mersenne Twister pseudo-random number generator.

`RandomState` exposes a number of methods for generating random numbers drawn from a variety of probability distributions. In addition to the distribution-specific arguments, each method takes a keyword argument
that defaults to None. If size is None, then a single value is generated and returned. If size is an integer, then a 1-D array filled with generated values is returned. If size is a tuple, then an array with that shape is filled and returned.

Parameters

- **seed**: {None, int, array_like}, optional
  Random seed initializing the pseudo-random number generator. Can be an integer, an array (or other sequence) of integers of any length, or None (the default). If seed is None, then RandomState will try to read data from /dev/urandom (or the Windows analogue) if available or seed from the clock otherwise.

Notes

The Python stdlib module “random” also contains a Mersenne Twister pseudo-random number generator with a number of methods that are similar to the ones available in RandomState. RandomState, besides being NumPy-aware, has the advantage that it provides a much larger number of probability distributions to choose from.

Methods

- **beta(a, b, size)**: The Beta distribution over [0, 1].
- **binomial(n, p[, size])**: Draw samples from a binomial distribution.
- **bytes(length)**: Return random bytes.
- **chisquare(df[, size])**: Draw samples from a chi-square distribution.
- **choice(a[, size, replace, p])**: Generates a random sample from a given 1-D array. ..
- **dirichlet(alpha[, size])**: Draw samples from the Dirichlet distribution.
- **exponential([scale, size])**: Exponential distribution.
- **f(dfnum, dfden[, size])**: Draw samples from a F distribution.
- **gamma(shape[, scale, size])**: Draw samples from a Gamma distribution.
- **geometric(p[, size])**: Draw samples from the geometric distribution.
- **get_state()**: Return a tuple representing the internal state of the generator.
- **gumbel([loc, scale, size])**: Gumbel distribution.
- **hypergeometric(ngood, nbad, nsample[, size])**: Draw samples from a Hypergeometric distribution.
- **laplace([loc, scale, size])**: Draw samples from the Laplace or double exponential distribution with specified location (or mean) and scale (decay).
- **logistic([loc, scale, size])**: Draw samples from a Logistic distribution.
- **lognormal([mean, sigma, size])**: Draw samples drawn from a log-normal distribution.
- **logseries(p[, size])**: Draw samples from a Logarithmic Series distribution.
- **multinomial(n, pvals[, size])**: Draw samples from a multinomial distribution.
- **multivariate_normal(mean, cov[, size])**: Draw random samples from a multivariate normal distribution.
- **negative_binomial(n, p[, size])**: Draw samples from a negative_binomial distribution.
- **noncentral_chisquare(df, nonc[, size])**: Draw samples from a noncentral chi-square distribution.
- **noncentral_f(dfnum, dfden, nonc[, size])**: Draw samples from a noncentral F distribution.
- **normal([loc, scale, size])**: Draw random samples from a normal (Gaussian) distribution.
- **negative_binomial(n, p[, size])**: Draw samples from a negative_binomial distribution.
- **noncentral_chisquare(df, nonc[, size])**: Draw samples from a noncentral chi-square distribution.
- **noncentral_f(dfnum, dfden, nonc[, size])**: Draw samples from a noncentral F distribution.
- **pareto(a[, size])**: Draw samples from a Pareto II or Lomax distribution with specified shape.
- **permutation(x)**: Randomly permute a sequence, or return a permuted range.
- **poisson([lam, size])**: Draw samples from a Poisson distribution.
- **power(a[, size])**: Draws samples in [0, 1] from a power distribution with positive exponent a - 1. Random values in a given shape.
- **rand(d0, d1, ..., dn)**: Return random integers from low (inclusive) to high (exclusive).
- **randint(low[, high, size])**: Return a sample (or samples) from the “standard normal” distribution.
- **random_integers(low[, high, size])**: Return random integers between low and high, inclusive.
- **random_sample([size])**: Return random floats in the half-open interval [0.0, 1.0).
- **rayleigh([scale, size])**: Draw samples from a Rayleigh distribution.
- **seed([seed])**: Seed the generator.
<table>
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<th>Function</th>
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<td><code>set_state(state)</code></td>
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<td><code>shuffle(x)</code></td>
<td>Modify a sequence in-place by shuffling its contents.</td>
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<tr>
<td><code>standard_cauchy([size])</code></td>
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<tr>
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<td>Draw samples from a Zipf distribution.</td>
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**RandomState.beta(a, b, size=None)**

The Beta distribution over `[0, 1]`.

The Beta distribution is a special case of the Dirichlet distribution, and is related to the Gamma distribution. It has the probability distribution function

\[
f(x; a, b) = \frac{1}{B(a, b)} x^{a-1}(1 - x)^{b-1},
\]

where the normalisation, B, is the beta function,

\[
B(a, b) = \int_0^1 t^{a-1}(1 - t)^{b-1}dt.
\]

It is often seen in Bayesian inference and order statistics.

**Parameters**
- `a`: float
  - Alpha, non-negative.
- `b`: float
  - Beta, non-negative.
- `size`: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is `None`, in which case a single value is returned.

**Returns**
- `out`: ndarray
  - Array of the given shape, containing values drawn from a Beta distribution.

**RandomState.binomial(n, p, size=None)**

Draw samples from a binomial distribution.

Samples are drawn from a Binomial distribution with specified parameters, n trials and p probability of success where n an integer >= 0 and p is in the interval [0,1]. (n may be input as a float, but it is truncated to an integer in use)

**Parameters**
- `n`: float (but truncated to an integer)
parameter, \( \geq 0 \).

**p** : float
parameter, \( \geq 0 \) and \( \leq 1 \).

**size** : int or tuple of ints, optional
Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

**Returns**
- **samples** : {ndarray, scalar}
  where the values are all integers in \([0, n]\).

**See also:**
- scipy.stats.distributions.binom
  probability density function, distribution or cumulative density function, etc.

**Notes**
The probability density for the Binomial distribution is

\[
P(N) = \binom{n}{N} p^N (1 - p)^{n-N},
\]

where \(n\) is the number of trials, \(p\) is the probability of success, and \(N\) is the number of successes.

When estimating the standard error of a proportion in a population by using a random sample, the normal distribution works well unless the product \(p \times n \leq 5\), where \(p\) = population proportion estimate, and \(n\) = number of samples, in which case the binomial distribution is used instead. For example, a sample of 15 people shows 4 who are left handed, and 11 who are right handed. Then \(p = 4/15 = 27\%\). \(0.27 \times 15 = 4\), so the binomial distribution should be used in this case.

**References**
[R125], [R126], [R127], [R128], [R129]

**Examples**
Draw samples from the distribution:

```python
>>> n, p = 10, .5  # number of trials, probability of each trial
>>> s = np.random.binomial(n, p, 1000)
# result of flipping a coin 10 times, tested 1000 times.
```

A real world example. A company drills 9 wild-cat oil exploration wells, each with an estimated probability of success of 0.1. All nine wells fail. What is the probability of that happening?

Let’s do 20,000 trials of the model, and count the number that generate zero positive results.

```python
>>> sum(np.random.binomial(9, 0.1, 20000)==0)/20000.
answer = 0.38885, or 38\%.
```

**RandomState.bytes(length)**
Return random bytes.

**Parameters**
- **length** : int
  Number of random bytes.
Returns

out : str

String of length \textit{length}.

Examples

```python
>>> np.random.bytes(10)
'eh\x85\x02SZ\x9d\xa4' #random
```

```python
RandomState.chisquare(df, size=None)
```

Draw samples from a chi-square distribution.

When \(df\) independent random variables, each with standard normal distributions (mean 0, variance 1), are squared and summed, the resulting distribution is chi-square (see Notes). This distribution is often used in hypothesis testing.

Parameters

- \textbf{df} : int
  - Number of degrees of freedom.

- \textbf{size} : int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m * n * k\) samples are drawn. Default is None, in which case a single value is returned.

Returns

- \textbf{output} : ndarray
  - Samples drawn from the distribution, packed in a \textit{size}-shaped array.

Raises

- \textbf{ValueError}
  - When \(df \leq 0\) or when an inappropriate \textit{size} (e.g. \textit{size}=-1) is given.

Notes

The variable obtained by summing the squares of \(df\) independent, standard normally distributed random variables:

\[
Q = \sum_{i=0}^{df} X_i^2
\]

is chi-square distributed, denoted

\[
Q \sim \chi^2_k.
\]

The probability density function of the chi-squared distribution is

\[
p(x) = \frac{(1/2)^{k/2}}{\Gamma(k/2)} x^{k/2-1} e^{-x/2},
\]

where \(\Gamma\) is the gamma function,

\[
\Gamma(x) = \int_0^{-\infty} t^{x-1} e^{-t} dt.
\]

References

NIST/SEMATECH e-Handbook of Statistical Methods
Examples

>>> np.random.chisquare(2, 4)
array([ 1.89920014, 9.00867716, 3.13710533, 5.62318272])

RandomState.choice(a, size=None, replace=True, p=None)
Generates a random sample from a given 1-D array

Parameters

a : 1-D array-like or int
If an ndarray, a random sample is generated from its elements. If an int, the random
sample is generated as if a was np.arange(n)

size : int or tuple of ints, optional
Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are
drawn. Default is None, in which case a single value is returned.

replace : boolean, optional
Whether the sample is with or without replacement

p : 1-D array-like, optional
The probabilities associated with each entry in a. If not given the sample assumes a
uniform distribution over all entries in a.

Returns

samples : 1-D ndarray, shape (size,)
The generated random samples

Raises

ValueError
If a is an int and less than zero, if a or p are not 1-dimensional, if a is an array-like
of size 0, if p is not a vector of probabilities, if a and p have different lengths, or if
replace=False and the sample size is greater than the population size

See also:
randint, shuffle, permutation

Examples

Generate a uniform random sample from np.arange(5) of size 3:

>>> np.random.choice(5, 3)
array([0, 3, 4])
>>> #This is equivalent to np.random.randint(0,5,3)

Generate a non-uniform random sample from np.arange(5) of size 3:

>>> np.random.choice(5, 3, p=[0.1, 0, 0.3, 0.6, 0])
array([3, 3, 0])

Generate a uniform random sample from np.arange(5) of size 3 without replacement:

>>> np.random.choice(5, 3, replace=False)
array([3, 1, 0])
>>> #This is equivalent to np.random.permutation(np.arange(5))[:3]
Generate a non-uniform random sample from np.arange(5) of size 3 without replacement:

```python
>>> np.random.choice(5, 3, replace=False, p=[0.1, 0, 0.3, 0.6, 0])
array([2, 3, 0])
```

Any of the above can be repeated with an arbitrary array-like instead of just integers. For instance:

```python
>>> aa_milne_arr = ['pooh', 'rabbit', 'piglet', 'Christopher']
>>> np.random.choice(aa_milne_arr, 5, p=[0.5, 0.1, 0.1, 0.3])
array(['pooh', 'pooh', 'pooh', 'Christopher', 'piglet'],
      dtype='|S11')
```

.RandomState.\texttt{dirichlet}(alpha, size=None)

Draw samples from the Dirichlet distribution.

Draw size samples of dimension k from a Dirichlet distribution. A Dirichlet-distributed random variable can be seen as a multivariate generalization of a Beta distribution. Dirichlet pdf is the conjugate prior of a multinomial in Bayesian inference.

**Parameters**

- **alpha**: array
  Parameter of the distribution (k dimension for sample of dimension k).
- **size**: array
  Number of samples to draw.

**Returns**

- **samples**: ndarray
  The drawn samples, of shape (alpha.ndim, size).

**Notes**

\[ X \approx \prod_{i=1}^{k} x_i^{\alpha_i - 1} \]

Uses the following property for computation: for each dimension, draw a random sample \( y_i \) from a standard gamma generator of shape alpha_i, then \( X = \sum_{i=1}^{n} \frac{1}{y_i} (y_1, \ldots, y_n) \) is Dirichlet distributed.

**References**

[R130], [R131]

**Examples**

Taking an example cited in Wikipedia, this distribution can be used if one wanted to cut strings (each of initial length 1.0) into \( K \) pieces with different lengths, where each piece had, on average, a designated average length, but allowing some variation in the relative sizes of the pieces.

```python
>>> s = np.random.dirichlet((10, 5, 3), 20).transpose()
>>> plt.barh(range(20), s[0])
>>> plt.barh(range(20), s[1], left=s[0], color='g')
>>> plt.barh(range(20), s[2], left=s[0]+s[1], color='r')
>>> plt.title("Lengths of Strings")
```

.RandomState.\texttt{exponential}(scale=1.0, size=None)

Exponential distribution.
Its probability density function is

\[ f(x; \frac{1}{\beta}) = \frac{1}{\beta} \exp\left(-\frac{x}{\beta}\right), \]

for \( x > 0 \) and 0 elsewhere. \( \beta \) is the scale parameter, which is the inverse of the rate parameter \( \lambda = 1/\beta \). The rate parameter is an alternative, widely used parameterization of the exponential distribution [R134].

The exponential distribution is a continuous analogue of the geometric distribution. It describes many common situations, such as the size of raindrops measured over many rainstorms [R132], or the time between page requests to Wikipedia [R133].

**Parameters**
- `scale`: float
  - The scale parameter, \( \beta = 1/\lambda \).
- `size`: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m * n * k\) samples are drawn. Default is None, in which case a single value is returned.

**References**
[R132], [R133], [R134]

**RandomState.f** *(dfnum, dfden, size=None)*

Draw samples from an F distribution.

Samples are drawn from an F distribution with specified parameters, `dfnum` (degrees of freedom in numerator) and `dfden` (degrees of freedom in denominator), where both parameters should be greater than zero.

The random variate of the F distribution (also known as the Fisher distribution) is a continuous probability distribution that arises in ANOVA tests, and is the ratio of two chi-square variates.

**Parameters**
- `dfnum`: float
  - Degrees of freedom in numerator. Should be greater than zero.
- `dfden`: float
  - Degrees of freedom in denominator. Should be greater than zero.
- `size`: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m * n * k\) samples are drawn. Default is None, in which case a single value is returned.

**Returns**
- `samples`: {ndarray, scalar}
  - Samples from the Fisher distribution.

**See also:**
- `scipy.stats.distributions.f`
  - probability density function, distribution or cumulative density function, etc.
Notes
The F statistic is used to compare in-group variances to between-group variances. Calculating the distribution depends on the sampling, and so it is a function of the respective degrees of freedom in the problem. The variable \( dfnum \) is the number of samples minus one, the between-groups degrees of freedom, while \( dfden \) is the within-groups degrees of freedom, the sum of the number of samples in each group minus the number of groups.

References
[R135], [R136]

Examples
An example from Glantz[1], pp 47-40. Two groups, children of diabetics (25 people) and children from people without diabetes (25 controls). Fasting blood glucose was measured, case group had a mean value of 86.1, controls had a mean value of 82.2. Standard deviations were 2.09 and 2.49 respectively. Are these data consistent with the null hypothesis that the parents diabetic status does not affect their children’s blood glucose levels? Calculating the F statistic from the data gives a value of 36.01.

Draw samples from the distribution:

```python
>>> dfnum = 1. # between group degrees of freedom
>>> dfden = 48. # within groups degrees of freedom
>>> s = np.random.f(dfnum, dfden, 1000)
```

The lower bound for the top 1% of the samples is:

```python
>>> sort(s)[-10]
7.61988120985
```

So there is about a 1% chance that the F statistic will exceed 7.62, the measured value is 36, so the null hypothesis is rejected at the 1% level.

RandomState. gamma(\( \text{shape} \), \( \text{scale}=1.0 \), \( \text{size}=\text{None} \))
Draw samples from a Gamma distribution.

Samples are drawn from a Gamma distribution with specified parameters, \( \text{shape} \) (sometimes designated “\( k \)”) and \( \text{scale} \) (sometimes designated “\( \theta \)”), where both parameters are > 0.

Parameters
- \( \text{shape} \): scalar > 0
  - The shape of the gamma distribution.
- \( \text{scale} \): scalar > 0, optional
  - The scale of the gamma distribution. Default is equal to 1.
- \( \text{size} \): int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \( (m, n, k) \), then \( m \times n \times k \) samples are drawn. Default is None, in which case a single value is returned.

Returns
- \( \text{out} \): ndarray, float
  - Returns one sample unless \( \text{size} \) parameter is specified.

See also:
- scipy.stats.distributions.gamma
  - probability density function, distribution or cumulative density function, etc.
**Notes**

The probability density for the Gamma distribution is

\[ p(x) = x^{k-1} \frac{e^{-x/\theta}}{\theta^k \Gamma(k)}, \]

where \( k \) is the shape and \( \theta \) the scale, and \( \Gamma \) is the Gamma function.

The Gamma distribution is often used to model the times to failure of electronic components, and arises naturally in processes for which the waiting times between Poisson distributed events are relevant.

**References**

[R137], [R138]

**Examples**

Draw samples from the distribution:

```python
>>> shape, scale = 2., 2.  # mean and dispersion
>>> s = np.random.gamma(shape, scale, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps

>>> count, bins, ignored = plt.hist(s, 50, normed=True)
>>> y = bins**(shape-1)*(np.exp(-bins/scale) / ...
...     (sps.gamma(shape)*scale**shape))
>>> plt.plot(bins, y, linewidth=2, color='r')
>>> plt.show()
```

**RandomState.geometric(p, size=None)**

Draw samples from the geometric distribution.

Bernoulli trials are experiments with one of two outcomes: success or failure (an example of such an experiment is flipping a coin). The geometric distribution models the number of trials that must be run in order to achieve success. It is therefore supported on the positive integers, \( k = 1, 2, \ldots \).

The probability mass function of the geometric distribution is

\[ f(k) = (1 - p)^{k-1} p \]

where \( p \) is the probability of success of an individual trial.

**Parameters**

- \( p \) : float
  - The probability of success of an individual trial.

- \( size \) : int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \( (m, n, k) \), then \( m \times n \times k \) samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- \( out \) : ndarray
  - Samples from the geometric distribution, shaped according to \( size \).
**Examples**

Draw ten thousand values from the geometric distribution, with the probability of an individual success equal to 0.35:

```python
>>> z = np.random.geometric(p=0.35, size=10000)
```

How many trials succeeded after a single run?

```python
>>> (z == 1).sum() / 10000.
0.34889999999999999  # random
```

`RandomState.get_state()`

Return a tuple representing the internal state of the generator.

For more details, see `set_state`.

**Returns**

- `out`: tuple(str, ndarray of 624 uints, int, int, float)

  The returned tuple has the following items:

  1. the string 'MT19937'.
  2. a 1-D array of 624 unsigned integer keys.
  3. an integer pos.
  4. an integer has_gauss.
  5. a float cached_gaussian.

**See also:**

- `set_state`

**Notes**

`set_state` and `get_state` are not needed to work with any of the random distributions in NumPy. If the internal state is manually altered, the user should know exactly what he/she is doing.

`RandomState.gumbel` *(loc=0.0, scale=1.0, size=None)*

Gumbel distribution.

Draw samples from a Gumbel distribution with specified location and scale. For more information on the Gumbel distribution, see Notes and References below.

**Parameters**

- `loc`: float

  The location of the mode of the distribution.

- `scale`: float

  The scale parameter of the distribution.

- `size`: int or tuple of ints, optional

  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- `out`: ndarray

  The samples
See also:
scipy.stats.gumbel_l, scipy.stats.gumbel_r
scipy.stats.genextreme
probability density function, distribution, or cumulative density function, etc. for each of the above
weibull

Notes
The Gumbel (or Smallest Extreme Value (SEV) or the Smallest Extreme Value Type I) distribution is one
of a class of Generalized Extreme Value (GEV) distributions used in modeling extreme value problems.
The Gumbel is a special case of the Extreme Value Type I distribution for maximums from distributions
with “exponential-like” tails.
The probability density for the Gumbel distribution is

\[ p(x) = \frac{e^{-(x-\mu)/\beta}}{\beta} e^{-e^{-(x-\mu)/\beta}}, \]

where \( \mu \) is the mode, a location parameter, and \( \beta \) is the scale parameter.
The Gumbel (named for German mathematician Emil Julius Gumbel) was used very early in the hydrology
literature, for modeling the occurrence of flood events. It is also used for modeling maximum wind speed
and rainfall rates. It is a “fat-tailed” distribution - the probability of an event in the tail of the distribution is
larger than if one used a Gaussian, hence the surprisingly frequent occurrence of 100-year floods. Floods
were initially modeled as a Gaussian process, which underestimated the frequency of extreme events.
It is one of a class of extreme value distributions, the Generalized Extreme Value (GEV) distributions,
which also includes the Weibull and Frechet.
The function has a mean of \( \mu + 0.57721\beta \) and a variance of \( \frac{\pi^2}{6} \beta^2 \).

References
Reiss, R.-D. and Thomas, M., *Statistical Analysis of Extreme Values from Insurance, Finance, Hydrology

Examples
Draw samples from the distribution:

```python
>>> mu, beta = 0, 0.1 # location and scale
>>> s = np.random.gumbel(mu, beta, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, normed=True)
>>> plt.plot(bins, (1/beta)*np.exp(-(bins - mu)/beta)
... * np.exp( -np.exp( -(bins - mu) /beta) ),
... linewidth=2, color='r')
```

```bash
>> plt.show()
```
Show how an extreme value distribution can arise from a Gaussian process and compare to a Gaussian:

```python
>>> means = []
>>> maxima = []
>>> for i in range(0, 1000):
...     a = np.random.normal(mu, beta, 1000)
...     means.append(a.mean())
...     maxima.append(a.max())
>>> count, bins, ignored = plt.hist(maxima, 30, normed=True)
>>> beta = np.std(maxima) * np.pi / np.sqrt(6)
>>> mu = np.mean(maxima) - 0.57721 * beta
>>> plt.plot(bins, (1 / beta) * np.exp(-(bins - mu) / beta)
... * np.exp(-np.exp(-(bins - mu) / beta)),
... linewidth=2, color='r')
>>> plt.plot(bins, 1 / (beta * np.sqrt(2 * np.pi))
... * np.exp(-(bins - mu)**2 / (2 * beta**2)),
... linewidth=2, color='g')
>>> plt.show()
```
RandomState.hypergeometric(ngood, nbad, nsample, size=None)

Draw samples from a Hypergeometric distribution.

Samples are drawn from a Hypergeometric distribution with specified parameters, ngood (ways to make a
good selection), nbad (ways to make a bad selection), and nsample = number of items sampled, which is
less than or equal to the sum ngood + nbad.

Parameters

ngood : int or array_like
    Number of ways to make a good selection. Must be nonnegative.

nbad : int or array_like
    Number of ways to make a bad selection. Must be nonnegative.

nsample : int or array_like
    Number of items sampled. Must be at least 1 and at most ngood + nbad.

size : int or tuple of ints, optional
    Output shape. If the given shape is, e.g., (m, n, k), then
    m * n * k samples are
drawn. Default is None, in which case a single value is returned.

Returns

samples : ndarray or scalar
    The values are all integers in [0, n].

See also:

scipy.stats.distributions.hypergeom
    probability density function, distribution or cumulative density function, etc.

Notes

The probability density for the Hypergeometric distribution is

\[ P(x) = \binom{m}{x} \frac{(N-m)}{n-x} \frac{x}{N} \]

where 0 \(\leq x \leq m\) and \(n + m - N \leq x \leq n\)
for \(P(x)\) the probability of \(x\) successes, \(n = ngood\), \(m = nbad\), and \(N = \text{number of samples}\).

Consider an urn with black and white marbles in it, ngood of them black and nbad are white. If you
draw nsample balls without replacement, then the Hypergeometric distribution describes the distribution
of black balls in the drawn sample.

Note that this distribution is very similar to the Binomial distribution, except that in this case, samples
are drawn without replacement, whereas in the Binomial case samples are drawn with replacement (or the
sample space is infinite). As the sample space becomes large, this distribution approaches the Binomial.

References

[R139], [R140], [R141]

Examples

Draw samples from the distribution:
Suppose you have an urn with 15 white and 15 black marbles. If you pull 15 marbles at random, how likely is it that 12 or more of them are one color?

```python
>>> s = np.random.hypergeometric(15, 15, 15, 100000)
>>> sum(s>=12)/100000. + sum(s<=3)/100000.
# answer = 0.003 ... pretty unlikely!
```

RandomState\texttt{.laplace}(loc=0.0, scale=1.0, size=None)

Draw samples from the Laplace or double exponential distribution with specified location (or mean) and scale (decay).

The Laplace distribution is similar to the Gaussian/normal distribution, but is sharper at the peak and has fatter tails. It represents the difference between two independent, identically distributed exponential random variables.

**Parameters**

- **loc**: float
  - The position, \(\mu\), of the distribution peak.

- **scale**: float
  - \(\lambda\), the exponential decay.

- **size**: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

**Notes**

It has the probability density function

\[
f(x; \mu, \lambda) = \frac{1}{2\lambda} \exp \left( -\frac{|x - \mu|}{\lambda} \right).\]

The first law of Laplace, from 1774, states that the frequency of an error can be expressed as an exponential function of the absolute magnitude of the error, which leads to the Laplace distribution. For many problems in Economics and Health sciences, this distribution seems to model the data better than the standard Gaussian distribution.

**References**

[R142], [R143], [R144], [R145]

**Examples**

Draw samples from the distribution

```python
>>> loc, scale = 0., 1.
>>> s = np.random.laplace(loc, scale, 1000)
```

Display the histogram of the samples, along with the probability density function:
```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, normed=True)
>>> x = np.arange(-8., 8., .01)
>>> pdf = np.exp(-abs(x-loc)/scale)/(2.*scale)
>>> plt.plot(x, pdf)

Plot Gaussian for comparison:

```python
>>> g = (1/(scale * np.sqrt(2 * np.pi)) * ... np.exp(-(x - loc)**2 / (2 * scale**2)))
>>> plt.plot(x,g)
```

RandomState.logistic(loc=0.0, scale=1.0, size=None)
Draw samples from a Logistic distribution.

Samples are drawn from a Logistic distribution with specified parameters, loc (location or mean, also median), and scale (>0).

**Parameters**
- **loc**: float
- **scale**: float > 0.
- **size**: int or tuple of ints, optional

Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**
- **samples**: {ndarray, scalar}
  where the values are all integers in [0, n].

See also:
- scipy.stats.distributions.logistic
  probability density function, distribution or cumulative density function, etc.
Notes

The probability density for the Logistic distribution is

\[ P(x) = P(x) = \frac{e^{-(x-\mu)/s}}{s(1 + e^{-(x-\mu)/s})^2}, \]

where \( \mu \) = location and \( s \) = scale.

The Logistic distribution is used in Extreme Value problems where it can act as a mixture of Gumbel distributions, in Epidemiology, and by the World Chess Federation (FIDE) where it is used in the Elo ranking system, assuming the performance of each player is a logistically distributed random variable.

References

[R146], [R147], [R148]

Examples

Draw samples from the distribution:

```python
>>> loc, scale = 10, 1
>>> s = np.random.logistic(loc, scale, 10000)
>>> count, bins, ignored = plt.hist(s, bins=50)
```

# plot against distribution

```python
>>> def logist(x, loc, scale):
...     return exp((loc-x)/scale)/(scale*(1+exp((loc-x)/scale))**2)
>>> plt.plot(bins, logist(bins, loc, scale)*count.max()/
...          logist(bins, loc, scale).max())
```

RandomState.lognormal(mean=0.0, sigma=1.0, size=None)

Return samples drawn from a log-normal distribution.

Draw samples from a log-normal distribution with specified mean, standard deviation, and array shape. Note that the mean and standard deviation are not the values for the distribution itself, but of the underlying normal distribution it is derived from.

Parameters

- **mean**: float
  Mean value of the underlying normal distribution

- **sigma**: float, > 0.
  Standard deviation of the underlying normal distribution

- **size**: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

Returns

- **samples**: ndarray or float
  The desired samples. An array of the same shape as \(size\) if given, if \(size\) is None a float is returned.

See also:

- scipy.stats.lognorm
  probability density function, distribution, cumulative density function, etc.
Notes

A variable \( x \) has a log-normal distribution if \( \log(x) \) is normally distributed. The probability density function for the log-normal distribution is:

\[
p(x) = \frac{1}{\sigma x \sqrt{2 \pi}} e^{\left(-\frac{(\log(x) - \mu)^2}{2\sigma^2}\right)}
\]

where \( \mu \) is the mean and \( \sigma \) is the standard deviation of the normally distributed logarithm of the variable.

A log-normal distribution results if a random variable is the product of a large number of independent, identically-distributed variables in the same way that a normal distribution results if the variable is the sum of a large number of independent, identically-distributed variables.

References


Examples

Draw samples from the distribution:

```python
>>> mu, sigma = 3., 1. # mean and standard deviation
>>> s = np.random.lognormal(mu, sigma, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 100, normed=True, align='mid')
>>> x = np.linspace(min(bins), max(bins), 10000)
>>> pdf = (np.exp(-(np.log(x) - mu)**2 / (2 * sigma**2))
... / (x * sigma * np.sqrt(2 * np.pi)))
>>> plt.plot(x, pdf, linewidth=2, color='r')
>>> plt.axis('tight')
>>> plt.show()
```

Demonstrate that taking the products of random samples from a uniform distribution can be fit well by a log-normal probability density function.

```python
>>> # Generate a thousand samples: each is the product of 100 random
>>> # values, drawn from a normal distribution.
>>> b = []
>>> for i in range(1000):
... a = 10. + np.random.normal(100)
... b.append(np.product(a))
>>> b = np.array(b) / np.min(b) # scale values to be positive
>>> count, bins, ignored = plt.hist(b, 100, normed=True, align='center')
>>> sigma = np.std(np.log(b))
>>> mu = np.mean(np.log(b))
>>> x = np.linspace(min(bins), max(bins), 10000)
>>> pdf = (np.exp(-(np.log(x) - mu)**2 / (2 * sigma**2))
... / (x * sigma * np.sqrt(2 * np.pi)))
```

1218 Chapter 3. Routines
RandomState.logseries (p, size=None)

Draw samples from a Logarithmic Series distribution.

Samples are drawn from a Log Series distribution with specified parameter, p (probability, 0 < p < 1).

Parameters

 loc : float

 scale : float > 0.

 size : int or tuple of ints, optional

 Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

Returns

 samples : {ndarray, scalar}

 where the values are all integers in [0, n].

See also:

 scipy.stats.distributions.logser

 probability density function, distribution or cumulative density function, etc.

Notes

The probability density for the Log Series distribution is

\[
P(k) = \frac{-p^k}{k \ln(1 - p)},
\]

where p = probability.

The Log Series distribution is frequently used to represent species richness and occurrence, first proposed by Fisher, Corbet, and Williams in 1943 [2]. It may also be used to model the numbers of occupants seen in cars [3].

References

[R149], [R150], [R151], [R152]

Examples

Draw samples from the distribution:

>>> a = .6
>>> s = np.random.logseries(a, 10000)
>>> count, bins, ignored = plt.hist(s)

# plot against distribution

>>> def logseries(k, p):
...     return -p**k/(k*log(1-p))
>>> plt.plot(bins, logseries(bins, a)*count.max()/logseries(bins, a).max(),'r')
>>> plt.show()
RandomState.multinomial(n, pvals, size=None)

Draw samples from a multinomial distribution.

The multinomial distribution is a multivariate generalisation of the binomial distribution. Take an experiment with one of p possible outcomes. An example of such an experiment is throwing a dice, where the outcome can be 1 through 6. Each sample drawn from the distribution represents n such experiments. Its values, \(X_i = [X_0, X_1, \ldots, X_p]\), represent the number of times the outcome was i.

**Parameters**

- **n**: int
  - Number of experiments.

- **pvals**: sequence of floats, length p
  - Probabilities of each of the p different outcomes. These should sum to 1 (however, the last element is always assumed to account for the remaining probability, as long as \(\sum(pvals[:-1]) \leq 1\)).

- **size**: tuple of ints
  - Given a size of (M, N, K), then MNK samples are drawn, and the output shape becomes (M, N, K, p), since each sample has shape (p,).

**Examples**

Throw a dice 20 times:

```python
>>> np.random.multinomial(20, [1/6.]*6, size=1)
array([[4, 1, 7, 5, 2, 1]])
```

It landed 4 times on 1, once on 2, etc.

Now, throw the dice 20 times, and 20 times again:

```python
>>> np.random.multinomial(20, [1/6.]*6, size=2)
array([[3, 4, 3, 3, 4, 3],
       [2, 4, 3, 4, 0, 7]])
```

For the first run, we threw 3 times 1, 4 times 2, etc. For the second, we threw 2 times 1, 4 times 2, etc.

A loaded dice is more likely to land on number 6:

```python
>>> np.random.multinomial(100, [1/7.]*5)
array([13, 16, 13, 16, 42])
```

RandomState.multivariate_normal(mean, cov[, size])

Draw random samples from a multivariate normal distribution.

The multivariate normal, multinormal or Gaussian distribution is a generalization of the one-dimensional normal distribution to higher dimensions. Such a distribution is specified by its mean and covariance matrix. These parameters are analogous to the mean (average or “center”) and variance (standard deviation, or “width,” squared) of the one-dimensional normal distribution.

**Parameters**

- **mean**: 1-D array_like, of length N
  - Mean of the N-dimensional distribution.

- **cov**: 2-D array_like, of shape (N, N)
  - Covariance matrix of the distribution. Must be symmetric and positive-semidefinite for “physically meaningful” results.
size : int or tuple of ints, optional

Given a shape of, for example, \((m, n, k)\), \(m\times n \times k\) samples are generated, and packed in an \(m\)-by-\(n\)-by-\(k\) arrangement. Because each sample is \(N\)-dimensional, the output shape is \((m, n, k, N)\). If no shape is specified, a single \((N\text{-D})\) sample is returned.

Returns
out : ndarray

The drawn samples, of shape \(size\), if that was provided. If not, the shape is \((N,)\).

In other words, each entry \(out[i,j,...,:]\) is an \(N\)-dimensional value drawn from the distribution.

Notes

The mean is a coordinate in \(N\)-dimensional space, which represents the location where samples are most likely to be generated. This is analogous to the peak of the bell curve for the one-dimensional or univariate normal distribution.

Covariance indicates the level to which two variables vary together. From the multivariate normal distribution, we draw \(N\)-dimensional samples, \(X = [x_1, x_2, ... x_N]\). The covariance matrix element \(C_{ij}\) is the covariance of \(x_i\) and \(x_j\). The element \(C_{ii}\) is the variance of \(x_i\) (i.e. its “spread”).

Instead of specifying the full covariance matrix, popular approximations include:

• Spherical covariance (\(cov\) is a multiple of the identity matrix)

• Diagonal covariance (\(cov\) has non-negative elements, and only on the diagonal)

This geometrical property can be seen in two dimensions by plotting generated data-points:

```python
mean = [0,0]
cov = [[1,0],[0,100]] # diagonal covariance, points lie on x or y-axis

import matplotlib.pyplot as plt
x,y = np.random.multivariate_normal(mean,cov,5000).T
plt.plot(x,y,'x'); plt.axis('equal'); plt.show()
```

Note that the covariance matrix must be non-negative definite.

References


Examples

```python
mean = (1,2)
cov = [[1,0],[1,0]]
x = np.random.multivariate_normal(mean,cov,(3,3))
x.shape
(3, 3, 2)
```

The following is probably true, given that 0.6 is roughly twice the standard deviation:

```python
print list( (x[0,0,:] - mean) < 0.6 )
[True, True]
```

`RandomState.negative_binomial(n, p, size=None)`

Draw samples from a negative_binomial distribution.
Samples are drawn from a negative_Binomial distribution with specified parameters, $n$ trials and $p$ probability of success where $n$ is an integer $>0$ and $p$ is in the interval $[0, 1]$.

**Parameters**

- **n**: int
  - Parameter, $>0$.
- **p**: float
  - Parameter, $\geq 0$ and $\leq 1$.
- **size**: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., $(m, n, k)$, then $m \times n \times k$ samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- **samples**: int or ndarray of ints
  - Drawn samples.

**Notes**

The probability density for the Negative Binomial distribution is

$$P(N; n, p) = \binom{N + n - 1}{n - 1} p^n (1 - p)^N,$$

where $n - 1$ is the number of successes, $p$ is the probability of success, and $N + n - 1$ is the number of trials.

The negative binomial distribution gives the probability of $n$-1 successes and $N$ failures in $N+n$-1 trials, and success on the $(N+n)$th trial.

If one throws a die repeatedly until the third time a “1” appears, then the probability distribution of the number of non-“1”s that appear before the third “1” is a negative binomial distribution.

**References**

[R153], [R154]

**Examples**

Draw samples from the distribution:

A real world example. A company drills wild-cat oil exploration wells, each with an estimated probability of success of 0.1. What is the probability of having one success for each successive well, that is what is the probability of a single success after drilling 5 wells, after 6 wells, etc.?

```python
>>> s = np.random.negative_binomial(1, 0.1, 100000)
>>> for i in range(1, 11):
...     probability = sum(s<i) / 100000.
...     print i, "wells drilled, probability of one success =", probability
```

RandomState.**noncentral_chisquare** $(df, nonc, size=None)$

Draw samples from a noncentral chi-square distribution.

The noncentral $\chi^2$ distribution is a generalisation of the $\chi^2$ distribution.

**Parameters**

- **df**: int
  - Degrees of freedom, should be $\geq 1$. 

---

**NumPy Reference, Release 1.9.2**
**nonc** : float
Non-centrality, should be > 0.

**size** : int or tuple of ints, optional
Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Notes**
The probability density function for the noncentral Chi-square distribution is

\[
P(x; df, nonc) = \sum_{i=0}^{\infty} \frac{e^{-nonc/2}(nonc/2)^i}{i!} P_{Y_{df+2i}}(x),
\]

where \( Y_q \) is the Chi-square with \( q \) degrees of freedom.

In Delhi (2007), it is noted that the noncentral chi-square is useful in bombing and coverage problems, the probability of killing the point target given by the noncentral chi-squared distribution.

**References**
[R155], [R156]

**Examples**
Draw values from the distribution and plot the histogram

```python
>>> import matplotlib.pyplot as plt
>>> values = plt.hist(np.random.noncentral_chisquare(3, 20, 100000),
...                    bins=200, normed=True)
>>> plt.show()
```

Draw values from a noncentral chi-square with very small noncentrality, and compare to a chi-square.

```python
>>> plt.figure()
>>> values = plt.hist(np.random.noncentral_chisquare(3, .0000001, 100000),
...                    bins=np.arange(0., 25, .1), normed=True)
>>> values2 = plt.hist(np.random.chisquare(3, 100000),
...                    bins=np.arange(0., 25, .1), normed=True)
```
```python
>>> plt.plot(values[1][0:-1], values[0]-values2[0], 'ob')
>>> plt.show()
```

```
Demonstrate how large values of non-centrality lead to a more symmetric distribution.
```
dfnum : int
Parameter, should be > 1.

dfden : int
Parameter, should be > 1.

nonc : float
Parameter, should be >= 0.

size : int or tuple of ints, optional
Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

Returns

samples : scalar or ndarray
Drawn samples.

Notes
When calculating the power of an experiment (power = probability of rejecting the null hypothesis when a specific alternative is true) the non-central F statistic becomes important. When the null hypothesis is true, the F statistic follows a central F distribution. When the null hypothesis is not true, then it follows a non-central F statistic.

References


Examples
In a study, testing for a specific alternative to the null hypothesis requires use of the Noncentral F distribution. We need to calculate the area in the tail of the distribution that exceeds the value of the F distribution for the null hypothesis. We’ll plot the two probability distributions for comparison.

```python
>>> dfnum = 3  # between group deg of freedom
>>> dfden = 20  # within groups degrees of freedom
>>> nonc = 3.0
>>> nc_vals = np.random.noncentral_f(dfnum, dfden, nonc, 1000000)
>>> NF = np.histogram(nc_vals, bins=50, normed=True)
>>> c_vals = np.random.f(dfnum, dfden, 1000000)
>>> F = np.histogram(c_vals, bins=50, normed=True)
>>> plt.plot(F[1][1:], F[0])
>>> plt.plot(NF[1][1:], NF[0])
>>> plt.show()
```

RandomState.normal (loc=0.0, scale=1.0, size=None)

Draw random samples from a normal (Gaussian) distribution.

The probability density function of the normal distribution, first derived by De Moivre and 200 years later by both Gauss and Laplace independently [R158], is often called the bell curve because of its characteristic shape (see the example below).

The normal distribution occurs often in nature. For example, it describes the commonly occurring distribution of samples influenced by a large number of tiny, random disturbances, each with its own unique distribution [R158].
Parameters

loc : float
   Mean (“centre”) of the distribution.

scale : float
   Standard deviation (spread or “width”) of the distribution.

size : int or tuple of ints, optional
   Output shape. If the given shape is, e.g., (m, n, k), then m * n * k
   samples are drawn. Default is None, in which case a single value is
   returned.

See also:

scipy.stats.distributions.norm
   probability density function, distribution or cumulative density function, etc.

Notes

The probability density for the Gaussian distribution is

\[ p(x) = \frac{1}{\sqrt{2\pi \sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \]

where \( \mu \) is the mean and \( \sigma \) the standard deviation. The square of the standard deviation, \( \sigma^2 \), is called the variance.

The function has its peak at the mean, and its “spread” increases with the standard deviation (the function reaches 0.607 times its maximum at \( x+\sigma \) and \( x-\sigma \) [R158]). This implies that numpy.random.normal is more likely to return samples lying close to the mean, rather than those far away.

References

[R157], [R158]

Examples

Draw samples from the distribution:

```python
>>> mu, sigma = 0, 0.1 # mean and standard deviation
>>> s = np.random.normal(mu, sigma, 1000)
```

Verify the mean and the variance:

```python
>>> abs(mu - np.mean(s)) < 0.01
True
>>> abs(sigma - np.std(s, ddof=1)) < 0.01
True
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, normed=True)
>>> plt.plot(bins, 1/(sigma * np.sqrt(2 * np.pi)) *
...          np.exp( - (bins - mu)**2 / (2 * sigma**2) ),
...          linewidth=2, color='r')
>>> plt.show()
```
**RandomState.pareto**(a, size=None)

Draw samples from a Pareto II or Lomax distribution with specified shape.

The Lomax or Pareto II distribution is a shifted Pareto distribution. The classical Pareto distribution can be obtained from the Lomax distribution by adding 1 and multiplying by the scale parameter \(m\) (see Notes). The smallest value of the Lomax distribution is zero while for the classical Pareto distribution it is \(\mu\), where the standard Pareto distribution has location \(\mu = 1\). Lomax can also be considered as a simplified version of the Generalized Pareto distribution (available in SciPy), with the scale set to one and the location set to zero.

The Pareto distribution must be greater than zero, and is unbounded above. It is also known as the “80-20 rule”. In this distribution, 80 percent of the weights are in the lowest 20 percent of the range, while the other 20 percent fill the remaining 80 percent of the range.

**Parameters**

- **shape**: float, > 0.
  
  Shape of the distribution.

- **size**: int or tuple of ints, optional
  
  Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

**See also:**

- `scipy.stats.distributions.lomax.pdf`
  
  probability density function, distribution or cumulative density function, etc.

- `scipy.stats.distributions.genpareto.pdf`
  
  probability density function, distribution or cumulative density function, etc.

**Notes**

The probability density for the Pareto distribution is

\[
p(x) = \frac{am^a}{x^{a+1}}
\]

where \(a\) is the shape and \(m\) the scale.
The Pareto distribution, named after the Italian economist Vilfredo Pareto, is a power law probability distribution useful in many real world problems. Outside the field of economics it is generally referred to as the Bradford distribution. Pareto developed the distribution to describe the distribution of wealth in an economy. It has also found use in insurance, web page access statistics, oil field sizes, and many other problems, including the download frequency for projects in Sourceforge [R159]. It is one of the so-called “fat-tailed” distributions.

References
[R159], [R160], [R161], [R162]

Examples

Draw samples from the distribution:

```python
>>> a, m = 3., 2.  # shape and mode
>>> s = (np.random.pareto(a, 1000) + 1) * m
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(s, 100, normed=True)
>>> fit = a*m**a / bins**(a+1)
>>> plt.plot(bins, max(count)*fit/max(fit), linewidth=2, color='r')
>>> plt.show()
```

RandomState.permutation(x)

Randomly permute a sequence, or return a permuted range.

If x is a multi-dimensional array, it is only shuffled along its first index.

Parameters

x : int or array_like

If x is an integer, randomly permute np.arange(x). If x is an array, make a copy and shuffle the elements randomly.

Returns

out : ndarray

Permuted sequence or array range.
Examples

```python
>>> np.random.permutation(10)
array([1, 7, 4, 3, 0, 9, 2, 5, 8, 6])

>>> np.random.permutation([1, 4, 9, 12, 15])
array([15, 1, 9, 4, 12])

>>> arr = np.arange(9).reshape((3, 3))
>>> np.random.permutation(arr)
array([[6, 7, 8],
       [0, 1, 2],
       [3, 4, 5]])
```

RandomState.poisson (lam=1.0, size=None)

Draw samples from a Poisson distribution.

The Poisson distribution is the limit of the Binomial distribution for large N.

**Parameters**

- **lam** : float or sequence of float
  Expectation of interval, should be >= 0. A sequence of expectation intervals must be broadcastable over the requested size.

- **size** : int or tuple of ints, optional
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Notes**

The Poisson distribution

\[ f(k; \lambda) = \frac{\lambda^k e^{-\lambda}}{k!} \]

For events with an expected separation \( \lambda \) the Poisson distribution \( f(k; \lambda) \) describes the probability of \( k \) events occurring within the observed interval \( \lambda \).

Because the output is limited to the range of the C long type, a ValueError is raised when \( \lambda \) is within 10 sigma of the maximum representable value.

**References**

[R163], [R164]

**Examples**

Draw samples from the distribution:

```python
>>> import numpy as np
>>> s = np.random.poisson(5, 10000)
```

Display histogram of the sample:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 14, normed=True)
>>> plt.show()
```
Draw each 100 values for lambda 100 and 500:

```python
>>> s = np.random.poisson(lam=(100., 500.), size=(100, 2))
```

**RandomState.power** *(a, size=None)*

Draws samples in [0, 1] from a power distribution with positive exponent a - 1.

Also known as the power function distribution.

**Parameters**

- **a**: float
  
  parameter, > 0

- **size**: int or tuple of ints, optional
  
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- **samples**: {ndarray, scalar}
  
  The returned samples lie in [0, 1].

**Raises**

- **ValueError**
  
  If a<1.

**Notes**

The probability density function is

\[ P(x; a) = a x^{a-1}, 0 \leq x \leq 1, a > 0. \]

The power function distribution is just the inverse of the Pareto distribution. It may also be seen as a special case of the Beta distribution.

It is used, for example, in modeling the over-reporting of insurance claims.

**References**

[R165], [R166]
Examples

Draw samples from the distribution:

```python
>>> a = 5.  # shape
>>> samples = 1000
>>> s = np.random.power(a, samples)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, bins=30)
>>> x = np.linspace(0, 1, 100)
>>> y = a*x**(a-1.)
>>> normed_y = samples*np.diff(bins)[0]*y
>>> plt.plot(x, normed_y)
>>> plt.show()
```

Compare the power function distribution to the inverse of the Pareto.

```python
>>> from scipy import stats
>>> rvs = np.random.power(5, 1000000)
>>> rvsp = np.random.pareto(5, 1000000)
>>> xx = np.linspace(0, 1, 100)
>>> powpdf = stats.powerlaw.pdf(xx,5)
```
Notes

This is a convenience function. If you want an interface that takes a shape-tuple as the first argument, refer to np.random.random_sample.

Examples

```python
>>> np.random.rand(3,2)
array([[0.14022471, 0.96360618],
[0.37601032, 0.25528411],
[0.49313049, 0.94909878]])
```

RandomState.randint

Return random integers from low (inclusive) to high (exclusive).

Return random integers from the “discrete uniform” distribution in the “half-open” interval [low, high). If high is None (the default), then results are from [0, low).

Parameters

- **low**: int
  - Lowest (signed) integer to be drawn from the distribution (unless high=None, in which case this parameter is the highest such integer).

- **high**: int, optional
  - If provided, one above the largest (signed) integer to be drawn from the distribution (see above for behavior if high=None).

- **size**: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

Returns

- **out**: int or ndarray of ints
  - size-shaped array of random integers from the appropriate distribution, or a single such random int if size not provided.

See also:

random.randint

similar to randint, only for the closed interval [low, high], and 1 is the lowest value if high is omitted. In particular, this other one is the one to use to generate uniformly distributed discrete non-integers.

Examples

```python
>>> np.random.randint(2, size=10)
array([1, 0, 0, 0, 1, 1, 0, 0, 1, 0])
```

Generate a 2 x 4 array of ints between 0 and 4, inclusive:

```python
>>> np.random.randint(5, size=(2, 4))
array([[4, 0, 2, 1],
[3, 2, 2, 0]])
```

RandomState.randn

Return a sample (or samples) from the “standard normal” distribution.
If positive, int_like or int-convertible arguments are provided, `randn` generates an array of shape `(d0, d1, ..., dn)`, filled with random floats sampled from a univariate “normal” (Gaussian) distribution of mean 0 and variance 1 (if any of the $d_i$ are floats, they are first converted to integers by truncation). A single float randomly sampled from the distribution is returned if no argument is provided.

This is a convenience function. If you want an interface that takes a tuple as the first argument, use `numpy.random.standard_normal` instead.

**Parameters**

- `d0, d1, ..., dn`: int, optional
  
The dimensions of the returned array, should be all positive. If no argument is given a single Python float is returned.

**Returns**

- `Z`: ndarray or float
  
  A `(d0, d1, ..., dn)`-shaped array of floating-point samples from the standard normal distribution, or a single such float if no parameters were supplied.

**See also:**

- `random.standard_normal`

  Similar, but takes a tuple as its argument.

**Notes**

For random samples from $\mathcal{N}(\mu, \sigma^2)$, use:

```
sigma * np.random.randn(...) + mu
```

**Examples**

```python
>>> np.random.randn()
2.1923875335537315 #random
```

Two-by-four array of samples from $\mathcal{N}(3, 6.25)$:

```python
>>> 2.5 * np.random.randn(2, 4) + 3
array([[-4.49401501, 4.00950034, -1.81814867, 7.29718677],
       [ 0.39924804, 4.68456316, 4.99394529, 4.84057254]]) #random
```

**RandomState.random_integers**

```
low, high=None, size=None
```

Return random integers from the “discrete uniform” distribution in the closed interval $[low, high]$. If `high` is None (the default), then results are from $[1, low]$.

**Parameters**

- `low`: int
  
  Lowest (signed) integer to be drawn from the distribution (unless `high=None`, in which case this parameter is the highest such integer).

- `high`: int, optional
  
  If provided, the largest (signed) integer to be drawn from the distribution (see above for behavior if `high=None`).

- `size`: int or tuple of ints, optional
  
  Output shape. If the given shape is, e.g., `(m, n, k)`, then $m * n * k$ samples are drawn. Default is None, in which case a single value is returned.
Returns

**out** : int or ndarray of ints

`size`-shaped array of random integers from the appropriate distribution, or a single such random int if `size` not provided.

See also:

`random.randint`

Similar to `random_integers`, only for the half-open interval `[low, high)`, and 0 is the lowest value if `high` is omitted.

Notes

To sample from `N` evenly spaced floating-point numbers between `a` and `b`, use:

```python
a + (b - a) * (np.random.random_integers(N) - 1) / (N - 1.)
```

Examples

```python
>>> np.random.random_integers(5)
4
>>> type(np.random.random_integers(5))
<type 'int'>
>>> np.random.random_integers(5, size=(3,.2))
array([[5, 4],
       [3, 3],
       [4, 5]])
```

Choose five random numbers from the set of five evenly-spaced numbers between 0 and 2.5, inclusive (*i.e.*, from the set 0, 5/8, 10/8, 15/8, 20/8):

```python
>>> 2.5 * (np.random.random_integers(5, size=(5,)) - 1) / 4.
array([ 0.625, 1.25 , 0.625, 0.625, 2.5 ])
```

Roll two six sided dice 1000 times and sum the results:

```python
d1 = np.random.random_integers(1, 6, 1000)
d2 = np.random.random_integers(1, 6, 1000)
dsums = d1 + d2
```

Display results as a histogram:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(dsums, 11, normed=True)
>>> plt.show()
```
RandomState.\texttt{random\_sample}(size=None)

Return random floats in the half-open interval \([0.0, 1.0)\).

Results are from the “continuous uniform” distribution over the stated interval. To sample \(Unif[a, b), b > a\) multiply the output of \texttt{random\_sample} by \((b-a)\) and add \(a\):

\[(b - a) \times \text{random\_sample}() + a\]

Parameters

\texttt{size} : int or tuple of ints, optional

Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

Returns

\texttt{out} : float or ndarray of floats

Array of random floats of shape \texttt{size} (unless \texttt{size=None}, in which case a single float is returned).

Examples

```python
>>> np.random.random_sample()
0.47108547995356098
>>> type(np.random.random_sample())
<type 'float'>
>>> np.random.random_sample((5,))
array([ 0.30220482,  0.86820401,  0.1654503 ,  0.11659149,  0.54323428])
```

Three-by-two array of random numbers from \([-5, 0)\):

```python
>>> 5 * np.random.random_sample((3, 2)) - 5
array([[-3.99149989, -0.52338984],
       [-2.99091858, -0.79479508],
       [-1.23204345, -1.75224494]])
```

RandomState.\texttt{rayleigh}(scale=1.0, size=None)

Draw samples from a Rayleigh distribution.

The \(\chi\) and Weibull distributions are generalizations of the Rayleigh.
Parameters

- **scale**: scalar
  Scale, also equals the mode. Should be \( \geq 0 \).

- **size**: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

Notes

The probability density function for the Rayleigh distribution is

\[
P(x; \text{scale}) = \frac{x}{\text{scale}^2} e^{\frac{x^2}{2 \cdot \text{scale}^2}}
\]

The Rayleigh distribution arises if the wind speed and wind direction are both gaussian variables, then the vector wind velocity forms a Rayleigh distribution. The Rayleigh distribution is used to model the expected output from wind turbines.

References

[R167], [R168]

Examples

Draw values from the distribution and plot the histogram

```python
>>> values = hist(np.random.rayleigh(3, 100000), bins=200, normed=True)
```

Wave heights tend to follow a Rayleigh distribution. If the mean wave height is 1 meter, what fraction of waves are likely to be larger than 3 meters?

```python
>>> meanvalue = 1
>>> modevalue = np.sqrt(2 / np.pi) * meanvalue
>>> s = np.random.rayleigh(modevalue, 1000000)
```

The percentage of waves larger than 3 meters is:

```python
>>> 100.*sum(s>3)/1000000.
0.08730000000000003
```

RandomState.seed

Seed the generator.

This method is called when RandomState is initialized. It can be called again to re-seed the generator. For details, see RandomState.

Parameters

- **seeds**: int or array_like, optional
  Seed for RandomState. Must be convertible to 32 bit unsigned integers.

See also:

RandomState

RandomState.set_state

Set the internal state of the generator from a tuple.

For use if one has reason to manually (re-)set the internal state of the “Mersenne Twister”[R169] pseudo-random number generating algorithm.
Parameters

state: tuple(str, ndarray of 624 uints, int, int, float)

The state tuple has the following items:

1. the string ‘MT19937’, specifying the Mersenne Twister algorithm.
2. a 1-D array of 624 unsigned integers keys.
3. an integer pos.
4. an integer has_gauss.
5. a float cached_gaussian.

Returns

out: None

Returns ‘None’ on success.

See also:

generate

Notes

set_state and get_state are not needed to work with any of the random distributions in NumPy. If the internal state is manually altered, the user should know exactly what he/she is doing.

For backwards compatibility, the form (str, array of 624 uints, int) is also accepted although it is missing some information about the cached Gaussian value: state = (‘MT19937’, keys, pos).

References

[R169]

RandomState.shuffle(x)

Modify a sequence in-place by shuffling its contents.

Parameters

x: array_like

The array or list to be shuffled.

Returns

None

Examples

```python
>>> arr = np.arange(10)
>>> np.random.shuffle(arr)
>>> arr
[1 7 5 2 9 4 3 6 0 8]
```

This function only shuffles the array along the first index of a multi-dimensional array:

```python
>>> arr = np.arange(9).reshape((3, 3))
>>> np.random.shuffle(arr)
>>> arr
array([[3, 4, 5],
       [6, 7, 8],
       [0, 1, 2]])
```
RandomState.

**standard_cauchy**(size=None)

Standard Cauchy distribution with mode = 0.

Also known as the Lorentz distribution.

**Parameters**

- **size**: int or tuple of ints, optional
  
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- **samples**: ndarray or scalar
  
  The drawn samples.

**Notes**

The probability density function for the full Cauchy distribution is

\[
P(x; x_0, \gamma) = \frac{1}{\pi \gamma \left[1 + \left(\frac{x-x_0}{\gamma}\right)^2\right]}
\]

and the Standard Cauchy distribution just sets \(x_0 = 0\) and \(\gamma = 1\)

The Cauchy distribution arises in the solution to the driven harmonic oscillator problem, and also describes spectral line broadening. It also describes the distribution of values at which a line tilted at a random angle will cut the x axis.

When studying hypothesis tests that assume normality, seeing how the tests perform on data from a Cauchy distribution is a good indicator of their sensitivity to a heavy-tailed distribution, since the Cauchy looks very much like a Gaussian distribution, but with heavier tails.

**References**

[R170], [R171], [R172]

**Examples**

Draw samples and plot the distribution:

```python
>>> s = np.random.standard_cauchy(1000000)
>>> s = s[(s>-25) & (s<25)]  # truncate distribution so it plots well
>>> plt.hist(s, bins=100)
>>> plt.show()
```

RandomState.

**standard_exponential**(size=None)

Draw samples from the standard exponential distribution.

**standard_exponential** is identical to the exponential distribution with a scale parameter of 1.

**Parameters**

- **size**: int or tuple of ints, optional
  
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- **out**: float or ndarray
  
  Drawn samples.
Examples

Output a 3x8000 array:

```python
>>> n = np.random.standard_exponential((3, 8000))
```

```
RandomState.standard_gamma(shape, size=None)
```

Draw samples from a Standard Gamma distribution.

Samples are drawn from a Gamma distribution with specified parameters, shape (sometimes designated “k”) and scale=1.

**Parameters**

- `shape`: float
  
  Parameter, should be > 0.

- `size`: int or tuple of ints, optional
  
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- `samples`: ndarray or scalar
  
  The drawn samples.

**See also**:

- `scipy.stats.distributions.gamma`

**Notes**

The probability density for the Gamma distribution is

\[
p(x) = x^{k-1} \frac{e^{-x/\theta}}{\theta^k \Gamma(k)},
\]

where \(k\) is the shape and \(\theta\) the scale, and \(\Gamma\) is the Gamma function.

The Gamma distribution is often used to model the times to failure of electronic components, and arises naturally in processes for which the waiting times between Poisson distributed events are relevant.

**References**

[R173], [R174]

**Examples**

Draw samples from the distribution:

```python
>>> shape, scale = 2., 1. # mean and width
>>> s = np.random.standard_gamma(shape, 1000000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps
>>> count, bins, ignored = plt.hist(s, 50, normed=True)
>>> y = bins**(shape-1) * ((np.exp(-bins/scale))/
...     (sps.gamma(shape) * scale**shape))
>>> plt.plot(bins, y, linewidth=2, color='r')
>>> plt.show()
```
RandomState.standard_normal(size=None)

Returns samples from a Standard Normal distribution (mean=0, stdev=1).

Parameters

size : int or tuple of ints, optional

Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

Returns

out : float or ndarray

Drawn samples.

Examples

```python
>>> s = np.random.standard_normal(8000)
>>> s
array([ 0.6888893 , 0.78096262, -0.89086505, ..., 0.49876311, #random
         -0.38672696, -0.4685006 ])

>>> s.shape
(8000,)

>>> s = np.random.standard_normal(size=(3, 4, 2))
>>> s.shape
(3, 4, 2)
```

RandomState.standard_t(df, size=None)

Standard Student’s t distribution with df degrees of freedom.

A special case of the hyperbolic distribution. As df gets large, the result resembles that of the standard normal distribution (standard_normal).

Parameters

df : int

Degrees of freedom, should be > 0.

size : int or tuple of ints, optional

Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

Returns

samples : ndarray or scalar

Drawn samples.

Notes

The probability density function for the t distribution is

\[ P(x, df) = \frac{\Gamma\left(\frac{df+1}{2}\right)}{\sqrt{\pi df} \Gamma\left(\frac{df}{2}\right)} \left(1 + \frac{x^2}{df}\right)^{-\frac{(df+1)}{2}} \]

The t test is based on an assumption that the data come from a Normal distribution. The t test provides a way to test whether the sample mean (that is the mean calculated from the data) is a good estimate of the true mean.

The derivation of the t-distribution was first published in 1908 by William Gisset while working for the Guinness Brewery in Dublin. Due to proprietary issues, he had to publish under a pseudonym, and so he used the name Student.
References

[R175], [R176]

Examples

From Dalgaard page 83 [R175], suppose the daily energy intake for 11 women in Kj is:

```python
>>> intake = np.array([5260., 5470, 5640, 6180, 6390, 6515, 6805, 7515, 
... 7515, 8230, 8770])
```

Does their energy intake deviate systematically from the recommended value of 7725 kJ?

We have 10 degrees of freedom, so is the sample mean within 95% of the recommended value?

```python
>>> s = np.random.standard_t(10, size=100000)
>>> np.mean(intake)
6753.636363636364
>>> intake.std(ddof=1)
1142.1232221373727
```

Calculate the t statistic, setting the ddof parameter to the unbiased value so the divisor in the standard deviation will be degrees of freedom, N-1.

```python
>>> t = (np.mean(intake)-7725)/(intake.std(ddof=1)/np.sqrt(len(intake)))
```

For a one-sided t-test, how far out in the distribution does the t statistic appear?

```python
>>> np.sum(s<t) / float(len(s))
0.0090699999999999999 #random
```

So the p-value is about 0.009, which says the null hypothesis has a probability of about 99% of being true.

**RandomState.tomaxint(size=None)**

Random integers between 0 and sys.maxint, inclusive.

Return a sample of uniformly distributed random integers in the interval [0, sys.maxint].

**Parameters**

- `size`: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- `out`: ndarray
  - Drawn samples, with shape `size`.

**See also:**

- `randint`
  - Uniform sampling over a given half-open interval of integers.

- `random_integers`
  - Uniform sampling over a given closed interval of integers.

**Examples**
```python
>>> RS = np.random.mtrand.RandomState()  # need a RandomState object
>>> RS.tomaxint((2,2,2))
array([[1170048599, 1600360186],
       [739731006, 1947757578]],
       [[1871712945, 752307660],
        [1601631370, 1479324245]])
```

```python
>>> import sys
>>> sys.maxint
2147483647
>>> RS.tomaxint((2,2,2)) < sys.maxint
array([[ True,  True],
        [ True,  True],
        [ True,  True],
        [ True,  True]], dtype=bool)
```

RandomState.\texttt{triangular}(\texttt{left}, \texttt{mode}, \texttt{right}, \texttt{size}=\texttt{None})

Draw samples from the triangular distribution.

The triangular distribution is a continuous probability distribution with lower limit \texttt{left}, peak at \texttt{mode}, and upper limit \texttt{right}. Unlike the other distributions, these parameters directly define the shape of the pdf.

**Parameters**

- \texttt{left} : scalar
  - Lower limit.

- \texttt{mode} : scalar
  - The value where the peak of the distribution occurs. The value should fulfill the condition \texttt{left} <= \texttt{mode} <= \texttt{right}.

- \texttt{right} : scalar
  - Upper limit, should be larger than \texttt{left}.

- \texttt{size} : int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \texttt{(m, n, k)}, then \texttt{m} * \texttt{n} * \texttt{k} samples are drawn. Default is None, in which case a single value is returned.

**Returns**

- \texttt{samples} : ndarray or scalar
  - The returned samples all lie in the interval [\texttt{left}, \texttt{right}].

**Notes**

The probability density function for the Triangular distribution is

\[
P(x; l, m, r) = \begin{cases}
  \frac{2(x-l)}{(r-l)(m-l)} & \text{for } l \leq x \leq m, \\
  \frac{2(m-x)}{(r-l)(r-m)} & \text{for } m \leq x \leq r, \\
  0 & \text{otherwise}.
\end{cases}
\]

The triangular distribution is often used in ill-defined problems where the underlying distribution is not known, but some knowledge of the limits and mode exists. Often it is used in simulations.

**References**

[R177]
Examples

Draw values from the distribution and plot the histogram:

```python
>>> import matplotlib.pyplot as plt
>>> h = plt.hist(np.random.triangular(-3, 0, 8, 100000), bins=200, ...
...     normed=True)
>>> plt.show()
```

RandomState.uniform (low=0.0, high=1.0, size=None)

Draw samples from a uniform distribution.

Samples are uniformly distributed over the half-open interval \([\text{low}, \text{high})\) (includes low, but excludes high). In other words, any value within the given interval is equally likely to be drawn by `uniform`.

Parameters

- **low**: float, optional
  - Lower boundary of the output interval. All values generated will be greater than or equal to low. The default value is 0.

- **high**: float
  - Upper boundary of the output interval. All values generated will be less than high. The default value is 1.0.

- **size**: int or tuple of ints, optional
  - Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

Returns

- **out**: ndarray
  - Drawn samples, with shape `size`.

See also:

- `randint`
  - Discrete uniform distribution, yielding integers.
**random_integers**
Discrete uniform distribution over the closed interval \([\text{low}, \text{high}]\).

**random_sample**
Floats uniformly distributed over \([0, 1)\).

**random**
Alias for **random_sample**.

**rand**
Convenience function that accepts dimensions as input, e.g., \(\text{rand}(2,2)\) would generate a 2-by-2 array of floats, uniformly distributed over \([0, 1)\).

**Notes**
The probability density function of the uniform distribution is

\[
p(x) = \frac{1}{b-a}
\]

anywhere within the interval \([a, b)\), and zero elsewhere.

**Examples**
Draw samples from the distribution:

```python
>>> s = np.random.uniform(-1,0,1000)
```

All values are within the given interval:

```python
>>> np.all(s >= -1)
True
>>> np.all(s < 0)
True
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 15, normed=True)
>>> plt.plot(bins, np.ones_like(bins), linewidth=2, color='r')
>>> plt.show()
```
RandomState.vonmises(mu, kappa, size=None)

Draw samples from a von Mises distribution.

Samples are drawn from a von Mises distribution with specified mode (mu) and dispersion (kappa), on the interval [-pi, pi].

The von Mises distribution (also known as the circular normal distribution) is a continuous probability distribution on the unit circle. It may be thought of as the circular analogue of the normal distribution.

**Parameters**
- **mu**: float
  Mode ("center") of the distribution.
- **kappa**: float
  Dispersion of the distribution, has to be >=0.
- **size**: int or tuple of ints, optional
  Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are drawn. Default is None, in which case a single value is returned.

**Returns**
- **samples**: scalar or ndarray
  The returned samples, which are in the interval [-pi, pi].

**See also:**
scipy.stats.distributions.vonmises

probability density function, distribution, or cumulative density function, etc.

**Notes**
The probability density for the von Mises distribution is

\[ p(x) = \frac{e^{\kappa \cos(x-\mu)}}{2\pi I_0(\kappa)}, \]

where \( \mu \) is the mode and \( \kappa \) the dispersion, and \( I_0(\kappa) \) is the modified Bessel function of order 0.

The von Mises is named for Richard Edler von Mises, who was born in Austria-Hungary, in what is now the Ukraine. He fled to the United States in 1939 and became a professor at Harvard. He worked in probability theory, aerodynamics, fluid mechanics, and philosophy of science.

**References**

**Examples**
Draw samples from the distribution:

```python
>>> mu, kappa = 0.0, 4.0 # mean and dispersion
>>> s = np.random.vonmises(mu, kappa, 1000)
```

Display the histogram of the samples, along with the probability density function:
RandomState.wald(mean, scale, size=None)

Draw samples from a Wald, or Inverse Gaussian, distribution.

As the scale approaches infinity, the distribution becomes more like a Gaussian.

Some references claim that the Wald is an Inverse Gaussian with mean=1, but this is by no means universal.

The Inverse Gaussian distribution was first studied in relationship to Brownian motion. In 1956 M.C.K.
Tweedie used the name Inverse Gaussian because there is an inverse relationship between the time to cover
a unit distance and distance covered in unit time.

Parameters

mean : scalar
    Distribution mean, should be > 0.

scale : scalar
    Scale parameter, should be >= 0.

size : int or tuple of ints, optional
    Output shape. If the given shape is, e.g., (m, n, k), then m * n * k samples are
drawn. Default is None, in which case a single value is returned.

Returns

samples : ndarray or scalar
    Drawn sample, all greater than zero.

Notes

The probability density function for the Wald distribution is

\[ P(x; \text{mean}, \text{scale}) = \sqrt{\frac{\text{scale}}{2\pi x^3}} \; e^{-\frac{\text{scale}(x-\text{mean})^2}{2\text{mean}^2x^2}} \]

As noted above the Inverse Gaussian distribution first arise from attempts to model Brownian Motion. It
is also a competitor to the Weibull for use in reliability modeling and modeling stock returns and interest
rate processes.

References

[R178], [R179], [R180]

Examples

Draw values from the distribution and plot the histogram:

>>> import matplotlib.pyplot as plt
>>> h = plt.hist(np.random.wald(3, 2, 100000), bins=200, normed=True)
>>> plt.show()
Weibull distribution.

Draw samples from a 1-parameter Weibull distribution with the given shape parameter \(a\).

\[ X = (\ln(U))^{1/a} \]

Here, \(U\) is drawn from the uniform distribution over (0,1].

The more common 2-parameter Weibull, including a scale parameter \(\lambda\) is just \(X = \lambda(\ln(U))^{1/a}\).

Parameters

\(a\) : float

Shape of the distribution.

\(size\) : int or tuple of ints, optional

Output shape. If the given shape is, e.g., \((m, n, k)\), then \(m \times n \times k\) samples are drawn. Default is None, in which case a single value is returned.

See also:

scipy.stats.distributions.weibull_max, scipy.stats.distributions.weibull_min, scipy.stats.distributions.genextreme, gumbel

Notes

The Weibull (or Type III asymptotic extreme value distribution for smallest values, SEV Type III, or Rosin-Rammler distribution) is one of a class of Generalized Extreme Value (GEV) distributions used in modeling extreme value problems. This class includes the Gumbel and Frechet distributions.

The probability density for the Weibull distribution is

\[ p(x) = \frac{a}{\lambda}(\frac{x}{\lambda})^{a-1}e^{-(x/\lambda)^a} \]

where \(a\) is the shape and \(\lambda\) the scale.

The function has its peak (the mode) at \(\lambda(\frac{a-1}{a})^{1/a}\).

When \(a = 1\), the Weibull distribution reduces to the exponential distribution.
References

[R181], [R182], [R183]

Examples

Draw samples from the distribution:

```python
>>> a = 5. # shape
>>> s = np.random.weibull(a, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> x = np.arange(1,100.)/50.
>>> def weib(x,n,a):
...     return (a / n) * (x / n)**(a - 1) * np.exp(-(x / n)**a)
>>> count, bins, ignored = plt.hist(np.random.weibull(5.,1000))
>>> x = np.arange(1,100.)/50.
>>> scale = count.max()/weib(x, 1., 5.).max()
>>> plt.plot(x, weib(x, 1., 5.)*scale)
>>> plt.show()
```

RandomState.zipf(a, size=None)

Draw samples from a Zipf distribution.

Samples are drawn from a Zipf distribution with specified parameter \( a > 1 \).

The Zipf distribution (also known as the zeta distribution) is a continuous probability distribution that satisfies Zipf’s law: the frequency of an item is inversely proportional to its rank in a frequency table.

**Parameters**

- **a**: float > 1

  Distribution parameter.

- **size**: int or tuple of ints, optional

  Output shape. If the given shape is, e.g., (m, n, k), then \( m \times n \times k \) samples are drawn. Default is None, in which case a single value is returned.
Returns

samples : scalar or ndarray

The returned samples are greater than or equal to one.

See also:

scipy.stats.distributions.zipf
probability density function, distribution, or cumulative density function, etc.

Notes

The probability density for the Zipf distribution is

\[ p(x) = \frac{x^{-a}}{\zeta(a)}, \]

where \( \zeta \) is the Riemann Zeta function.

It is named for the American linguist George Kingsley Zipf, who noted that the frequency of any word in a sample of a language is inversely proportional to its rank in the frequency table.

References


Examples

Draw samples from the distribution:

```python
>>> a = 2. # parameter
>>> s = np.random.zipf(a, 1000)
```

Display the histogram of the samples, along with the probability density function:

```python
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps
>>> count, bins, ignored = plt.hist(s[s<50], 50, normed=True)
>>> x = np.arange(1., 50.)
>>> y = x**(-a)/sps.zetac(a)
>>> plt.plot(x, y/max(y), linewidth=2, color='r')
>>> plt.show()
```

numpy.random.seed (seed=None)

Seed the generator.

This method is called when RandomState is initialized. It can be called again to re-seed the generator. For details, see RandomState.

Parameters

seed : int or array_like, optional

Seed for RandomState. Must be convertable to 32 bit unsigned integers.

See also:

RandomState

numpy.random.get_state()

Return a tuple representing the internal state of the generator.

For more details, see set_state.
Returns

\textbf{out} : tuple(str, ndarray of 624 uints, int, int, float)

The returned tuple has the following items:

1. the string ‘MT19937’.
2. a 1-D array of 624 unsigned integer keys.
3. an integer \texttt{pos}.
4. an integer \texttt{has_gauss}.
5. a float \texttt{cached_gaussian}.

See also:

\texttt{set_state}

Notes

\texttt{set_state} and \texttt{get_state} are not needed to work with any of the random distributions in NumPy. If the internal state is manually altered, the user should know exactly what he/she is doing.

\texttt{numpy.random.set_state(state)}

Set the internal state of the generator from a tuple.

For use if one has reason to manually (re-)set the internal state of the “Mersenne Twister”\[R228\] pseudo-random number generating algorithm.

Parameters

\texttt{state} : tuple(str, ndarray of 624 uints, int, int, float)

The \texttt{state} tuple has the following items:

1. the string ‘MT19937’, specifying the Mersenne Twister algorithm.
2. a 1-D array of 624 unsigned integers \texttt{keys}.
3. an integer \texttt{pos}.
4. an integer \texttt{has_gauss}.
5. a float \texttt{cached_gaussian}.

Returns

\textbf{out} : None

Returns ‘None’ on success.

See also:

\texttt{get_state}

Notes

\texttt{set_state} and \texttt{get_state} are not needed to work with any of the random distributions in NumPy. If the internal state is manually altered, the user should know exactly what he/she is doing.

For backwards compatibility, the form (str, array of 624 uints, int) is also accepted although it is missing some information about the cached Gaussian value: \texttt{state = (‘MT19937’, keys, pos)}.

References

\[R228\]
NumPy Reference, Release 1.9.2

3.26 Set routines

3.26.1 Making proper sets

```
unique(ar[, return_index, return_inverse, ...])  Find the unique elements of an array.
```

```
numpy.unique (ar, return_index=False, return_inverse=False, return_counts=False)

Find the unique elements of an array.

Returns the sorted unique elements of an array. There are three optional outputs in addition to the unique elements: the indices of the input array that give the unique values, the indices of the unique array that reconstruct the input array, and the number of times each unique value comes up in the input array.

Parameters

- **ar**: array_like
  Input array. This will be flattened if it is not already 1-D.

- **return_index**: bool, optional
  If True, also return the indices of ar that result in the unique array.

- **return_inverse**: bool, optional
  If True, also return the indices of the unique array that can be used to reconstruct ar.

- **return_counts**: bool, optional
  New in version 1.9.0.
  If True, also return the number of times each unique value comes up in ar.

Returns

- **unique**: ndarray
  The sorted unique values.

- **unique_indices**: ndarray, optional
  The indices of the first occurrences of the unique values in the (flattened) original array.
  Only provided if return_index is True.

- **unique_inverse**: ndarray, optional
  The indices to reconstruct the (flattened) original array from the unique array. Only provided if return_inverse is True.

- **unique_counts**: ndarray, optional
  New in version 1.9.0.
  The number of times each of the unique values comes up in the original array. Only provided if return_counts is True.

See also:

- `numpy.lib.arraysetops`
  Module with a number of other functions for performing set operations on arrays.
Examples

```python
>>> np.unique([1, 1, 2, 2, 3, 3])
array([1, 2, 3])
```

Return the indices of the original array that give the unique values:

```python
>>> a = np.array([[1, 1], [2, 3]])
>>> np.unique(a)
array([1, 2, 3])
```

Reconstruct the input array from the unique values:

```python
>>> a = np.array([1, 2, 6, 4, 2, 3, 2])
>>> u, indices = np.unique(a, return_inverse=True)
>>> u
array([1, 2, 3, 4, 6])
>>> indices
array([0, 1, 4, 3, 1, 2, 1])
>>> u[indices]
array([1, 2, 6, 4, 2, 3, 2])
```

3.26.2 Boolean operations

- **in1d(ar1, ar2[, assume_unique, invert])**  
  Test whether each element of a 1-D array is also present in a second array.

- **intersect1d(ar1, ar2[, assume_unique])**  
  Find the intersection of two arrays.

- **setdiff1d(ar1, ar2[, assume_unique])**  
  Find the set difference of two arrays.

- **setxor1d(ar1, ar2[, assume_unique])**  
  Find the set exclusive-or of two arrays.

- **union1d(ar1, ar2)**  
  Find the union of two arrays.

**numpy.in1d(ar1, ar2, assume_unique=False, invert=False)**  
Test whether each element of a 1-D array is also present in a second array.

Returns a boolean array the same length as `ar1` that is True where an element of `ar1` is in `ar2` and False otherwise.

**Parameters**

- **ar1** : (M,) array_like
  Input array.

- **ar2** : array_like
  The values against which to test each value of `ar1`.

- **assume_unique** : bool, optional
  If True, the input arrays are both assumed to be unique, which can speed up the calculation. Default is False.
invert : bool, optional

- If True, the values in the returned array are inverted (that is, False where an element of \(ar1\) is in \(ar2\) and True otherwise). Default is False. np.in1d(a, b, invert=True) is equivalent to (but is faster than) np.invert(in1d(a, b)).

New in version 1.8.0.

Returns

- \(in1d\) : (M,) ndarray, bool

  - The values \(ar1[in1d]\) are in \(ar2\).

See also:

- numpy.lib.arraysetops

  Module with a number of other functions for performing set operations on arrays.

Notes

in1d can be considered as an element-wise function version of the python keyword \(in\), for 1-D sequences. in1d(a, b) is roughly equivalent to np.array([item in b for item in a]).

New in version 1.4.0.

Examples

```python
>>> test = np.array([0, 1, 2, 5, 0])
>>> states = [0, 2]
>>> mask = np.in1d(test, states)
array([ True, False,  True, False,  True], dtype=bool)
>>> test[mask]
array([0, 2, 0])
>>> mask = np.in1d(test, states, invert=True)
array([False,  True, False,  True, False], dtype=bool)
>>> test[mask]
array([1, 5])
```

numpy.intersect1d (ar1, ar2, assume_unique=False)

Find the intersection of two arrays.

Return the sorted, unique values that are in both of the input arrays.

Parameters

- \(ar1, ar2\) : array_like

  - Input arrays.

- assume_unique : bool

  - If True, the input arrays are both assumed to be unique, which can speed up the calculation. Default is False.

Returns

- \(intersect1d\) : ndarray

  - Sorted 1D array of common and unique elements.
numpy.lib.arraysetops
Module with a number of other functions for performing set operations on arrays.

Examples
```python
>>> np.intersect1d([1, 3, 4, 3], [3, 1, 2, 1])
array([1, 3])
```

numpy.setdiff1d(ar1, ar2, assume_unique=False)
Find the set difference of two arrays.

Return the sorted, unique values in `ar1` that are not in `ar2`.

Parameters
- **ar1**: array_like
  Input array.
- **ar2**: array_like
  Input comparison array.
- **assume_unique**: bool
  If True, the input arrays are both assumed to be unique, which can speed up the calculation. Default is False.

Returns
- **setdiff1d**: ndarray
  Sorted 1D array of values in `ar1` that are not in `ar2`.

See also:

numpy.lib.arraysetops
Module with a number of other functions for performing set operations on arrays.

Examples
```python
>>> a = np.array([1, 2, 3, 2, 4, 1])
>>> b = np.array([3, 4, 5, 6])
>>> np.setdiff1d(a, b)
array([1, 2])
```

numpy.setxor1d(ar1, ar2, assume_unique=False)
Find the set exclusive-or of two arrays.

Return the sorted, unique values that are in only one (not both) of the input arrays.

Parameters
- **ar1, ar2**: array_like
  Input arrays.
- **assume_unique**: bool
  If True, the input arrays are both assumed to be unique, which can speed up the calculation. Default is False.

Returns
- **setxor1d**: ndarray
  Sorted 1D array of unique values that are in only one of the input arrays.
Examples

```python
>>> a = np.array([1, 2, 3, 2, 4])
>>> b = np.array([2, 3, 5, 7, 5])
>>> np.setxor1d(a, b)
array([1, 4, 5, 7])
```

`numpy.union1d(ar1, ar2)`

Find the union of two arrays.

Return the unique, sorted array of values that are in either of the two input arrays.

**Parameters**

- `ar1, ar2`: array_like
  Input arrays. They are flattened if they are not already 1D.

**Returns**

- `union1d`: ndarray
  Unique, sorted union of the input arrays.

**See also:**

`numpy.lib.arraysetops`
Module with a number of other functions for performing set operations on arrays.

Examples

```python
>>> np.union1d([-1, 0, 1], [-2, 0, 2])
array([-2, -1, 0, 1, 2])
```

### 3.27 Sorting, searching, and counting

#### 3.27.1 Sorting

`numpy.sort(a[, axis, kind, order])`

Return a sorted copy of an array.

**Parameters**

- `a`: array_like
  Array to be sorted.

- `axis`: int or None, optional
  Axis along which to sort. If None, the array is flattened before sorting. The default is -1, which sorts along the last axis.
kind : {'quicksort', 'mergesort', 'heapsort'}, optional

Sorting algorithm. Default is 'quicksort'.

order : list, optional

When a is a structured array, this argument specifies which fields to compare first, second, and so on. This list does not need to include all of the fields.

Returns

sorted_array : ndarray

Array of the same type and shape as a.

See also:

ndarray.sort
Method to sort an array in-place.

argsort
Indirect sort.

lexsort
Indirect stable sort on multiple keys.

searchsorted
Find elements in a sorted array.

partition
Partial sort.

Notes

The various sorting algorithms are characterized by their average speed, worst case performance, work space size, and whether they are stable. A stable sort keeps items with the same key in the same relative order. The three available algorithms have the following properties:

<table>
<thead>
<tr>
<th>kind</th>
<th>speed</th>
<th>worst case</th>
<th>work space</th>
<th>stable</th>
</tr>
</thead>
<tbody>
<tr>
<td>'quicksort'</td>
<td>1</td>
<td>O(n^2)</td>
<td>0</td>
<td>no</td>
</tr>
<tr>
<td>'mergesort'</td>
<td>2</td>
<td>O(n*log(n))</td>
<td>~n/2</td>
<td>yes</td>
</tr>
<tr>
<td>'heapsort'</td>
<td>3</td>
<td>O(n*log(n))</td>
<td>0</td>
<td>no</td>
</tr>
</tbody>
</table>

All the sort algorithms make temporary copies of the data when sorting along any but the last axis. Consequently, sorting along the last axis is faster and uses less space than sorting along any other axis.

The sort order for complex numbers is lexicographic. If both the real and imaginary parts are non-nan then the order is determined by the real parts except when they are equal, in which case the order is determined by the imaginary parts.

Previous to numpy 1.4.0 sorting real and complex arrays containing nan values led to undefined behaviour. In numpy versions >= 1.4.0 nan values are sorted to the end. The extended sort order is:

- Real: [R, nan]
- Complex: [R + Rj, R + nanj, nan + Rj, nan + nanj]

where R is a non-nan real value. Complex values with the same nan placements are sorted according to the non-nan part if it exists. Non-nan values are sorted as before.

Examples
>>> a = np.array([[1,4],[3,1]])
>>> np.sort(a)                      # sort along the last axis
array([[1, 4],
       [3, 1]])
>>> np.sort(a, axis=None)          # sort the flattened array
array([1, 1, 3, 4])
>>> np.sort(a, axis=0)             # sort along the first axis
array([[1, 1],
       [3, 4]])

Use the `order` keyword to specify a field to use when sorting a structured array:

```python
def dtype = [('name', 'S10'), ('height', float), ('age', int)]
values = [ ('Arthur', 1.8, 41), ('Lancelot', 1.9, 38), ...
('Galahad', 1.7, 38)]
a = np.array(values, dtype=dtype)        # create a structured array
>>> np.sort(a, order='height')           # sort by age, then height if ages are equal:
array([('Galahad', 1.7, 38), ('Arthur', 1.8, 41),
       ('Lancelot', 1.8999999999999999, 38)],
dtype=[('name', '|S10'), ('height', '<f8'), ('age', '<i4')])
```

numpy.**lexsort**(keys, axis=-1)

Perform an indirect sort using a sequence of keys.

Given multiple sorting keys, which can be interpreted as columns in a spreadsheet, lexsort returns an array of
ter integers that describes the sort order by multiple columns. The last key in the sequence is used for the
primary sort order, the second-to-last key for the secondary sort order, and so on. The keys argument must be
a sequence of objects that can be converted to arrays of the same shape. If a 2D array is provided for the keys
argument, its rows are interpreted as the sorting keys and sorting is according to the last row, second last row
etc.

**Parameters**

- **keys**: (k, N) array or tuple containing k (N,)-shaped sequences
  The k different “columns” to be sorted. The last column (or row if keys is a 2D array) is
  the primary sort key.

- **axis**: int, optional
  Axis to be indirectly sorted. By default, sort over the last axis.

**Returns**

- **indices**: (N,) ndarray of ints
  Array of indices that sort the keys along the specified axis.

**See also:**

- **argsort**: Indirect sort.
- **ndarray.sort**: In-place sort.
sort

Return a sorted copy of an array.

Examples

Sort names: first by surname, then by name.

```python
>>> surnames = ('Hertz', 'Galilei', 'Hertz')
>>> first_names = ('Heinrich', 'Galileo', 'Gustav')
>>> ind = np.lexsort((first_names, surnames))
>>> ind
array([1, 2, 0])

>>> [surnames[i] + ', ' + first_names[i] for i in ind]
['Galilei, Galileo', 'Hertz, Gustav', 'Hertz, Heinrich']
```

Sort two columns of numbers:

```python
>>> a = [1,5,1,4,3,4,4]  # First column
>>> b = [9,4,0,4,0,2,1]  # Second column
>>> ind = np.lexsort((b,a))  # Sort by a, then by b
>>> ind
array([2, 0, 4, 6, 5, 3, 1])

>>> [(a[i],b[i]) for i in ind]
[(1, 0), (1, 9), (3, 0), (4, 1), (4, 2), (4, 4), (5, 4)]
```

Note that sorting is first according to the elements of `a`. Secondary sorting is according to the elements of `b`.

A normal `argsort` would have yielded:

```python
>>> [(a[i],b[i]) for i in np.argsort(a)]
[(1, 9), (1, 0), (3, 0), (4, 4), (4, 2), (4, 1), (5, 4)]
```

Structured arrays are sorted lexically by `argsort`:

```python
>>> x = np.array([(1,9), (5,4), (1,0), (4,4), (3,0), (4,2), (4,1)],
...               dtype=np.dtype([('x', int), ('y', int)]))
>>> np.argsort(x)  # or np.argsort(x, order=('x', 'y'))
array([2, 0, 4, 6, 5, 3, 1])
```

`numpy.argsort(a, axis=-1, kind='quicksort', order=None)`

Returns the indices that would sort an array.

Perform an indirect sort along the given axis using the algorithm specified by the `kind` keyword. It returns an array of indices of the same shape as `a` that index data along the given axis in sorted order.

Parameters

- `a` : array_like
  Array to sort.

- `axis` : int or None, optional
  Axis along which to sort. The default is -1 (the last axis). If None, the flattened array is used.

- `kind` : {'quicksort', 'mergesort', 'heapsort'}, optional
  Sorting algorithm.

- `order` : list, optional
When \( a \) is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

**Returns**

`index_array` : ndarray, int

Array of indices that sort \( a \) along the specified axis. In other words, \( a[index_array] \) yields a sorted \( a \).

**See also:**

- `sort`
  Describes sorting algorithms used.
- `lexsort`
  Indirect stable sort with multiple keys.
- `ndarray.sort`
  Inplace sort.
- `argpartition`
  Indirect partial sort.

**Notes**

See `sort` for notes on the different sorting algorithms.

As of NumPy 1.4.0 `argsort` works with real/complex arrays containing `nan` values. The enhanced sort order is documented in `sort`.

**Examples**

One dimensional array:

```python
g = np.arange(6)
g
np.argsort(g)
```

Two-dimensional array:

```python
g = np.arange(12).reshape(3, 4)
g
np.argsort(g, axis=0)
np.argsort(g, axis=1)
```

Sorting with keys:

```python
g = np.array([(1, 0), (0, 1)], dtype=[('x', '<i4'), ('y', '<i4')])
g
```
>>> np.argsort(x, order=('x','y'))
array([1, 0])

>>> np.argsort(x, order=('y','x'))
array([0, 1])

ndarray.sort(axis=-1, kind='quicksort', order=None)
Sort an array, in-place.

Parameters
axis : int, optional
Axis along which to sort. Default is -1, which means sort along the last axis.

kind : {'quicksort', 'mergesort', 'heapsort'}, optional
Sorting algorithm. Default is 'quicksort'.

order : list, optional
When a is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

See also:

numpy.sort
Return a sorted copy of an array.

argsort
Indirect sort.

lexsort
Indirect stable sort on multiple keys.

searchsorted
Find elements in sorted array.

partition
Partial sort.

Notes
See sort for notes on the different sorting algorithms.

Examples

>>> a = np.array([[1, 4], [3, 1]])
>>> a.sort(axis=1)
>>> a
array([[1, 4],
       [1, 3]])

>>> a.sort(axis=0)
>>> a
array([[1, 3],
       [1, 4]])

Use the order keyword to specify a field to use when sorting a structured array:

>>> a = np.array([('a', 2), ('c', 1)], dtype=[('x', 'S1'), ('y', int)])
>>> a.sort(order='y')
>>> a
array([b'c', b'a'], dtype=[('x', '<S1'), ('y', '<i4')])
numpy.msort(a)
Return a copy of an array sorted along the first axis.

Parameters
a : array_like
    Array to be sorted.

Returns
sorted_array : ndarray
    Array of the same type and shape as a.

See also:
sort

Notes
np.msort(a) is equivalent to np.sort(a, axis=0).

numpy.sort_complex(a)
Sort a complex array using the real part first, then the imaginary part.

Parameters
a : array_like
    Input array

Returns
out : complex ndarray
    Always returns a sorted complex array.

Examples
>>> np.sort_complex([5, 3, 6, 2, 1])
array([ 1.+0.j, 2.+0.j, 3.+0.j, 5.+0.j, 6.+0.j])

>>> np.sort_complex([1 + 2j, 2 - 1j, 3 - 2j, 3 - 3j, 3 + 5j])
array([ 1.+2.j, 2.-1.j, 3.-3.j, 3.-2.j, 3.+5.j])

numpy.partition(a, kth=-1, kind='introselect', order=None)
Return a partitioned copy of an array.

Creates a copy of the array with its elements rearranged in such a way that the value of the element in kth position
is in the position it would be in a sorted array. All elements smaller than the kth element are moved before this
element and all equal or greater are moved behind it. The ordering of the elements in the two partitions is
undefined.

New in version 1.8.0.

Parameters
a : array_like
    Array to be sorted.

kth : int or sequence of ints
Element index to partition by. The kth value of the element will be in its final sorted position and all smaller elements will be moved before it and all equal or greater elements behind it. The order all elements in the partitions is undefined. If provided with a sequence of kth it will partition all elements indexed by kth of them into their sorted position at once.

axis : int or None, optional

Axis along which to sort. If None, the array is flattened before sorting. The default is -1, which sorts along the last axis.

kind : {'introselect'}, optional

Selection algorithm. Default is ‘introselect’.

order : list, optional

When a is a structured array, this argument specifies which fields to compare first, second, and so on. This list does not need to include all of the fields.

Returns

partitioned_array : ndarray

Array of the same type and shape as a.

See also:

ndarray.partition

Method to sort an array in-place.

argpartition

Indirect partition.

sort

Full sorting

Notes

The various selection algorithms are characterized by their average speed, worst case performance, work space size, and whether they are stable. A stable sort keeps items with the same key in the same relative order. The available algorithms have the following properties:

<table>
<thead>
<tr>
<th>kind</th>
<th>speed</th>
<th>worst case</th>
<th>work space</th>
<th>stable</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘introselect’</td>
<td>1</td>
<td>O(n)</td>
<td>0</td>
<td>no</td>
</tr>
</tbody>
</table>

All the partition algorithms make temporary copies of the data when partitioning along any but the last axis. Consequently, partitioning along the last axis is faster and uses less space than partitioning along any other axis.

The sort order for complex numbers is lexicographic. If both the real and imaginary parts are non-nan then the order is determined by the real parts except when they are equal, in which case the order is determined by the imaginary parts.

Examples

```python
>>> a = np.array([3, 4, 2, 1])
>>> np.partition(a, 3)
array([2, 1, 3, 4])

>>> np.partition(a, [1, 3])
array([1, 2, 3, 4])
```
numpy.argpartition(a, kth, axis=-1, kind='introselect', order=None)

Perform an indirect partition along the given axis using the algorithm specified by the kind keyword. It returns an array of indices of the same shape as a that index data along the given axis in partitioned order.

New in version 1.8.0.

Parameters

- **a**: array_like
  - Array to sort.

- **kth**: int or sequence of ints
  - Element index to partition by. The kth element will be in its final sorted position and all smaller elements will be moved before it and all larger elements behind it. The order all elements in the partitions is undefined. If provided with a sequence of kth it will partition all of them into their sorted position at once.

- **axis**: int or None, optional
  - Axis along which to sort. The default is -1 (the last axis). If None, the flattened array is used.

- **kind**: {'introselect'}, optional
  - Selection algorithm. Default is 'introselect'

- **order**: list, optional
  - When a is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

Returns

- **index_array**: ndarray, int
  - Array of indices that partition a along the specified axis. In other words, a[index_array] yields a sorted a.

See also:

- partition
  - Describes partition algorithms used.

- ndarray.partition
  - Inplace partition.

- argsort
  - Full indirect sort

Notes

See partition for notes on the different selection algorithms.

Examples

One dimensional array:

```python
>>> x = np.array([3, 4, 2, 1])
>>> x[np.argpartition(x, 3)]
array([2, 1, 3, 4])
>>> x[np.argpartition(x, (1, 3))]
array([1, 2, 3, 4])
```
3.27.2 Searching

- `argmax(a[, axis])`: Indices of the maximum values along an axis.
  - Parameters
    - `a`: array_like
      - Input array.
    - `axis`: int, optional
      - By default, the index is into the flattened array, otherwise along the specified axis.
  - Returns
    - `index_array`: ndarray of ints
      - Array of indices into the array. It has the same shape as `a.shape` with the dimension along `axis` removed.
  - See also:
    - `ndarray.argmax`, `argmin`
    - `amax`
      - The maximum value along a given axis.
    - `unravel_index`
      - Convert a flat index into an index tuple.
  - Notes
    - In case of multiple occurrences of the maximum values, the indices corresponding to the first occurrence are returned.
  - Examples
    ```python
    >>> a = np.arange(6).reshape(2,3)
    >>> a
    array([[0, 1, 2],
           [3, 4, 5]])
    >>> np.argmax(a)
    5
    ```
>>> np.argmax(a, axis=0)
array([1, 1, 1])
>>> np.argmax(a, axis=1)
array([2, 2])

>>> b = np.arange(6)
>>> b[1] = 5
>>> b
array([0, 5, 2, 3, 4, 5])
>>> np.argmax(b) # Only the first occurrence is returned.
1

NumPy `nanargmax` $(a, axis=None)$
Return the indices of the maximum values in the specified axis ignoring NaNs. For all-NaN slices `ValueError` is raised. Warning: the results cannot be trusted if a slice contains only NaNs and -Infs.

**Parameters**
- `a`: array_like
  Input data.
- `axis`: int, optional
  Axis along which to operate. By default flattened input is used.

**Returns**
- `index_array`: ndarray
  An array of indices or a single index value.

**See also:**
- `argmax`, `nanargmin`

**Examples**

```python
>>> a = np.array([[np.nan, 4], [2, 3]])
>>> np.argmax(a)
0
>>> np.nanargmax(a)
1
>>> np.nanargmax(a, axis=0)
array([1, 0])
>>> np.nanargmax(a, axis=1)
array([1, 1])
```

NumPy `argmin` $(a, axis=None)$
Return the indices of the minimum values along an axis.

**See also:**
- `argmax`
  Similar function. Please refer to NumPy `argmax` for detailed documentation.

NumPy `nanargmin` $(a, axis=None)$
Return the indices of the minimum values in the specified axis ignoring NaNs. For all-NaN slices `ValueError` is raised. Warning: the results cannot be trusted if a slice contains only NaNs and Infs.

**Parameters**
- `a`: array_like
  Input data.
axis : int, optional
Axis along which to operate. By default flattened input is used.

Returns
index_array : ndarray
An array of indices or a single index value.

See also:
argmin, nanargmax

Examples
>>> a = np.array([[np.nan, 4], [2, 3]])
>>> np.argmin(a)
0
>>> np.nanargmin(a)
2
>>> np.nanargmin(a, axis=0)
array([1, 1])
>>> np.nanargmin(a, axis=1)
array([1, 0])

numpy.argwhere(a)
Find the indices of array elements that are non-zero, grouped by element.

Parameters
a : array_like
Input data.

Returns
index_array : ndarray
Indices of elements that are non-zero. Indices are grouped by element.

See also:
where, nonzero

Notes
np.argwhere(a) is the same as np.transpose(np.nonzero(a)).
The output of argwhere is not suitable for indexing arrays. For this purpose use where(a) instead.

Examples
>>> x = np.arange(6).reshape(2,3)
>>> x
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.argwhere(x>1)
array([[0, 2],
       [1, 0],
       [1, 1],
       [1, 2]])

numpy.nonzero(a)
Return the indices of the elements that are non-zero.
Returns a tuple of arrays, one for each dimension of \( a \), containing the indices of the non-zero elements in that dimension. The corresponding non-zero values can be obtained with:

\[
\text{a[nonzero(a)]}
\]

To group the indices by element, rather than dimension, use:

\[
\text{transpose(nonzero(a))}
\]

The result of this is always a 2-D array, with a row for each non-zero element.

**Parameters**

- \( a \): array_like
  
  Input array.

**Returns**

- \( \text{tuple_of_arrays} \): tuple
  
  Indices of elements that are non-zero.

**See also:**

- \text{flatnonzero}
  
  Return indices that are non-zero in the flattened version of the input array.

- \text{ndarray.nonzero}
  
  Equivalent ndarray method.

- \text{count_nonzero}
  
  Counts the number of non-zero elements in the input array.

**Examples**

```python
>>> x = np.eye(3)
>>> x
array([[ 1., 0., 0.],
       [ 0., 1., 0.],
       [ 0., 0., 1.]])
>>> np.nonzero(x)
(array([0, 1, 2]), array([0, 1, 2]))

>>> x[np.nonzero(x)]
array([ 1., 1., 1.])
>>> np.transpose(np.nonzero(x))
array([[0, 0],
       [1, 1],
       [2, 2]])
```

A common use for `nonzero` is to find the indices of an array, where a condition is True. Given an array \( a \), the condition \( a > 3 \) is a boolean array and since False is interpreted as 0, \( \text{np.nonzero}(a > 3) \) yields the indices of the \( a \) where the condition is true.

```python
>>> a = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])
>>> a > 3
array([[False, False, False],
       [ True, True, True],
       [ True, True, True]], dtype=bool)
>>> np.nonzero(a > 3)
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```
The `nonzero` method of the boolean array can also be called.

```python
>>> (a > 3).nonzero()
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

**numpy.flatnonzero(a)**

Return indices that are non-zero in the flattened version of `a`.

This is equivalent to `a.ravel().nonzero()[0]`.

**Parameters**

- `a` : ndarray
  Input array.

**Returns**

- `res` : ndarray
  Output array, containing the indices of the elements of `a.ravel()` that are non-zero.

**See also:**

- `nonzero`
  Return the indices of the non-zero elements of the input array.

- `ravel`
  Return a 1-D array containing the elements of the input array.

**Examples**

```python
>>> x = np.arange(-2, 3)
>>> x
array([-2, -1, 0, 1, 2])
>>> np.flatnonzero(x)
array([0, 1, 3, 4])
```

Use the indices of the non-zero elements as an index array to extract these elements:

```python
>>> x.ravel()[np.flatnonzero(x)]
array([-2, -1, 1, 2])
```

**numpy.where(condition[, x, y])**

Return elements, either from `x` or `y`, depending on `condition`.

If only `condition` is given, return `condition.nonzero()`.

**Parameters**

- `condition` : array_like, bool
  When True, yield `x`, otherwise yield `y`.

- `x, y` : array_like, optional
  Values from which to choose. `x` and `y` need to have the same shape as `condition`.

**Returns**

- `out` : ndarray or tuple of ndarrays
  If both `x` and `y` are specified, the output array contains elements of `x` where `condition` is True, and elements from `y` elsewhere.

  If only `condition` is given, return the tuple `condition.nonzero()`, the indices where `condition` is True.
See also:

\texttt{nonzero, choose}

Notes

If \(x\) and \(y\) are given and input arrays are 1-D, \texttt{where} is equivalent to:

\[
[xv \text{ if } c \text{ else } yv \text{ for } (c,xv,yv) \text{ in zip(condition,x,y)}]
\]

Examples

\begin{verbatim}
>>> np.where([[[True, False], [True, True]],
               [[1, 2], [3, 4]],
               [[9, 8], [7, 6]]
           )
array([[[1, 8],
        [3, 4]]])

>>> np.where([[0, 1], [1, 0]])
(array([0, 1]), array([1, 0]))

>>> x = np.arange(9.).reshape(3, 3)
>>> np.where(x > 5)
(array([2, 2, 2]), array([0, 1, 2]))

>>> x[np.where( x > 3.0 )]   # Note: result is 1D.
array([ 4., 5., 6., 7., 8.])

>>> np.where(x < 5, x, -1)  # Note: broadcasting.
array([[ 0., 1., 2.],
       [ 3., 4., -1.],
       [-1., -1., -1.]]
      )
\end{verbatim}

Find the indices of elements of \(x\) that are in \texttt{goodvalues}.

\begin{verbatim}
>>> goodvalues = [3, 4, 7]
>>> ix = np.in1d(x.ravel(), goodvalues).reshape(x.shape)
>>> ix
array([[False, False, False],
        [ True,  True, False],
        [False,  True, False]], dtype=bool)

>>> np.where(ix)
(array([1, 1, 2]), array([0, 1, 1]))
\end{verbatim}

\texttt{numpy.searchsorted(a, v, side='left', sorter=None)}

Find indices where elements should be inserted to maintain order.

Find the indices into a sorted array \(a\) such that, if the corresponding elements in \(v\) were inserted before the indices, the order of \(a\) would be preserved.

Parameters

\begin{itemize}
  \item \texttt{a} : 1-D array_like
    Input array. If \texttt{sorter} is None, then it must be sorted in ascending order, otherwise \texttt{sorter} must be an array of indices that sort it.
  \item \texttt{v} : array_like
    Values to insert into \(a\).
  \item \texttt{side} : ['left', 'right'], optional
\end{itemize}
If ‘left’, the index of the first suitable location found is given. If ‘right’, return the last such index. If there is no suitable index, return either 0 or N (where N is the length of a).

**sorter** : 1-D array_like, optional

New in version 1.7.0.

Optional array of integer indices that sort array a into ascending order. They are typically the result of argsort.

**Returns**

**indices** : array of ints

Array of insertion points with the same shape as v.

**See also:**

**sort**

Return a sorted copy of an array.

**histogram**

Produce histogram from 1-D data.

**Notes**

Binary search is used to find the required insertion points.

As of Numpy 1.4.0 `searchsorted` works with real/complex arrays containing nan values. The enhanced sort order is documented in `sort`.

**Examples**

```python
>>> np.searchsorted([1,2,3,4,5], 3)
2
>>> np.searchsorted([1,2,3,4,5], 3, side='right')
3
>>> np.searchsorted([1,2,3,4,5], [-10, 10, 2, 3])
array([0, 5, 1, 2])
```

`numpy.extract(condition, arr)`

Return the elements of an array that satisfy some condition.

This is equivalent to `np.compress(ravel(condition), ravel(arr))`. If `condition` is boolean `np.extract` is equivalent to `arr[condition]`.

**Parameters**

**condition** : array_like

An array whose nonzero or True entries indicate the elements of `arr` to extract.

**arr** : array_like

Input array of the same size as `condition`.

**Returns**

**extract** : ndarray

Rank 1 array of values from `arr` where `condition` is True.

**See also:**

`take`, `put`, `copyto`, `compress`
Examples

```python
>>> arr = np.arange(12).reshape((3, 4))
>>> arr
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
>>> condition = np.mod(arr, 3)==0
>>> condition
array([[ True, False, False,  True],
       [False, False,  True, False],
       [False,  True, False, False]], dtype=bool)
```

If `condition` is boolean:

```python
>>> arr[condition]
array([0, 3, 6, 9])
```

3.27.3 Counting

```python
3.27.3 Counting

numpy.count_nonzero(a) Counts the number of non-zero values in the array a.

Parameters

a : array_like

The array for which to count non-zeros.

Returns

count : int or array of int

Number of non-zero values in the array.

See also:

nonzero

Return the coordinates of all the non-zero values.

Examples

```python
>>> np.count_nonzero(np.eye(4))
4
>>> np.count_nonzero([[0,1,7,0],[3,0,0,2],[19]])
5
```

3.28 Statistics

3.28.1 Order statistics
**NumPy Reference, Release 1.9.2**

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>amin(a[, axis, out, keepdims])</code></td>
<td>Return the minimum of an array or minimum along an axis.</td>
</tr>
<tr>
<td><code>amax(a[, axis, out, keepdims])</code></td>
<td>Return the maximum of an array or maximum along an axis.</td>
</tr>
<tr>
<td><code>nanmin(a[, axis, out, keepdims])</code></td>
<td>Return minimum of an array or minimum along an axis, ignoring any NaNs.</td>
</tr>
<tr>
<td><code>nanmax(a[, axis, out, keepdims])</code></td>
<td>Return the maximum of an array or maximum along an axis, ignoring any NaNs.</td>
</tr>
<tr>
<td><code>ptp(a[, axis, out])</code></td>
<td>Range of values (maximum - minimum) along an axis.</td>
</tr>
<tr>
<td><code>percentile(a, q[, axis, out,...])</code></td>
<td>Compute the qth percentile of the data along the specified axis.</td>
</tr>
</tbody>
</table>

**numpy.amin** *(a, axis=None, out=None, keepdims=False)*

Return the minimum of an array or minimum along an axis.

**Parameters**

- **a**: array_like
  - Input data.
- **axis**: int, optional
  - Axis along which to operate. By default, flattened input is used.
- **out**: ndarray, optional
  - Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output. See doc.ufuncs (Section “Output arguments”) for more details.
- **keepdims**: bool, optional
  - If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original `arr`.

**Returns**

- **amin**: ndarray or scalar
  - Minimum of `a`. If `axis` is None, the result is a scalar value. If `axis` is given, the result is an array of dimension `a.ndim - 1`.

**See also:**

- **amax**
  - The maximum value of an array along a given axis, propagating any NaNs.
- **nanmin**
  - The minimum value of an array along a given axis, ignoring any NaNs.
- **minimum**
  - Element-wise minimum of two arrays, propagating any NaNs.
- **fmin**
  - Element-wise minimum of two arrays, ignoring any NaNs.
- **argmin**
  - Return the indices of the minimum values.
- **nanmax, maximum, fmax**

**Notes**

NaN values are propagated, that is if at least one item is NaN, the corresponding min value will be NaN as well. To ignore NaN values (MATLAB behavior), please use `nanmin`.
Don’t use \texttt{amin} for element-wise comparison of 2 arrays; when \texttt{a.shape[0]} is 2, \texttt{minimum(a[0], a[1])} is faster than \texttt{amin(a, axis=0)}.

\textbf{Examples}

```python
>>> a = np.arange(4).reshape((2,2))
>>> a
array([[0, 1],
       [2, 3]])
>>> np.amin(a)   # Minimum of the flattened array
0
>>> np.amin(a, axis=0)  # Minima along the first axis
array([0, 1])
>>> np.amin(a, axis=1)  # Minima along the second axis
array([0, 2])

>>> b = np.arange(5, dtype=np.float)

>>> np.amin(b)
nan
>>> np.nanmin(b)
0.0
```

\texttt{numpy.amax} \((a, axis=None, out=None, keepdims=False)\)

Return the maximum of an array or maximum along an axis.

\textbf{Parameters}

- \texttt{a} : array_like
  Input data.
- \texttt{axis} : int, optional
  Axis along which to operate. By default, flattened input is used.
- \texttt{out} : ndarray, optional
  Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output. See \texttt{doc.ufuncs} (Section “Output arguments”) for more details.
- \texttt{keepdims} : bool, optional
  If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original \texttt{arr}.

\textbf{Returns}

- \texttt{amax} : ndarray or scalar
  Maximum of \texttt{a}. If \texttt{axis} is None, the result is a scalar value. If \texttt{axis} is given, the result is an array of dimension \texttt{a.ndim - 1}.

\textbf{See also:}

- \texttt{amin}
  The minimum value of an array along a given axis, propagating any NaNs.

- \texttt{nanmax}
  The maximum value of an array along a given axis, ignoring any NaNs.

- \texttt{maximum}
  Element-wise maximum of two arrays, propagating any NaNs.
**fmax**
Element-wise maximum of two arrays, ignoring any NaNs.

**argmax**
Return the indices of the maximum values.

**nanmin, minimum, fmin**

**Notes**
NaN values are propagated, that is if at least one item is NaN, the corresponding max value will be NaN as well. To ignore NaN values (MATLAB behavior), please use nanmax.

Don’t use `amax` for element-wise comparison of 2 arrays; when `a.shape[0]` is 2, `maximum(a[0], a[1])` is faster than `amax(a, axis=0)`.

**Examples**
```python
generate example code here...
```

**numpy.nanmin**(a, axis=None, out=None, keepdims=False)
Return minimum of an array or minimum along an axis, ignoring any NaNs. When all-NaN slices are encountered a `RuntimeWarning` is raised and Nan is returned for that slice.

**Parameters**
- **a**: array_like
  Array containing numbers whose minimum is desired. If `a` is not an array, a conversion is attempted.
- **axis**: int, optional
  Axis along which the minimum is computed. The default is to compute the minimum of the flattened array.
- **out**: ndarray, optional
  Alternate output array in which to place the result. The default is `None`; if provided, it must have the same shape as the expected output, but the type will be cast if necessary. See `doc.ufuncs` for details.

New in version 1.8.0.
- **keepdims**: bool, optional
  New in version 1.8.0.
If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original a.

New in version 1.8.0.

Returns

nanmin : ndarray

An array with the same shape as a, with the specified axis removed. If a is a 0-d array, or if axis is None, an ndarray scalar is returned. The same dtype as a is returned.

See also:
	nanmax

The maximum value of an array along a given axis, ignoring any NaNs.

amin

The minimum value of an array along a given axis, propagating any NaNs.

fmin

Element-wise minimum of two arrays, ignoring any NaNs.

minimum

Element-wise minimum of two arrays, propagating any NaNs.

isnan

Shows which elements are Not a Number (NaN).

isfinite

Shows which elements are neither NaN nor infinity.

amax, fmax, maximum

Notes

Numpy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity. Positive infinity is treated as a very large number and negative infinity is treated as a very small (i.e. negative) number.

If the input has a integer type the function is equivalent to np.min.

Examples

>>> a = np.array([[1, 2], [3, np.nan]])
>>> np.nanmin(a)
1.0
>>> np.nanmin(a, axis=0)
array([ 1.,  2.])
>>> np.nanmin(a, axis=1)
array([ 1.,  3.])

When positive infinity and negative infinity are present:

>>> np.nanmin([1, 2, np.nan, np.inf])
1.0
>>> np.nanmin([1, 2, np.nan, np.NINF])
-inf

numpy.nanmax(a, axis=None, out=None, keepdims=False)

Return the maximum of an array or maximum along an axis, ignoring any NaNs. When all-NaN slices are encountered a RuntimeWarning is raised and NaN is returned for that slice.
Parameters

- **a**: array_like
  Array containing numbers whose maximum is desired. If `a` is not an array, a conversion is attempted.
- **axis**: int, optional
  Axis along which the maximum is computed. The default is to compute the maximum of the flattened array.
- **out**: ndarray, optional
  Alternate output array in which to place the result. The default is `None`; if provided, it must have the same shape as the expected output, but the type will be cast if necessary. See `doc.ufuncs` for details.
  New in version 1.8.0.
- **keepdims**: bool, optional
  If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original `a`.
  New in version 1.8.0.

Returns

- **nanmax**: ndarray
  An array with the same shape as `a`, with the specified axis removed. If `a` is a 0-d array, or if `axis` is `None`, an ndarray scalar is returned. The same dtype as `a` is returned.

See also:

- **nanmin**: The minimum value of an array along a given axis, ignoring any NaNs.
- **amax**: The maximum value of an array along a given axis, propagating any NaNs.
- **fmax**: Element-wise maximum of two arrays, ignoring any NaNs.
- **maximum**: Element-wise maximum of two arrays, propagating any NaNs.
- **isnan**: Shows which elements are Not a Number (NaN).
- **isfinite**: Shows which elements are neither NaN nor infinity.
- **amin, fmin, minimum**:

Notes

NumPy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity. Positive infinity is treated as a very large number and negative infinity is treated as a very small (i.e. negative) number.

If the input has a integer type the function is equivalent to `np.max`. 
Examples

```python
>>> a = np.array([[1, 2], [3, np.nan]])
3.0
>>> np.nanmax(a)
array([ 3., 2.])
>>> np.nanmax(a, axis=0)
array([ 3., 2.])
>>> np.nanmax(a, axis=1)
array([ 2., 3.])
```

When positive infinity and negative infinity are present:

```python
>>> np.nanmax([1, 2, np.nan, np.NINF])
2.0
>>> np.nanmax([1, 2, np.nan, np.inf])
inf
```

```
numpy.ptp(a, axis=None, out=None)

Range of values (maximum - minimum) along an axis.

The name of the function comes from the acronym for 'peak to peak'.
```

Parameters

- **a**: array_like
  - Input values.
- **axis**: int, optional
  - Axis along which to find the peaks. By default, flatten the array.
- **out**: array_like
  - Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output, but the type of the output values will be cast if necessary.

Returns

- **ptp**: ndarray
  - A new array holding the result, unless `out` was specified, in which case a reference to `out` is returned.

Examples

```python
>>> x = np.arange(4).reshape((2,2))
array([[0, 1],
       [2, 3]])
>>> np.ptp(x, axis=0)
array([2, 2])
>>> np.ptp(x, axis=1)
array([1, 1])
```

```
numpy.percentile(a, q, axis=None, out=None, overwrite_input=False, interpolation='linear', keepdims=False)

Compute the qth percentile of the data along the specified axis.

Returns the qth percentile of the array elements.
Parameters

a : array_like
Input array or object that can be converted to an array.

q : float in range of [0,100] (or sequence of floats)
Percentile to compute which must be between 0 and 100 inclusive.

axis : int or sequence of int, optional
Axis along which the percentiles are computed. The default (None) is to compute the percentiles along a flattened version of the array. A sequence of axes is supported since version 1.9.0.

out : ndarray, optional
Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output, but the type (of the output) will be cast if necessary.

overwrite_input : bool, optional
If True, then allow use of memory of input array a for calculations. The input array will be modified by the call to percentile. This will save memory when you do not need to preserve the contents of the input array. In this case you should not make any assumptions about the content of the passed in array a after this function completes – treat it as undefined. Default is False. Note that, if the a input is not already an array this parameter will have no effect, a will be converted to an array internally regardless of the value of this parameter.

interpolation : {'linear', 'lower', 'higher', 'midpoint', 'nearest'}
This optional parameter specifies the interpolation method to use, when the desired quantile lies between two data points i and j:

- linear: \( i + (j - i) \times fraction \), where \( fraction \) is the fractional part of the index surrounded by \( i \) and \( j \).
- lower: \( i \).
- higher: \( j \).
- nearest: \( i \) or \( j \) whichever is nearest.
- midpoint: \( (i + j) / 2 \).

New in version 1.9.0.

keepdims : bool, optional
If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original \( arr \).

New in version 1.9.0.

Returns

percentile : scalar or ndarray
If a single percentile \( q \) is given and axis=None a scalar is returned. If multiple percentiles \( q \) are given an array holding the result is returned. The results are listed in the first axis. (If \( out \) is specified, in which case that array is returned instead). If the input contains integers, or floats of smaller precision than 64, then the output data-type is float64. Otherwise, the output data-type is the same as that of the input.
See also:

mean, median

Notes

Given a vector V of length N, the q-th percentile of V is the q-th ranked value in a sorted copy of V. The values and distances of the two nearest neighbors as well as the interpolation parameter will determine the percentile if the normalized ranking does not match q exactly. This function is the same as the median if q=50, the same as the minimum if q=0 and the same as the maximum if q=100.

Examples

```python
>>> a = np.array([[10, 7, 4], [3, 2, 1]])
>>> a
array([[10, 7, 4],
       [ 3, 2, 1]])
>>> np.percentile(a, 50)
array([ 3.5])
>>> np.percentile(a, 50, axis=0)
array([[ 6.5, 4.5, 2.5]])
>>> np.percentile(a, 50, axis=1)
array([[ 7.],
       [ 2.]])
>>> m = np.percentile(a, 50, axis=0)
>>> out = np.zeros_like(m)
>>> np.percentile(a, 50, axis=0, out=m)
array([[ 6.5, 4.5, 2.5]])
>>> m
array([[ 6.5, 4.5, 2.5]])
>>> b = a.copy()
>>> np.percentile(b, 50, axis=1, overwrite_input=True)
array([[ 7.],
       [ 2.]])
>>> assert not np.all(a==b)
>>> b = a.copy()
>>> np.percentile(b, 50, axis=None, overwrite_input=True)
array([ 3.5])
```

3.28.2 Averages and variances

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```python
numpy.median(a, axis=None, out=None, overwrite_input=False, keepdims=False)
```

Compute the median along the specified axis.

Returns the median of the array elements.
Parameters

**a** : array_like
Input array or object that can be converted to an array.

**axis** : int or sequence of int, optional
Axis along which the medians are computed. The default (axis=None) is to compute
the median along a flattened version of the array. A sequence of axes is supported since
version 1.9.0.

**out** : ndarray, optional
Alternative output array in which to place the result. It must have the same shape and
buffer length as the expected output, but the type (of the output) will be cast if necessary.

**overwrite_input** : bool, optional
If True, then allow use of memory of input array (a) for calculations. The input array
will be modified by the call to median. This will save memory when you do not need to
preserve the contents of the input array. Treat the input as undefined, but it will probably
be fully or partially sorted. Default is False. Note that, if overwrite_input is True and
the input is not already an ndarray, an error will be raised.

**keepdims** : bool, optional
If this is set to True, the axes which are reduced are left in the result as dimensions with
size one. With this option, the result will broadcast correctly against the original arr.

New in version 1.9.0.

Returns

**median** : ndarray
A new array holding the result (unless out is specified, in which case that array is re-
turned instead). If the input contains integers, or floats of smaller precision than 64,
then the output data-type is float64. Otherwise, the output data-type is the same as that
of the input.

See also:

mean, percentile

Notes

Given a vector V of length N, the median of V is the middle value of a sorted copy of V, V_sorted - i.e.,
V_sorted[(N-1)/2], when N is odd. When N is even, it is the average of the two middle values of
V_sorted.

Examples

```python
>>> a = np.array([[10, 7, 4],
                 [ 3, 2, 1]])
>>> a
array([[10,  7,  4],
       [ 3,  2,  1]])
>>> np.median(a)
3.5
>>> np.median(a, axis=0)
array([ 6.5,  4.5,  2.5])
>>> np.median(a, axis=1)
array([ 7.,  2.])
>>> m = np.median(a, axis=0)
>>> out = np.zeros_like(m)
```

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```python
>>> np.median(a, axis=0, out=m)
array([ 6.5, 4.5, 2.5])
>>> m
array([ 6.5, 4.5, 2.5])
>>> b = a.copy()
>>> np.median(b, axis=1, overwrite_input=True)
array([ 7., 2.])
>>> assert not np.all(a==b)
>>> b = a.copy()
>>> np.median(b, axis=None, overwrite_input=True)
3.5
>>> assert not np.all(a==b)
```

`numpy.average(a, axis=None, weights=None, returned=False)`

Compute the weighted average along the specified axis.

**Parameters**

- **a**: array_like
  
  Array containing data to be averaged. If a is not an array, a conversion is attempted.

- **axis**: int, optional
  
  Axis along which to average a. If None, averaging is done over the flattened array.

- **weights**: array_like, optional
  
  An array of weights associated with the values in a. Each value in a contributes to the average according to its associated weight. The weights array can either be 1-D (in which case its length must be the size of a along the given axis) or of the same shape as a. If weights=None, then all data in a are assumed to have a weight equal to one.

- **returned**: bool, optional
  
  Default is False. If True, the tuple (average, sum_of_weights) is returned, otherwise only the average is returned. If weights=None, sum_of_weights is equivalent to the number of elements over which the average is taken.

**Returns**

- **average, [sum_of_weights]** : {array_type, double}
  
  Return the average along the specified axis. When returned is True, return a tuple with the average as the first element and the sum of the weights as the second element. The return type is Float if a is of integer type, otherwise it is of the same type as a. sum_of_weights is of the same type as average.

**Raises**

- **ZeroDivisionError**
  
  When all weights along axis are zero. See `numpy.ma.average` for a version robust to this type of error.

- **TypeError**
  
  When the length of 1D weights is not the same as the shape of a along axis.

**See also:**

- `mean`
- `ma.average`
  
  average for masked arrays – useful if your data contains “missing” values
Examples

```python
>>> data = range(1,5)
>>> data
[1, 2, 3, 4]
>>> np.average(data)
2.5
>>> np.average(range(1,11), weights=range(10,0,-1))
4.0

>>> data = np.arange(6).reshape((3,2))
>>> data
array([[0, 1],
       [2, 3],
       [4, 5]])
>>> np.average(data, axis=1, weights=[1./4, 3./4])
array([ 0.75, 2.75, 4.75])
>>> np.average(data, weights=[1./4, 3./4])
Traceback (most recent call last):
  ...  
TypeError: Axis must be specified when shapes of a and weights differ.
```

def numpy.mean(a, axis=None, dtype=None, out=None, keepdims=False)
Compute the arithmetic mean along the specified axis.

Returns the average of the array elements. The average is taken over the flattened array by default, otherwise over the specified axis. float64 intermediate and return values are used for integer inputs.

Parameters
- a : array_like
  Array containing numbers whose mean is desired. If a is not an array, a conversion is attempted.
- axis : int, optional
  Axis along which the means are computed. The default is to compute the mean of the flattened array.
- dtype : data-type, optional
  Type to use in computing the mean. For integer inputs, the default is float64; for floating point inputs, it is the same as the input dtype.
- out : ndarray, optional
  Alternate output array in which to place the result. The default is None; if provided, it must have the same shape as the expected output, but the type will be cast if necessary. See doc.ufuncs for details.
- keepdims : bool, optional
  If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original arr.

Returns
- m : ndarray, see dtype parameter above
  If out=None, returns a new array containing the mean values, otherwise a reference to the output array is returned.
See also:

average
   Weighted average

std, var, nanmean, nanstd, nanvar

Notes
The arithmetic mean is the sum of the elements along the axis divided by the number of elements.

Note that for floating-point input, the mean is computed using the same precision the input has. Depending
on the input data, this can cause the results to be inaccurate, especially for float32 (see example below).
Specifying a higher-precision accumulator using the dtype keyword can alleviate this issue.

Examples

```python
>>> a = np.array([[1, 2], [3, 4]])
>>> np.mean(a)
2.5
>>> np.mean(a, axis=0)
array([ 2., 3.])
>>> np.mean(a, axis=1)
array([ 1.5, 3.5])
```

In single precision, mean can be inaccurate:

```python
>>> a = np.zeros((2, 512*512), dtype=np.float32)
>>> a[0, :] = 1.0
>>> a[1, :] = 0.1
>>> np.mean(a)
0.546875
```

Computing the mean in float64 is more accurate:

```python
>>> np.mean(a, dtype=np.float64)
0.55000000074505806
```

numpy.std(a, axis=None, dtype=None, out=None, ddof=0, keepdims=False)
Compute the standard deviation along the specified axis.

Returns the standard deviation, a measure of the spread of a distribution, of the array elements. The standard
deviation is computed for the flattened array by default, otherwise over the specified axis.

Parameters

- a : array_like
  Calculate the standard deviation of these values.

- axis : int, optional
  Axis along which the standard deviation is computed. The default is to compute the
  standard deviation of the flattened array.

- dtype : dtype, optional
  Type to use in computing the standard deviation. For arrays of integer type the default
  is float64, for arrays of float types it is the same as the array type.

- out : ndarray, optional
  Alternative output array in which to place the result. It must have the same shape as the
  expected output but the type (of the calculated values) will be cast if necessary.
ddof : int, optional

Means Delta Degrees of Freedom. The divisor used in calculations is \( N - ddof \), where \( N \) represents the number of elements. By default \( ddof \) is zero.

keepdims : bool, optional

If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original \( arr \).

Returns

standard_deviation : ndarray, see dtype parameter above.

If \( out \) is None, return a new array containing the standard deviation, otherwise return a reference to the output array.

See also:

\( \text{var}, \text{mean}, \text{nanmean}, \text{nanstd}, \text{nanvar} \)

\( \text{numpy.doc.ufuncs} \)

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Notes

The standard deviation is the square root of the average of the squared deviations from the mean, i.e., \( \text{std} = \sqrt{\text{mean}(\text{abs}(x - \text{x.mean()}**)2)} \).

The average squared deviation is normally calculated as \( x.\text{sum}() / N \), where \( N = \text{len}(x) \). If, however, \( ddof \) is specified, the divisor \( N - ddof \) is used instead. In standard statistical practice, \( ddof=1 \) provides an unbiased estimator of the variance of the infinite population. \( ddof=0 \) provides a maximum likelihood estimate of the variance for normally distributed variables. The standard deviation computed in this function is the square root of the estimated variance, so even with \( ddof=1 \), it will not be an unbiased estimate of the standard deviation per se.

Note that, for complex numbers, \( \text{std} \) takes the absolute value before squaring, so that the result is always real and nonnegative.

For floating-point input, the \( \text{std} \) is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the dtype keyword can alleviate this issue.

Examples

>>> a = np.array([[1, 2], [3, 4]])
>>> np.std(a)
1.1180339887498949

>>> np.std(a, axis=0)
array([ 1., 1.])

>>> np.std(a, axis=1)
array([ 0.5, 0.5])

In single precision, \( \text{std}() \) can be inaccurate:

>>> a = np.zeros((2,512*512), dtype=np.float32)
>>> a[0,:] = 1.0
>>> a[1,:] = 0.1

Computing the standard deviation in float64 is more accurate:
numpy.var(a, axis=None, dtype=None, out=None, ddof=0, keepdims=False)

Compute the variance along the specified axis.

Returns the variance of the array elements, a measure of the spread of a distribution. The variance is computed for the flattened array by default, otherwise over the specified axis.

Parameters

- **a**: array_like
  - Array containing numbers whose variance is desired. If `a` is not an array, a conversion is attempted.

- **axis**: int, optional
  - Axis along which the variance is computed. The default is to compute the variance of the flattened array.

- **dtype**: data-type, optional
  - Type to use in computing the variance. For arrays of integer type the default is float32; for arrays of float types it is the same as the array type.

- **out**: ndarray, optional
  - Alternate output array in which to place the result. It must have the same shape as the expected output, but the type is cast if necessary.

- **ddof**: int, optional
  - “Delta Degrees of Freedom”: the divisor used in the calculation is N - ddof, where N represents the number of elements. By default ddof is zero.

- **keepdims**: bool, optional
  - If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original arr.

Returns

- **variance**: ndarray, see dtype parameter above
  - If out=None, returns a new array containing the variance; otherwise, a reference to the output array is returned.

See also:

- std, mean, nanmean, nanstd, nanvar

Notes

The variance is the average of the squared deviations from the mean, i.e., \( \text{var} = \text{mean}(\text{abs}(x - x.\text{mean}())^2) \).

The mean is normally calculated as \( x.\text{sum()} / N \), where \( N = \text{len}(x) \). If, however, \( ddof \) is specified, the divisor \( N - ddof \) is used instead. In standard statistical practice, \( ddof=1 \) provides an unbiased estimator of the variance of a hypothetical infinite population. \( ddof=0 \) provides a maximum likelihood estimate of the variance for normally distributed variables.

Note that for complex numbers, the absolute value is taken before squaring, so that the result is always real and nonnegative.
For floating-point input, the variance is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the dtype keyword can alleviate this issue.

**Examples**

```python
>>> a = np.array([[1,2],[3,4]])
>>> np.var(a)
1.25
>>> np.var(a, axis=0)
array([ 1., 1.])
>>> np.var(a, axis=1)
array([ 0.25, 0.25])
```

In single precision, var() can be inaccurate:

```python
>>> a = np.zeros((2,512*512), dtype=np.float32)
>>> a[0,:] = 1.0
>>> a[1,:] = 0.1
>>> np.var(a)
0.20405951142311096
```

Computing the variance in float64 is more accurate:

```python
>>> np.var(a, dtype=np.float64)
0.20249999932997387
>>> ((1-0.55)**2 + (0.1-0.55)**2)/2
0.20250000000000001
```

**numpy.nanmean** *(a, axis=None, dtype=None, out=None, keepdims=False)*

Compute the arithmetic mean along the specified axis, ignoring NaNs.

Returns the average of the array elements. The average is taken over the flattened array by default, otherwise over the specified axis. float64 intermediate and return values are used for integer inputs.

For all-NaN slices, NaN is returned and a *RuntimeWarning* is raised.

New in version 1.8.0.

**Parameters**

- **a**: array_like
  
  Array containing numbers whose mean is desired. If a is not an array, a conversion is attempted.

- **axis**: int, optional
  
  Axis along which the means are computed. The default is to compute the mean of the flattened array.

- **dtype**: data-type, optional
  
  Type to use in computing the mean. For integer inputs, the default is float64; for inexact inputs, it is the same as the input dtype.

- **out**: ndarray, optional
  
  Alternate output array in which to place the result. The default is None; if provided, it must have the same shape as the expected output, but the type will be cast if necessary. See doc.ufuncs for details.

- **keepdims**: bool, optional
If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original arr.

Returns

- `m` : ndarray, see dtype parameter above
  
  If `out=None`, returns a new array containing the mean values, otherwise a reference to the output array is returned. Nan is returned for slices that contain only NaNs.

See also:

- `average` : Weighted average
- `mean` : Arithmetic mean taken while not ignoring NaNs
- `var`, `nanvar`

Notes

The arithmetic mean is the sum of the non-NaN elements along the axis divided by the number of non-NaN elements.

Note that for floating-point input, the mean is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32. Specifying a higher-precision accumulator using the `dtype` keyword can alleviate this issue.

Examples

```python
>>> a = np.array([[1, np.nan], [3, 4]])
>>> np.nanmean(a)
2.6666666666666665
>>> np.nanmean(a, axis=0)
array([ 2., 4.])
>>> np.nanmean(a, axis=1)
array([ 1., 3.5])
```

`numpy.nanstd(a, axis=None, dtype=None, out=None, ddof=0, keepdims=False)`

Compute the standard deviation along the specified axis, while ignoring NaNs.

Returns the standard deviation, a measure of the spread of a distribution, of the non-NaN array elements. The standard deviation is computed for the flattened array by default, otherwise over the specified axis.

For all-NaN slices or slices with zero degrees of freedom, NaN is returned and a `RuntimeWarning` is raised.

New in version 1.8.0.

Parameters

- `a` : array_like
  
  Calculate the standard deviation of the non-NaN values.

- `axis` : int, optional
  
  Axis along which the standard deviation is computed. The default is to compute the standard deviation of the flattened array.

- `dtype` : dtype, optional
  
  Type to use in computing the standard deviation. For arrays of integer type the default is float64, for arrays of float types it is the same as the array type.
**out**: ndarray, optional

Alternative output array in which to place the result. It must have the same shape as the expected output but the type (of the calculated values) will be cast if necessary.

**ddof**: int, optional

Means Delta Degrees of Freedom. The divisor used in calculations is \(N - ddof\), where \(N\) represents the number of non-NaN elements. By default \(ddof = 0\).

**keepdims**: bool, optional

If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original \(arr\).

**Returns**

**standard_deviation**: ndarray, see dtype parameter above.

If \(out\) is None, return a new array containing the standard deviation, otherwise return a reference to the output array. If \(ddof\) is \(\geq\) the number of non-NaN elements in a slice or the slice contains only NaNs, then the result for that slice is NaN.

**See also:**

*var*, *mean*, *std*, *nanvar*, *nanmean*

**numpy.doc.ufuncs**

Section “Output arguments”

**Notes**

The standard deviation is the square root of the average of the squared deviations from the mean: \(std = \sqrt{\text{mean}(\text{abs}(x - x.\text{mean}())**2)}\).

The average squared deviation is normally calculated as \(x.\text{sum()} / N\), where \(N = \text{len}(x)\). If, however, \(ddof\) is specified, the divisor \(N - ddof\) is used instead. In standard statistical practice, \(ddof=1\) provides an unbiased estimator of the variance of the infinite population. \(ddof=0\) provides a maximum likelihood estimate of the variance for normally distributed variables. The standard deviation computed in this function is the square root of the estimated variance, so even with \(ddof=1\), it will not be an unbiased estimate of the standard deviation per se.

Note that, for complex numbers, \(std\) takes the absolute value before squaring, so that the result is always real and nonnegative.

For floating-point input, the \(std\) is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the \(\text{dtype}\) keyword can alleviate this issue.

**Examples**

```python
>>> a = np.array([[1, np.nan], [3, 4]]
>>> np.nanstd(a)
1.247219128924647
>>> np.nanstd(a, axis=0)
array([ 1., 0.])
>>> np.nanstd(a, axis=1)
array([ 0., 0.5])
```

**numpy.nanvar** *(a, axis=None, dtype=None, out=None, ddof=0, keepdims=False)*

Compute the variance along the specified axis, while ignoring NaNs.

Returns the variance of the array elements, a measure of the spread of a distribution. The variance is computed for the flattened array by default, otherwise over the specified axis.
For all-NaN slices or slices with zero degrees of freedom, NaN is returned and a `RuntimeWarning` is raised.

New in version 1.8.0.

**Parameters**

- `a` : array_like
  Array containing numbers whose variance is desired. If `a` is not an array, a conversion is attempted.

- `axis` : int, optional
  Axis along which the variance is computed. The default is to compute the variance of the flattened array.

- `dtype` : data-type, optional
  Type to use in computing the variance. For arrays of integer type the default is `float32`; for arrays of float types it is the same as the array type.

- `out` : ndarray, optional
  Alternate output array in which to place the result. It must have the same shape as the expected output, but the type is cast if necessary.

- `ddof` : int, optional
  “Delta Degrees of Freedom”: the divisor used in the calculation is \( N - \text{ddof} \), where \( N \) represents the number of non-NaN elements. By default `ddof` is zero.

- `keepdims` : bool, optional
  If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original `arr`.

**Returns**

- `variance` : ndarray, see dtype parameter above
  If `out` is None, return a new array containing the variance, otherwise return a reference to the output array. If `ddof` is \( \geq \) the number of non-NaN elements in a slice or the slice contains only NaNs, then the result for that slice is NaN.

**See also:**

- `std`
  Standard deviation

- `mean`
  Average

- `var`
  Variance while not ignoring NaNs

- `nanstd`, `nanmean`

- `numpy.doc.ufuncs`
  Section “Output arguments”

**Notes**

The variance is the average of the squared deviations from the mean, i.e., \( \text{var} = \text{mean}(|x - x.\text{mean()}|)^2 \).
The mean is normally calculated as \( \frac{\text{x}.\text{sum}}{N} \), where \( N = \text{len(x)} \). If, however, \( ddof \) is specified, the divisor \( N - ddof \) is used instead. In standard statistical practice, \( ddof=1 \) provides an unbiased estimator of the variance of a hypothetical infinite population. \( ddof=0 \) provides a maximum likelihood estimate of the variance for normally distributed variables.

Note that for complex numbers, the absolute value is taken before squaring, so that the result is always real and nonnegative.

For floating-point input, the variance is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for \( \text{float32} \) (see example below). Specifying a higher-accuracy accumulator using the \( \text{dtype} \) keyword can alleviate this issue.

**Examples**

```python
g = np.arange(5)
>>> np.std(g)
1.4142135623730951
```

**3.28.3 Correlating**

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<td><code>numpy.corrcoef(x, y=None, rowvar=1, bias=0, ddof=None)</code></td>
<td>Return correlation coefficients.</td>
</tr>
<tr>
<td><code>numpy.correlate(a, v[, mode, old_behavior])</code></td>
<td>Cross-correlation of two 1-dimensional sequences.</td>
</tr>
<tr>
<td><code>numpy.cov(m[, y, rowvar=1, bias=0, ddof=None])</code></td>
<td>Estimate a covariance matrix, given data.</td>
</tr>
</tbody>
</table>

Please refer to the documentation for `cov` for more detail. The relationship between the correlation coefficient matrix, \( P \), and the covariance matrix, \( C \), is

\[
P_{ij} = \frac{C_{ij}}{\sqrt{C_{ii} \times C_{jj}}}
\]

The values of \( P \) are between -1 and 1, inclusive.

**Parameters**

- **x** : array_like
  
  A 1-D or 2-D array containing multiple variables and observations. Each row of \( m \) represents a variable, and each column a single observation of all those variables. Also see `rowvar` below.

- **y** : array_like, optional
  
  An additional set of variables and observations. \( y \) has the same shape as \( m \).

- **rowvar** : int, optional
  
  If `rowvar` is non-zero (default), then each row represents a variable, with observations in the columns. Otherwise, the relationship is transposed: each column represents a variable, while the rows contain observations.

- **bias** : int, optional
Default normalization is by \((N - 1)\), where \(N\) is the number of observations (unbiased estimate). If \(bias\) is 1, then normalization is by \(N\). These values can be overridden by using the keyword \(ddof\) in numpy versions \(\geq 1.5\).

\(ddof\): \([\text{None, int}]\), optional

New in version 1.5.

If not \(\text{None}\) normalization is by \((N - ddof)\), where \(N\) is the number of observations; this overrides the value implied by \(bias\). The default value is \(\text{None}\).

Returns

\(\text{out}\) : ndarray

The correlation coefficient matrix of the variables.

See also:

- \texttt{cov}
  Covariance matrix

\texttt{numpy.correlate}(a, v, \texttt{mode}='valid', \texttt{old_behavior}=\texttt{False})

Cross-correlation of two 1-dimensional sequences.

This function computes the correlation as generally defined in signal processing texts:

\[
c_{av}[k] = \sum_n a[n+k] \ast \text{conj}(v[n])
\]

with \(a\) and \(v\) sequences being zero-padded where necessary and \(\text{conj}\) being the conjugate.

Parameters

- \(a, v\) : array_like
  Input sequences.

- \texttt{mode}\ : \{'valid', 'same', 'full'\}, optional
  Refer to the \texttt{convolve docstring}. Note that the default is \texttt{valid}, unlike \texttt{convolve}, which uses \texttt{full}.

- \texttt{old_behavior}\ : bool
  If True, uses the old behavior from Numeric, \((\text{correlate}(a,v) == \text{correlate}(v,a))\), and the conjugate is not taken for complex arrays). If False, uses the conventional signal processing definition.

Returns

\(\text{out}\) : ndarray

Discrete cross-correlation of \(a\) and \(v\).

See also:

- \texttt{convolve}
  Discrete, linear convolution of two one-dimensional sequences.

Notes

The definition of correlation above is not unique and sometimes correlation may be defined differently. Another common definition is:

\[
c'_{av}[k] = \sum_n a[n] \ast \text{conj}(v[n+k])
\]

which is related to \(c_{av}[k]\) by \(c'_{av}[k] = c_{av}[-k]\).
Examples

```python
>>> np.correlate([1, 2, 3], [0, 1, 0.5])
array([ 3.5])
>>> np.correlate([1, 2, 3], [0, 1, 0.5], "same")
array([ 2. , 3.5, 3. ])
>>> np.correlate([1, 2, 3], [0, 1, 0.5], "full")
array([ 0.5, 2. , 3.5, 3. , 0. ])
```

Using complex sequences:

```python
>>> np.correlate([1+1j, 2, 3-1j], [0, 1, 0.5j], 'full')
array([ 0.5-0.5j, 1.0+0.j , 1.5-1.5j, 3.0-1.j , 0.0+0.j ])

Note that you get the time reversed, complex conjugated result when the two input sequences change places, i.e., \( c_{va}[k] = c^\ast_{av}[-k] \):

```python
>>> np.correlate([0, 1, 0.5j], [1+1j, 2, 3-1j], 'full')
array([ 0.0+0.j , 3.0+1.j , 1.5+1.5j, 1.0+0.j , 0.5+0.5j])
```

`numpy.cov(m, y=None, rowvar=1, bias=0, ddof=None)`

Estimate a covariance matrix, given data.

Covariance indicates the level to which two variables vary together. If we examine N-dimensional samples, \( X = [x_1, x_2, ... x_N]^T \), then the covariance matrix element \( C_{ij} \) is the covariance of \( x_i \) and \( x_j \). The element \( C_{ii} \) is the variance of \( x_i \).

Parameters

- **m** : array_like
  A 1-D or 2-D array containing multiple variables and observations. Each row of \( m \) represents a variable, and each column a single observation of all those variables. Also see `rowvar` below.

- **y** : array_like, optional
  An additional set of variables and observations. \( y \) has the same form as that of \( m \).

- **rowvar** : int, optional
  If `rowvar` is non-zero (default), then each row represents a variable, with observations in the columns. Otherwise, the relationship is transposed: each column represents a variable, while the rows contain observations.

- **bias** : int, optional
  Default normalization is by \( (N - 1) \), where \( N \) is the number of observations given (unbiased estimate). If `bias` is 1, then normalization is by \( N \). These values can be overridden by using the keyword `ddof` in numpy versions >= 1.5.

- **ddof** : int, optional
  New in version 1.5.
  If not None normalization is by \( (N - ddof) \), where \( N \) is the number of observations; this overrides the value implied by `bias`. The default value is None.

Returns

- **out** : ndarray
  The covariance matrix of the variables.

See also:
**corrcoef**

Normalized covariance matrix

**Examples**

Consider two variables, \( x_0 \) and \( x_1 \), which correlate perfectly, but in opposite directions:

```python
>>> x = np.array([[0, 2], [1, 1], [2, 0]]).T
>>> x
array([[0, 1, 2],
       [2, 1, 0]])
```

Note how \( x_0 \) increases while \( x_1 \) decreases. The covariance matrix shows this clearly:

```python
>>> np.cov(x)
array([[ 1., -1.],
       [-1., 1.]])
```

Note that element \( C_{0,1} \), which shows the correlation between \( x_0 \) and \( x_1 \), is negative.

Further, note how \( x \) and \( y \) are combined:

```python
>>> x = [-2.1, -1, 4.3]
>>> y = [3, 1.1, 0.12]
>>> X = np.vstack((x, y))
>>> print np.cov(X)
[[ 11.71 -4.286  
  -4.286 2.14413333]]
>>> print np.cov(x, y)
[[ 11.71 -4.286  
  -4.286 2.14413333]]
>>> print np.cov(x)
11.71
```

### 3.28.4 Histograms

<table>
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<td><code>histogram(a, bins=10, range=None, normed=False, weights=None, density=None)</code></td>
<td>Compute the histogram of a set of data.</td>
</tr>
<tr>
<td><code>histogram2d(x, y, bins, range, normed, weights)</code></td>
<td>Compute the bi-dimensional histogram of two data samples.</td>
</tr>
<tr>
<td><code>histogramdd(sample, bins, range, normed, ...)</code></td>
<td>Compute the multidimensional histogram of some data.</td>
</tr>
<tr>
<td><code>bincount(x, weights, minlength)</code></td>
<td>Count number of occurrences of each value in array of non-negative ints.</td>
</tr>
<tr>
<td><code>digitize(x, bins[, right])</code></td>
<td>Return the indices of the bins to which each value in input array belongs.</td>
</tr>
</tbody>
</table>

numpy.h

```
Compute the histogram of a set of data.

**Parameters**

- **a**: array_like
  
  Input data. The histogram is computed over the flattened array.

- **bins**: int or sequence of scalars, optional
  
  If `bins` is an int, it defines the number of equal-width bins in the given range (10, by default). If `bins` is a sequence, it defines the bin edges, including the rightmost edge, allowing for non-uniform bin widths.

- **range**: (float, float), optional
  
  Lower and upper range of the bins.
The lower and upper range of the bins. If not provided, range is simply \((a.min(), a.max())\). Values outside the range are ignored.

**normed** : bool, optional

This keyword is deprecated in Numpy 1.6 due to confusing/buggy behavior. It will be removed in Numpy 2.0. Use the density keyword instead. If False, the result will contain the number of samples in each bin. If True, the result is the value of the probability density function at the bin, normalized such that the integral over the range is 1. Note that this latter behavior is known to be buggy with unequal bin widths; use density instead.

**weights** : array_like, optional

An array of weights, of the same shape as \(a\). Each value in \(a\) only contributes its associated weight towards the bin count (instead of 1). If normed is True, the weights are normalized, so that the integral of the density over the range remains 1

**density** : bool, optional

If False, the result will contain the number of samples in each bin. If True, the result is the value of the probability density function at the bin, normalized such that the integral over the range is 1. Note that the sum of the histogram values will not be equal to 1 unless bins of unity width are chosen; it is not a probability mass function. Overrides the normed keyword if given.

**Returns**

**hist** : array

The values of the histogram. See normed and weights for a description of the possible semantics.

**bin_edges** : array of dtype float

Return the bin edges \((\text{length(hist)+1})\).

**Examples**

```python
>>> np.histogram([1, 2, 1], bins=[0, 1, 2, 3])
(array([0, 2, 1]), array([0, 1, 2, 3]))

>>> np.histogram(np.arange(4), bins=np.arange(5), density=True)
(array([ 0.25, 0.25, 0.25, 0.25]), array([0, 1, 2, 3, 4]))

>>> np.histogram([[1, 2, 1], [1, 0, 1]], bins=[0,1,2,3])
(array([1, 4, 1]), array([0, 1, 2, 3]))

>>> a = np.arange(5)

>>> hist, bin_edges = np.histogram(a, density=True)

>>> hist
array([ 0.5, 0., 0.5, 0., 0.5, 0., 0.5, 0., 0.5])
```
NumPy Reference, Release 1.9.2

```python
>>> hist.sum()
2.4999999999999996

>>> np.sum(hist*np.diff(bin_edges))
1.0
```

numpy.histogram2d(x, y, bins=10, range=None, normed=False, weights=None)

Compute the bi-dimensional histogram of two data samples.

**Parameters**

- **x**: array_like, shape (N,)
  
  An array containing the x coordinates of the points to be histogrammed.

- **y**: array_like, shape (N,)
  
  An array containing the y coordinates of the points to be histogrammed.

- **bins**: int or [int, int] or array_like or [array, array], optional
  
  The bin specification:
  
  - If int, the number of bins for the two dimensions (nx=ny=bins).
  - If [int, int], the number of bins in each dimension (nx, ny = bins).
  - If array_like, the bin edges for the two dimensions (x_edges=y_edges=bins).
  - If [array, array], the bin edges in each dimension (x_edges, y_edges = bins).

- **range**: array_like, shape(2,2), optional
  
  The leftmost and rightmost edges of the bins along each dimension (if not specified explicitly in the bins parameters): [[xmin, xmax], [ymin, ymax]]. All values outside of this range will be considered outliers and not tallied in the histogram.

- **normed**: bool, optional
  
  If False, returns the number of samples in each bin. If True, returns the bin density `bin_count / sample_count / bin_area`.

- **weights**: array_like, shape(N,), optional
  
  An array of values `w_i` weighing each sample `(x_i, y_i)`. Weights are normalized to 1 if normed is True. If normed is False, the values of the returned histogram are equal to the sum of the weights belonging to the samples falling into each bin.

**Returns**

- **H**: ndarray, shape(nx, ny)
  
  The bi-dimensional histogram of samples x and y. Values in x are histogrammed along the first dimension and values in y are histogrammed along the second dimension.

- **xedges**: ndarray, shape(nx,)
  
  The bin edges along the first dimension.

- **yedges**: ndarray, shape(ny,)
  
  The bin edges along the second dimension.

**See also:**

- **histogram**
  
  1D histogram
**histogramdd**

Multidimensional histogram

**Notes**

When `normed` is True, then the returned histogram is the sample density, defined such that the sum over bins of the product `bin_value * bin_area` is 1.

Please note that the histogram does not follow the Cartesian convention where `x` values are on the abscissa and `y` values on the ordinate axis. Rather, `x` is histogrammed along the first dimension of the array (vertical), and `y` along the second dimension of the array (horizontal). This ensures compatibility with `histogramdd`.

**Examples**

```python
>>> import matplotlib as mpl
>>> import matplotlib.pyplot as plt

Construct a 2D-histogram with variable bin width. First define the bin edges:

```python
g xedges = [0, 1, 1.5, 3, 5]
>>> yedges = [0, 2, 3, 4, 6]
```

Next we create a histogram `H` with random bin content:

```python
>>> x = np.random.normal(3, 1, 100)
>>> y = np.random.normal(1, 1, 100)
>>> H, xedges, yedges = np.histogram2d(y, x, bins=(xedges, yedges))
```

Or we fill the histogram `H` with a determined bin content:

```python
>>> H = np.ones((4, 4)).cumsum().reshape(4, 4)
```

Imshow can only do an equidistant representation of bins:

```python
>>> fig = plt.figure(figsize=(7, 3))
>>> ax = fig.add_subplot(131)
>>> ax.set_title('imshow: equidistant')
>>> im = plt.imshow(H, interpolation='nearest', origin='low',
                  extent=[xedges[0], xedges[-1], yedges[0], yedges[-1]])
```

Pcolormesh can display exact bin edges:

```python
>>> ax = fig.add_subplot(132)
>>> ax.set_title('pcolormesh: exact bin edges')
>>> X, Y = np.meshgrid(xedges, yedges)
>>> ax.pcolormesh(X, Y, H)
>>> ax.set_aspect('equal')
```

NonUniformImage displays exact bin edges with interpolation:

```python
>>> ax = fig.add_subplot(133)
>>> ax.set_title('NonUniformImage: interpolated')
>>> im = mpl.image.NonUniformImage(ax, interpolation='bilinear')
>>> xcenters = xedges[:-1] + 0.5 * (xedges[1:] - xedges[:-1])
>>> ycenters = yedges[:-1] + 0.5 * (yedges[1:] - yedges[:-1])
>>> im.set_data(xcenters, ycenters, H)
```
numpy.histogramdd(sample, bins=10, range=None, normed=False, weights=None)

Compute the multidimensional histogram of some data.

Parameters

- **sample**: array_like
  The data to be histogrammed. It must be an (N,D) array or data that can be converted to such. The rows of the resulting array are the coordinates of points in a D dimensional polytope.

- **bins**: sequence or int, optional
  The bin specification:
  - A sequence of arrays describing the bin edges along each dimension.
  - The number of bins for each dimension (nx, ny, ... =bins)
  - The number of bins for all dimensions (nx=ny=...=bins).

- **range**: sequence, optional
  A sequence of lower and upper bin edges to be used if the edges are not given explicitly in bins. Defaults to the minimum and maximum values along each dimension.

- **normed**: bool, optional
  If False, returns the number of samples in each bin. If True, returns the bin density bin_count / sample_count / bin_volume.

- **weights**: array_like (N,), optional
  An array of values w_i weighing each sample (x_i, y_i, z_i, ...). Weights are normalized to 1 if normed is True. If normed is False, the values of the returned histogram are equal to the sum of the weights belonging to the samples falling into each bin.

Returns

- **H**: ndarray
  The multidimensional histogram of sample x. See normed and weights for the different possible semantics.

- **edges**: list
  A list of D arrays describing the bin edges for each dimension.

See also:

- **histogram**
  1-D histogram

- **histogram2d**
  2-D histogram

Examples
>>> r = np.random.randn(100, 3)
>>> H, edges = np.histogramdd(r, bins = (5, 8, 4))
>>> H.shape, edges[0].size, edges[1].size, edges[2].size
>((5, 8, 4), 6, 9, 5)

numpy.bincount (x, weights=None, minlength=None)

Count number of occurrences of each value in array of non-negative ints.

The number of bins (of size 1) is one larger than the largest value in \textit{x}. If \textit{minlength} is specified, there will be at least this number of bins in the output array (though it will be longer if necessary, depending on the contents of \textit{x}). Each bin gives the number of occurrences of its index value in \textit{x}. If \textit{weights} is specified the input array is weighted by it, i.e. if a value \textit{n} is found at position \textit{i}, \textit{out}[\textit{n}] += \textit{weight}[\textit{i}] instead of \textit{out}[\textit{n}] += 1.

Parameters

\begin{itemize}
\item \textit{x} : array_like, 1 dimension, nonnegative ints
  \begin{itemize}
  \item Input array.
  \end{itemize}
\item \textit{weights} : array_like, optional
  \begin{itemize}
  \item Weights, array of the same shape as \textit{x}.
  \end{itemize}
\item \textit{minlength} : int, optional
  \begin{itemize}
  \item New in version 1.6.0.
  \end{itemize}
  \begin{itemize}
  \item A minimum number of bins for the output array.
  \end{itemize}
\end{itemize}

Returns

\textit{out} : ndarray of ints

The result of binning the input array. The length of \textit{out} is equal to np.amax(\textit{x})+1.

Raises

\begin{itemize}
\item ValueError
  \begin{itemize}
  \item If the input is not 1-dimensional, or contains elements with negative values, or if \textit{minlength} is non-positive.
  \end{itemize}
\item TypeError
  \begin{itemize}
  \item If the type of the input is float or complex.
  \end{itemize}
\end{itemize}

See also:

\begin{itemize}
\item histogram, digitize, unique
\end{itemize}

Examples

\begin{verbatim}
>>> np.bincount(np.arange(5))
array([1, 1, 1, 1, 1])
>>> np.bincount(np.array([0, 1, 1, 3, 2, 1, 7]))
array([1, 3, 1, 0, 0, 0, 1])

>>> x = np.array([0, 1, 1, 3, 2, 1, 7, 23])
>>> np.bincount(x).size == np.amax(x)+1
True
\end{verbatim}

The input array needs to be of integer dtype, otherwise a TypeError is raised:

\begin{verbatim}
>>> np.bincount(np.arange(5, dtype=np.float))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: array cannot be safely cast to required type
\end{verbatim}
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: array cannot be safely cast to required type

A possible use of `bincount` is to perform sums over variable-size chunks of an array, using the `weights` keyword.

```python
>>> w = np.array([0.3, 0.5, 0.2, 0.7, 1., -0.6]) # weights
>>> x = np.array([0, 1, 1, 2, 2, 2])
>>> np.bincount(x, weights=w)
array([ 0.3, 0.7, 1.1])
```

```python
numpy.digitize(x, bins, right=False)
```

Return the indices of the bins to which each value in input array belongs.

Each index `i` returned is such that `bins[i-1] <= x < bins[i]` if `bins` is monotonically increasing, or `bins[i-1] > x >= bins[i]` if `bins` is monotonically decreasing. If values in `x` are beyond the bounds of `bins`, `0` or `len(bins)` is returned as appropriate. If `right` is True, then the right bin is closed so that the index `i` is such that `bins[i-1] < x <= bins[i]` or `bins[i-1] >= x > bins[i]` if `bins` is monotonically increasing or decreasing, respectively.

**Parameters**
- `x`: array_like
  Input array to be binned. It has to be 1-dimensional.
- `bins`: array_like
  Array of bins. It has to be 1-dimensional and monotonic.
- `right`: bool, optional
  Indicating whether the intervals include the right or the left bin edge. Default behavior is (right==False) indicating that the interval does not include the right edge. The left bin and is open in this case. Ie., `bins[i-1] <= x < bins[i]` is the default behavior for monotonically increasing bins.

**Returns**
- `out`: ndarray of ints
  Output array of indices, of same shape as `x`.

**Raises**
- `ValueError`
  If the input is not 1-dimensional, or if `bins` is not monotonic.
- `TypeError`
  If the type of the input is complex.

**See also:**
- `bincount`, `histogram`, `unique`

**Notes**
If values in `x` are such that they fall outside the bin range, attempting to index `bins` with the indices that `digitize` returns will result in an `IndexError`. 

---

**3.28. Statistics**

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Examples

```python
>>> x = np.array([0.2, 6.4, 3.0, 1.6])
>>> bins = np.array([0.0, 1.0, 2.5, 4.0, 10.0])
>>> inds = np.digitize(x, bins)
>>> inds
array([1, 4, 3, 2])
>>> for n in range(x.size):
...     print(bins[inds[n]-1], "<=" , x[n], "<", bins[inds[n]])
... 0.0 <= 0.2 < 1.0
4.0 <= 6.4 < 10.0
2.5 <= 3.0 < 4.0
1.0 <= 1.6 < 2.5
```

```python
>>> x = np.array([1.2, 10.0, 12.4, 15.5, 20.])
>>> bins = np.array([0,5,10,15,20])
>>> np.digitize(x,bins,right=True)
array([1, 2, 3, 4, 4])
>>> np.digitize(x,bins,right=False)
array([1, 3, 3, 4, 5])
```

3.29 Test Support (numpy.testing)

Common test support for all numpy test scripts.

This single module should provide all the common functionality for numpy tests in a single location, so that test scripts can just import it and work right away.

3.29.1 Asserts

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</tr>
</tbody>
</table>

```python
numpy.testing.assert_almost_equal(actual, desired[, decimal=7, err_msg='', verbose=True])
```

Raises an AssertionError if two items are not equal up to desired precision.

The test is equivalent to 

\[
| \text{desired} - \text{actual} | < 0.5 \times 10^{-\text{decimal}}
\]
Given two objects (numbers or ndarrays), check that all elements of these objects are almost equal. An exception is raised at conflicting values. For ndarrays this delegates to assert_array_almost_equal

**Parameters**

- **actual**: array_like
  - The object to check.
- **desired**: array_like
  - The expected object.
- **decimal**: int, optional
  - Desired precision, default is 7.
- **err_msg**: str, optional
  - The error message to be printed in case of failure.
- **verbose**: bool, optional
  - If True, the conflicting values are appended to the error message.

**Raises**

- **AssertionError**
  - If actual and desired are not equal up to specified precision.

**See also:**

- **assert_allclose**
  - Compare two array_like objects for equality with desired relative and/or absolute precision.

**Examples**

```python
>>> import numpy.testing as npt
>>> npt.assert_almost_equal(2.3333333333333, 2.33333334)
>>> npt.assert_almost_equal(2.3333333333333, 2.33333334, decimal=10)
...<type 'exceptions.AssertionError'>:
Items are not equal:
ACTUAL: 2.3333333333333002
DESIRED: 2.3333333399999998

>>> npt.assert_almost_equal(np.array([1.0,2.3333333333333]),
                         np.array([1.0,2.33333334]), decimal=9)
...<type 'exceptions.AssertionError'>:
Arrays are not almost equal

(mismatch 50.0%)
  x: array([ 1. , 2.33333333])
  y: array([ 1. , 2.33333334])
```

**Note:** It is recommended to use one of `assert_allclose`, `assert_array_almost_equal_nulp` or `assert_array_max_ulp` instead of this function for more consistent floating point comparisons.
Given two numbers, check that they are approximately equal. Approximately equal is defined as the number of significant digits that agree.

**Parameters**

- `actual` : scalar
  The object to check.

- `desired` : scalar
  The expected object.

- `significant` : int, optional
  Desired precision, default is 7.

- `err_msg` : str, optional
  The error message to be printed in case of failure.

- `verbose` : bool, optional
  If True, the conflicting values are appended to the error message.

**Raises**

- `AssertionError`
  If actual and desired are not equal up to specified precision.

**See also:**

- `assert_allclose`
  Compare two array_like objects for equality with desired relative and/or absolute precision.

- `assert_array_almost_equal`, `assert_array_max_ulp`, `assert_equal`

**Examples**

```python
>>> np.testing.assert_approx_equal(0.12345677777777e-20, 0.1234567e-20)
>>> np.testing.assert_approx_equal(0.12345670e-20, 0.12345671e-20, significant=8)
>>> np.testing.assert_approx_equal(0.12345670e-20, 0.12345672e-20, significant=8)
...<type 'exceptions.AssertionError'>: Items are not equal to 8 significant digits:
  ACTUAL: 1.234567e-021
  DESIRED: 1.2345672000000001e-021

the evaluated condition that raises the exception is

```python
>>> abs(0.12345670e-20/1e-21 - 0.12345672e-20/1e-21) >= 10**-(8-1)
True
```

```python
numpy.testing.assert_array_almost_equal(x, y, decimal=6, err_msg='', verbose=True)
```

Raises an AssertionError if two objects are not equal up to desired precision.

**Note:** It is recommended to use one of `assert_allclose`, `assert_array_almost_equal_nulp` or `assert_array_max_ulp` instead of this function for more consistent floating point comparisons.

The test verifies identical shapes and verifies values with `abs(desired-actual) < 0.5 * 10**(decimal)`. 

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Given two array_like objects, check that the shape is equal and all elements of these objects are almost equal. An exception is raised at shape mismatch or conflicting values. In contrast to the standard usage in numpy, NaNs are compared like numbers, no assertion is raised if both objects have NaNs in the same positions.

**Parameters**
- **x**: array_like
  The actual object to check.
- **y**: array_like
  The desired, expected object.
- **decimal**: int, optional
  Desired precision, default is 6.
- **err_msg**: str, optional
  The error message to be printed in case of failure.
- **verbose**: bool, optional
  If True, the conflicting values are appended to the error message.

**Raises**
- **AssertionError**: If actual and desired are not equal up to specified precision.

**See also:**
- `assert_allclose`  
  Compare two array_like objects for equality with desired relative and/or absolute precision.
- `assert_array_almost_equal_nulp, assert_array_max_ulp, assert_equal`

**Examples**
the first assert does not raise an exception

```python
>>> np.testing.assert_array_almost_equal([1.0, 2.333, np.nan],  
[1.0, 2.333, np.nan])
```

```python
>>> np.testing.assert_array_almost_equal([1.0, 2.33333, np.nan],  
[1.0, 2.33339, np.nan], decimal=5)
<type 'exceptions.AssertionError'>:
AssertionError:
Arrays are not almost equal
(mismatch 50.0%)  
x: array([ 1.  , 2.33333, NaN])
y: array([ 1.  , 2.33339, NaN])
```

```python
>>> np.testing.assert_array_almost_equal([1.0, 2.33333, np.nan],  
[1.0, 2.33333, 5], decimal=5)
<type 'exceptions.ValueError'>:
ValueError:
Arrays are not almost equal
x: array([ 1.  , 2.33333, NaN])
y: array([ 1.  , 2.33333, 5.  ])
```
The function `numpy.testing.assert_allclose(actual, desired, rtol=1e-07, atol=0, err_msg='', verbose=True)` raises an AssertionError if two objects are not equal up to desired tolerance. The test is equivalent to `allclose(actual, desired, rtol, atol)`. It compares the difference between `actual` and `desired` to `atol + rtol * abs(desired)`.

New in version 1.5.0.

**Parameters**
- `actual` : array_like
  Array obtained.
- `desired` : array_like
  Array desired.
- `rtol` : float, optional
  Relative tolerance.
- `atol` : float, optional
  Absolute tolerance.
- `err_msg` : str, optional
  The error message to be printed in case of failure.
- `verbose` : bool, optional
  If True, the conflicting values are appended to the error message.

**Raises**
- `AssertionError`
  If actual and desired are not equal up to specified precision.

**See also:**
- `assert_array_almost_equal_nulp`, `assert_array_max_ulp`

**Examples**

```python
>>> x = [1e-5, 1e-3, 1e-1]
>>> y = np.arccos(np.cos(x))
>>> assert_allclose(x, y, rtol=1e-5, atol=0)
```

`numpy.testing.assert_array_almost_equal_nulp(x, y, nulp=1)` compares two arrays relatively to their spacing.

This is a relatively robust method to compare two arrays whose amplitude is variable.

**Parameters**
- `x, y` : array_like
  Input arrays.
- `nulp` : int, optional
  The maximum number of unit in the last place for tolerance (see Notes). Default is 1.

**Returns**
- None

**Raises**
- `AssertionError`
If the spacing between \( x \) and \( y \) for one or more elements is larger than \( \text{nulp} \).

**See also:**

**assert_array_max_ulp**
Check that all items of arrays differ in at most \( \text{N} \) Units in the Last Place.

**spacing**
Return the distance between \( x \) and the nearest adjacent number.

**Notes**
An assertion is raised if the following condition is not met:

\[
\text{abs}(x - y) <= \text{nulps} \times \text{spacing} \left( \text{maximum}(\text{abs}(x), \text{abs}(y)) \right)
\]

**Examples**

```python
>>> x = np.array([1., 1e-10, 1e-20])
>>> eps = np.finfo(x.dtype).eps
>>> np.testing.assert_array_almost_equal_nulp(x, x*eps/2 + x)
```

```
>>> np.testing.assert_array_almost_equal_nulp(x, x*eps + x)
Traceback (most recent call last):
  ... 
AssertionError: X and Y are not equal to 1 ULP (max is 2)
```

```
>>> np.testing.assert_array_almost_equal_nulp(x, x*eps/2 + x)
```

```
>>> np.testing.assert_array_almost_equal_nulp(x, x*eps + x)
Traceback (most recent call last):
  ... 
AssertionError: X and Y are not equal to 1 ULP (max is 2)
```

**numpy.testing.assert_array_max_ulp** \((a, b, \text{maxulp}=1, \text{dtype=None})\)
Check that all items of arrays differ in at most \( \text{N} \) Units in the Last Place.

**Parameters**

\( a, b \) : array_like
Input arrays to be compared.

\( \text{maxulp} \) : int, optional
The maximum number of units in the last place that elements of \( a \) and \( b \) can differ. Default is 1.

\( \text{dtype} \) : dtype, optional
Data-type to convert \( a \) and \( b \) to if given. Default is None.

**Returns**

\( \text{ret} \) : ndarray
Array containing number of representable floating point numbers between items in \( a \) and \( b \).

**Raises**

AssertionError
If one or more elements differ by more than \( \text{maxulp} \).

**See also:**

**assert_array_almost_equal_nulp**
Compare two arrays relatively to their spacing.
Examples

```python
>>> a = np.linspace(0., 1., 100)
>>> res = np.testing.assert_array_max_ulp(a, np.arcsin(np.sin(a)))
```

numpy.testing.assert_array_equal (x, y, err_msg='', verbose=True)

Raises an AssertionError if two array_like objects are not equal.

Given two array_like objects, check that the shape is equal and all elements of these objects are equal. An exception is raised at shape mismatch or conflicting values. In contrast to the standard usage in numpy, NaNs are compared like numbers, no assertion is raised if both objects have NaNs in the same positions.

The usual caution for verifying equality with floating point numbers is advised.

Parameters

- `x` : array_like
  The actual object to check.

- `y` : array_like
  The desired, expected object.

- `err_msg` : str, optional
  The error message to be printed in case of failure.

- `verbose` : bool, optional
  If True, the conflicting values are appended to the error message.

Raises

AssertionError

If actual and desired objects are not equal.

See also:

assert_allclose

Compare two array_like objects for equality with desired relative and/or absolute precision.

assert_array_almost_equal_nulp, assert_array_max_ulp, assert_equal

Examples

The first assert does not raise an exception:

```python
>>> np.testing.assert_array_equal([1.0, 2.33333, np.nan],
...                          [np.exp(0), 2.33333, np.nan])
```

Assert fails with numerical inprecision with floats:

```python
>>> np.testing.assert_array_equal([1.0, np.pi, np.nan],
...                          [1, np.sqrt(np.pi)**2, np.nan])
...<type 'exceptions.ValueError'>:
AssertionError:
Arrays are not equal
(mismatch 50.0%)
  x: array([ 1., 3.14159265,       NaN])
  y: array([ 1., 3.14159265,       NaN])
```
Use `assert_allclose` or one of the nulp (number of floating point values) functions for these cases instead:

```python
>>> np.testing.assert_allclose([1.0, np.pi, np.nan],
   ... [1, np.sqrt(np.pi)**2, np.nan],
   ... rtol=1e-10, atol=0)
```

`numpy.testing.assert_array_less(x, y, err_msg=' ', verbose=True)`

Raises an `AssertionError` if two array_like objects are not ordered by less than.

Given two array_like objects, check that the shape is equal and all elements of the first object are strictly smaller than those of the second object. An exception is raised at shape mismatch or incorrectly ordered values. Shape mismatch does not raise if an object has zero dimension. In contrast to the standard usage in numpy, NaNs are compared, no assertion is raised if both objects have NaNs in the same positions.

**Parameters**

- `x`: array_like
  The smaller object to check.

- `y`: array_like
  The larger object to compare.

- `err_msg`: string
  The error message to be printed in case of failure.

- `verbose`: bool
  If True, the conflicting values are appended to the error message.

**Raises**

- `AssertionError`
  If actual and desired objects are not equal.

**See also:**

- `assert_array_equal`
  tests objects for equality

- `assert_array_almost_equal`
  test objects for equality up to precision

**Examples**

```python
>>> np.testing.assert_array_less([1.0, 1.0, np.nan], [1.1, 2.0, np.nan])
>>> np.testing.assert_array_less([1.0, 1.0, np.nan], [1, 2.0, np.nan])
...<type 'exceptions.ValueError'>:
Arrays are not less-ordered
(mismatch 50.0%)
x: array([ 1., 1., NaN])
y: array([ 1., 2., NaN])
```

```python
>>> np.testing.assert_array_less([1.0, 4.0], 3)
...<type 'exceptions.ValueError'>:
Arrays are not less-ordered
(mismatch 50.0%)
x: array([ 1., 4.])
y: array(3)
```
>>> np.testing.assert_array_less([1.0, 2.0, 3.0], [4])
...
<type 'exceptions.ValueError'>:
Arrays are not less-ordered
(shapes (3,), (1,) mismatch)
x: array([ 1.,  2.,  3.])
y: array([4])

numpy.testing.assert_equal(actual, desired, err_msg='', verbose=True)

Raises an AssertionError if two objects are not equal.

Given two objects (scalars, lists, tuples, dictionaries or numpy arrays), check that all elements of these objects are equal. An exception is raised at the first conflicting values.

Parameters
    actual : array_like
        The object to check.
    desired : array_like
        The expected object.
    err_msg : str, optional
        The error message to be printed in case of failure.
    verbose : bool, optional
        If True, the conflicting values are appended to the error message.

Raises
    AssertionError
        If actual and desired are not equal.

Examples

>>> np.testing.assert_equal([4,5], [4,6])
...
<type 'exceptions.AssertionError'>:
Items are not equal:
item=1
ACTUAL: 5
DESIRED: 6

numpy.testing.assert_raises(exception_class, callable, *args, **kwargs)

Fail unless an exception of class exception_class is thrown by callable when invoked with arguments args and keyword arguments kwargs. If a different type of exception is thrown, it will not be caught, and the test case will be deemed to have suffered an error, exactly as for an unexpected exception.

numpy.testing.assert_raises_regex(exception_class, expected_regexp, callable_obj=None, *args, **kwargs)

Fail unless an exception of class exception_class and with message that matches expected_regexp is thrown by callable when invoked with arguments args and keyword arguments kwargs.

Name of this function adheres to Python 3.2+ reference, but should work in all versions down to 2.6.

numpy.testing.assert_warns(warning_class, func, *args, **kw)

Fail unless the given callable throws the specified warning.
A warning of class warning_class should be thrown by the callable when invoked with arguments args and keyword arguments kwargs. If a different type of warning is thrown, it will not be caught, and the test case will be deemed to have suffered an error.

New in version 1.4.0.

Parameters

warning_class : class
    The class defining the warning that func is expected to throw.

func : callable
    The callable to test.

*args : Arguments
    Arguments passed to func.

**kwargs : Kwargs
    Keyword arguments passed to func.

Returns

The value returned by func.

numpy.testing.assert_string_equal(actual, desired)

Test if two strings are equal.

If the given strings are equal, assert_string_equal does nothing. If they are not equal, an AssertionError is raised, and the diff between the strings is shown.

Parameters

actual : str
    The string to test for equality against the expected string.

desired : str
    The expected string.

Examples

>>> np.testing.assert_string_equal('abc', 'abc')
>>> np.testing.assert_string_equal('abc', 'abcd')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
...
AssertionError: Differences in strings:
- abc + abcd
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
...
AssertionError: Differences in strings:

3.29.2 Decorators

decorators.deprecated([conditional])
    Filter deprecation warnings while running the test suite.

decorators.knownfailureif(fail_condition[, msg])
    Make function raise KnownFailureTest exception if given condition is true.

decorators.setastest([tf])
    Signals to nose that this function is or is not a test.

decorators.skipif(skip_condition[, msg])
    Make function raise SkipTest exception if a given condition is true.
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<tr>
<th>Function</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td><code>numpy.testing.decorators.slow(t)</code></td>
<td>Label a test as ‘slow’.</td>
</tr>
<tr>
<td><code>numpy.testing.decorators.decorate_methods(cls, decorator[, testmatch])</code></td>
<td>Apply a decorator to all methods in a class matching a regular expression.</td>
</tr>
</tbody>
</table>

```python
numpy.testing.decorators.deprecated(conditional=True)

Filter deprecation warnings while running the test suite.

This decorator can be used to filter DeprecationWarning’s, to avoid printing them during the test suite run, while checking that the test actually raises a DeprecationWarning.

**Parameters**

- `conditional`: bool or callable, optional
  
  Flag to determine whether to mark test as deprecated or not. If the condition is a callable, it is used at runtime to dynamically make the decision. Default is True.

**Returns**

- `decorator`: function
  
  The deprecated decorator itself.

**Notes**

New in version 1.4.0.

```python
numpy.testing.decorators.knownfailureif(fail_condition, msg=None)

Make function raise KnownFailureTest exception if given condition is true.

If the condition is a callable, it is used at runtime to dynamically make the decision. This is useful for tests that may require costly imports, to delay the cost until the test suite is actually executed.

**Parameters**

- `fail_condition`: bool or callable
  
  Flag to determine whether to mark the decorated test as a known failure (if True) or not (if False).

- `msg`: str, optional
  
  Message to give on raising a KnownFailureTest exception. Default is None.

**Returns**

- `decorator`: function
  
  Decorator, which, when applied to a function, causes SkipTest to be raised when `skip_condition` is True, and the function to be called normally otherwise.

**Notes**

The decorator itself is decorated with the `nose.tools.make_decorator` function in order to transmit function name, and various other metadata.

```python
numpy.testing.decorators.setastest(tf=True)

Signals to nose that this function is or is not a test.

**Parameters**

- `tf`: bool
  
  If True, specifies that the decorated callable is a test. If False, specifies that the decorated callable is not a test. Default is True.
Notes

This decorator can’t use the nose namespace, because it can be called from a non-test module. See also istest and nottest in nose.tools.

Examples

setastest can be used in the following way:

```python
from numpy.testing.decorators import setastest

@setastest(False)
def func_with_test_in_name(arg1, arg2):
    pass
```

numpy.testing.decorators.skipif(skip_condition, msg=None)

Make function raise SkipTest exception if a given condition is true.

If the condition is a callable, it is used at runtime to dynamically make the decision. This is useful for tests that may require costly imports, to delay the cost until the test suite is actually executed.

Parameters

- **skip_condition**: bool or callable
  - Flag to determine whether to skip the decorated test.
- **msg**: str, optional
  - Message to give on raising a SkipTest exception. Default is None.

Returns

- **decorator**: function
  - Decorator which, when applied to a function, causes SkipTest to be raised when `skip_condition` is True, and the function to be called normally otherwise.

Notes

The decorator itself is decorated with the nose.tools.make_decorator function in order to transmit function name, and various other metadata.

numpy.testing.decorators.slow(t)

Label a test as ‘slow’.

The exact definition of a slow test is obviously both subjective and hardware-dependent, but in general any individual test that requires more than a second or two should be labeled as slow (the whole suite consists of thousands of tests, so even a second is significant).

Parameters

- **t**: callable
  - The test to label as slow.

Returns

- **t**: callable
  - The decorated test `t`.

Examples

The numpy.testing module includes import decorators as dec. A test can be decorated as slow like this:
from numpy.testing import *

@dec.slow
def test_big(self):
    print 'Big, slow test'

numpy.testing.decorate_methods(cls, decorator, testmatch=None)
Apply a decorator to all methods in a class matching a regular expression.

The given decorator is applied to all public methods of `cls` that are matched by the regular expression `testmatch`
(testmatch.search(methodname)). Methods that are private, i.e. start with an underscore, are ignored.

Parameters
  cls : class
    Class whose methods to decorate.
  decorator : function
    Decorator to apply to methods
  testmatch : compiled regexp or str, optional
    The regular expression. Default value is None, in which case the nose default
    (re.compile(r'(?:^|[_\s.-])\text\([0-9].*\)') is used. If
    `testmatch` is a string, it is compiled to a regular expression first.

3.29.3 Test Running

Tester
run_module_suite([file_to_run, argv]) Run a test module.
rundocs([filename, raise_on_error]) Run doctests found in the given file.

numpy.testing.Tester
  alias of NoseTester

numpy.testing.run_module_suite(file_to_run=None, argv=None)
Run a test module.

Equivalent to calling $ nosetests <argv> <file_to_run> from the command line

Parameters
  file_to_run : str, optional
    Path to test module, or None. By default, run the module from which this function is
called.
  argv : list of strings
    Arguments to be passed to the nose test runner. argv[0] is ignored. All command
    line arguments accepted by nosetests will work.

New in version 1.9.0.

Examples
Adding the following:

if __name__ == "__main__":
    run_module_suite(argv=sys.argv)
at the end of a test module will run the tests when that module is called in the python interpreter.

Alternatively, calling:

```python
>>> run_module_suite(file_to_run="numpy/tests/test_matlib.py")
```

from an interpreter will run all the test routine in ‘test_matlib.py’.

```
numpy.testing.rundocs (filename=None, raise_on_error=True)
```

Run doctests found in the given file.

By default `rundocs` raises an `AssertionError` on failure.

**Parameters**

- `filename` : str
  
The path to the file for which the doctests are run.

- `raise_on_error` : bool
  
  Whether to raise an `AssertionError` when a doctest fails. Default is True.

**Notes**

The doctests can be run by the user/developer by adding the `doctests` argument to the `test()` call. For example, to run all tests (including doctests) for `numpy.lib`:

```python
>>> np.lib.test(doctests=True)
```

### 3.30 Window functions

#### 3.30.1 Various windows

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>bartlett(M)</code></td>
<td>Return the Bartlett window.</td>
</tr>
<tr>
<td><code>blackman(M)</code></td>
<td>Return the Blackman window.</td>
</tr>
<tr>
<td><code>hamming(M)</code></td>
<td>Return the Hamming window.</td>
</tr>
<tr>
<td><code>hanning(M)</code></td>
<td>Return the Hanning window.</td>
</tr>
<tr>
<td><code>kaiser(M, beta)</code></td>
<td>Return the Kaiser window.</td>
</tr>
</tbody>
</table>

```
numpy.bartlett (M)
```

Return the Bartlett window.

The Bartlett window is very similar to a triangular window, except that the end points are at zero. It is often used in signal processing for tapering a signal, without generating too much ripple in the frequency domain.

**Parameters**

- `M` : int
  
  Number of points in the output window. If zero or less, an empty array is returned.

**Returns**

- `out` : array
  
  The triangular window, with the maximum value normalized to one (the value one appears only if the number of samples is odd), with the first and last samples equal to zero.

**See also:**
blackman, hamming, hanning, kaiser

Notes

The Bartlett window is defined as

\[ w(n) = \frac{2}{M-1} \left( \frac{M-1}{2} - \left| n - \frac{M-1}{2} \right| \right) \]

Most references to the Bartlett window come from the signal processing literature, where it is used as one of many windowing functions for smoothing values. Note that convolution with this window produces linear interpolation. It is also known as an apodization (which means "removing the foot", i.e. smoothing discontinuities at the beginning and end of the sampled signal) or tapering function. The Fourier transform of the Bartlett is the product of two sinc functions. Note the excellent discussion in Kanasewich.

References

[R11], [R12], [R13], [R14], [R15]

Examples

```python
>>> np.bartlett(12)
array([ 0.        ,  0.18181818,  0.36363636,  0.54545455,  0.72727273,
        0.90909091,  0.90909091,  0.72727273,  0.54545455,  0.36363636,
        0.18181818,  0.        ])
```

Plot the window and its frequency response (requires SciPy and matplotlib):

```python
>>> from numpy.fft import fft, fftshift
>>> window = np.bartlett(51)
>>> plt.plot(window)
<matplotlib.lines.Line2D object at 0x...>
>>> plt.title("Bartlett window")
<matplotlib.text.Text object at 0x...>
>>> plt.ylabel("Amplitude")
<matplotlib.text.Text object at 0x...>
>>> plt.xlabel("Sample")
<matplotlib.text.Text object at 0x...>
>>> plt.show()

```

```python
>>> A = fft(window, 2048) / 25.5
>>> mag = np.abs(fftshift(A))
>>> freq = np.linspace(-0.5, 0.5, len(A))
>>> response = 20 * np.log10(mag)
>>> response = np.clip(response, -100, 100)
>>> plt.plot(freq, response)
<matplotlib.lines.Line2D object at 0x...>
>>> plt.title("Frequency response of Bartlett window")
<matplotlib.text.Text object at 0x...>
>>> plt.ylabel("Magnitude [dB]")
<matplotlib.text.Text object at 0x...>
>>> plt.xlabel("Normalized frequency [cycles per sample]")
<matplotlib.text.Text object at 0x...>
>>> plt.axis('tight')
(-0.5, 0.5, -100.0, ...)
>>> plt.show()
```

def blackman(M)
    Return the Blackman window.
The Blackman window is a taper formed by using the first three terms of a summation of cosines. It was designed to have close to the minimal leakage possible. It is close to optimal, only slightly worse than a Kaiser window.

Parameters

- M : int
  
  Number of points in the output window. If zero or less, an empty array is returned.

Returns

- out : ndarray
  
  The window, with the maximum value normalized to one (the value one appears only if the number of samples is odd).

See also:

- bartlett, hamming, hanning, kaiser

Notes

The Blackman window is defined as

$$w(n) = 0.42 - 0.5 \cos(2\pi n / M) + 0.08 \cos(4\pi n / M)$$

Most references to the Blackman window come from the signal processing literature, where it is used as one of many windowing functions for smoothing values. It is also known as an apodization (which means “removing the foot”, i.e. smoothing discontinuities at the beginning and end of the sampled signal) or tapering function. It is known as a “near optimal” tapering function, almost as good (by some measures) as the kaiser window.

References


Examples

```python
>>> np.blackman(12)
array([-1.38777878e-17, 3.26064346e-02, 1.59903635e-01,
       4.14397981e-01, 7.36045180e-01, 9.67046769e-01,
       9.67046769e-01, 7.36045180e-01, 4.14397981e-01,
       1.59903635e-01, 3.26064346e-02, -1.38777878e-17])
```

Plot the window and the frequency response:

```python
>>> from numpy.fft import fft, fftshift
>>> window = np.blackman(51)
>>> plt.plot(window)
>>> plt.title("Blackman window")
>>> plt.ylabel("Amplitude")
>>> plt.xlabel("Sample")
```

```python
>>> A = fft(window, 2048) / 25.5
>>> mag = np.abs(fftshift(A))
```
>>> freq = np.linspace(-0.5, 0.5, len(A))
>>> response = 20 * np.log10(mag)
>>> response = np.clip(response, -100, 100)
>>> plt.plot(freq, response)
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.title("Frequency response of Blackman window")
<matplotlib.text.Text object at 0x...>
>>> plt.ylabel("Magnitude [dB]")
<matplotlib.text.Text object at 0x...>
>>> plt.xlabel("Normalized frequency [cycles per sample]")
<matplotlib.text.Text object at 0x...>
>>> plt.axis('tight')
(-0.5, 0.5, -100.0, ...)
>>> plt.show()

numpy.hamming(M)
Return the Hamming window.

The Hamming window is a taper formed by using a weighted cosine.

Parameters
M : int
   Number of points in the output window. If zero or less, an empty array is returned.

Returns
out : ndarray
   The window, with the maximum value normalized to one (the value one appears only if
   the number of samples is odd).

See also:
bartlett, blackman, hanning, kaiser

Notes
The Hamming window is defined as

\[ w(n) = 0.54 - 0.46 \cos \left( \frac{2\pi n}{M - 1} \right) \quad 0 \leq n \leq M - 1 \]

The Hamming was named for R. W. Hamming, an associate of J. W. Tukey and is described in Blackman and
Tukey. It was recommended for smoothing the truncated autocovariance function in the time domain. Most
references to the Hamming window come from the signal processing literature, where it is used as one of many
windowing functions for smoothing values. It is also known as an apodization (which means “removing the
foot”, i.e. smoothing discontinuities at the beginning and end of the sampled signal) or tapering function.

References
[R21], [R22], [R23], [R24]

Examples
>>> np.hamming(12)
array([0.08, 0.15302337, 0.34890909, 0.60546483, 0.84123594, 0.98136677, 0.98136677, 0.84123594, 0.60546483, 0.34890909, 0.15302337, 0.08])

Plot the window and the frequency response:
```python
>>> from numpy.fft import fft, fftshift
>>> window = np.hamming(51)
>>> plt.plot(window)
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.title("Hamming window")
<matplotlib.text.Text object at 0x...>
>>> plt.ylabel("Amplitude")
<matplotlib.text.Text object at 0x...>
>>> plt.xlabel("Sample")
<matplotlib.text.Text object at 0x...>
>>> plt.show()

>>> plt.figure()
<matplotlib.figure.Figure object at 0x...>
>>> A = fft(window, 2048) / 25.5
>>> mag = np.abs(fftshift(A))
>>> freq = np.linspace(-0.5, 0.5, len(A))
>>> response = 20 * np.log10(mag)
>>> response = np.clip(response, -100, 100)
>>> plt.plot(freq, response)
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.title("Frequency response of Hamming window")
<matplotlib.text.Text object at 0x...>
>>> plt.ylabel("Magnitude [dB]")
<matplotlib.text.Text object at 0x...>
>>> plt.xlabel("Normalized frequency [cycles per sample]")
<matplotlib.text.Text object at 0x...>
>>> plt.axis('tight')
(-0.5, 0.5, -100.0,...)
>>> plt.show()
```

**numpy.hamming(M)**
Return the Hanning window.

The Hanning window is a taper formed by using a weighted cosine.

**Parameters**

- **M**: int
  Number of points in the output window. If zero or less, an empty array is returned.

**Returns**

- **out**: ndarray, shape(M,)
  The window, with the maximum value normalized to one (the value one appears only if M is odd).

**See also:**

- bartlett, blackman, hamming, kaiser

**Notes**

The Hanning window is defined as

\[ w(n) = 0.5 - 0.5 \cos \left( \frac{2\pi n}{M-1} \right) \quad 0 \leq n \leq M - 1 \]

The Hanning was named for Julius van Hann, an Austrian meteorologist. It is also known as the Cosine Bell. Some authors prefer that it be called a Hann window, to help avoid confusion with the very similar Hamming window.
Most references to the Hanning window come from the signal processing literature, where it is used as one of many windowing functions for smoothing values. It is also known as an apodization (which means “removing the foot”, i.e. smoothing discontinuities at the beginning and end of the sampled signal) or tapering function.

References

[R25], [R26], [R27], [R28]

Examples

```python
>>> np.hanning(12)
array([ 0. , 0.07937323, 0.29229249, 0.57115742, 0.82743037,
       0.97974649, 0.97974649, 0.82743037, 0.57115742, 0.29229249,
       0.07937323, 0. ])
```

Plot the window and its frequency response:

```python
>>> from numpy.fft import fft, fftshift
>>> window = np.hanning(51)
>>> plt.plot(window)
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.title("Hann window")
<matplotlib.text.Text object at 0x...>
>>> plt.ylabel("Amplitude")
<matplotlib.text.Text object at 0x...>
>>> plt.xlabel("Sample")
<matplotlib.text.Text object at 0x...>
>>> plt.show()

>>> plt.figure()
<matplotlib.figure.Figure object at 0x...>
>>> A = fft(window, 2048) / 25.5
>>> mag = np.abs(fftshift(A))
>>> freq = np.linspace(-0.5, 0.5, len(A))
>>> response = 20 * np.log10(mag)
>>> response = np.clip(response, -100, 100)
>>> plt.plot(freq, response)
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.title("Frequency response of the Hann window")
<matplotlib.text.Text object at 0x...>
>>> plt.ylabel("Magnitude [dB]")
<matplotlib.text.Text object at 0x...>
>>> plt.xlabel("Normalized frequency [cycles per sample]")
<matplotlib.text.Text object at 0x...>
>>> plt.axis('tight')
(-0.5, 0.5, -100.0, ...)
>>> plt.show()
```

**numpy.kaiser** (*M, beta*)

Return the Kaiser window.

The Kaiser window is a taper formed by using a Bessel function.

**Parameters**

- **M**: int
  
  Number of points in the output window. If zero or less, an empty array is returned.

- **beta**: float
  
  Shape parameter for window.
Returns

out : array

The window, with the maximum value normalized to one (the value one appears only if the number of samples is odd).

See also:

bartlett, blackman, hamming, hanning

Notes

The Kaiser window is defined as

\[ w(n) = I_0 \left( \beta \sqrt{1 - \frac{4n^2}{(M-1)^2}} \right) / I_0(\beta) \]

with

\[-\frac{M-1}{2} \leq n \leq \frac{M-1}{2},\]

where \( I_0 \) is the modified zeroth-order Bessel function.

The Kaiser was named for Jim Kaiser, who discovered a simple approximation to the DPSS window based on Bessel functions. The Kaiser window is a very good approximation to the Digital Prolate Spheroidal Sequence, or Slepian window, which is the transform which maximizes the energy in the main lobe of the window relative to total energy.

The Kaiser can approximate many other windows by varying the beta parameter.

<table>
<thead>
<tr>
<th>beta</th>
<th>Window shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Rectangular</td>
</tr>
<tr>
<td>5</td>
<td>Similar to a Hamming</td>
</tr>
<tr>
<td>6</td>
<td>Similar to a Hanning</td>
</tr>
<tr>
<td>8.6</td>
<td>Similar to a Blackman</td>
</tr>
</tbody>
</table>

A beta value of 14 is probably a good starting point. Note that as beta gets large, the window narrows, and so the number of samples needs to be large enough to sample the increasingly narrow spike, otherwise NaNs will get returned.

Most references to the Kaiser window come from the signal processing literature, where it is used as one of many windowing functions for smoothing values. It is also known as an apodization (which means “removing the foot”, i.e. smoothing discontinuities at the beginning and end of the sampled signal) or tapering function.

References

[R34], [R35], [R36]

Examples

```python
>>> np.kaiser(12, 14)
array([  7.72686684e-06,   3.46009194e-03,   4.600194e-02,
       2.29737120e-01,   5.9988516e-01,   9.4567498e-01,
       9.4567498e-01,   5.9988516e-01,   2.29737120e-01,
       4.65200189e-02,   3.46009194e-03,   7.72686684e-06])
```

Plot the window and the frequency response:

```python
>>> from numpy.fft import fft, fftshift
>>> window = np.kaiser(51, 14)
>>> plt.plot(window)
```

3.30. Window functions
```python
>>> plt.title("Kaiser window")
>>> plt.ylabel("Amplitude")
>>> plt.xlabel("Sample")

>>> plt.figure()

>>> A = fft(window, 2048) / 25.5
>>> mag = np.abs(fftshift(A))
>>> freq = np.linspace(-0.5, 0.5, len(A))
>>> response = 20 * np.log10(mag)
>>> response = np.clip(response, -100, 100)

>>> plt.plot(freq, response)

>>> plt.title("Frequency response of Kaiser window")

>>> plt.ylabel("Magnitude [dB]"

>>> plt.xlabel("Normalized frequency [cycles per sample]"

>>> plt.axis('tight')

>>> plt.show()
```
NumPy provides enhanced distutils functionality to make it easier to build and install sub-packages, auto-generate code, and extension modules that use Fortran-compiled libraries. To use features of NumPy distutils, use the `setup` command from `numpy.distutils.core`. A useful `Configuration` class is also provided in `numpy.distutils.misc_util` that can make it easier to construct keyword arguments to pass to the `setup` function (by passing the dictionary obtained from the `todict()` method of the class). More information is available in the NumPy Distutils Users Guide in `<site-packages>/numpy/doc/DISTUTILS.txt`.

### 4.1 Modules in `numpy.distutils`

#### 4.1.1 misc_util

- `get_numpy_include_dirs()`: Convert a `/`-separated pathname to one using the OS's path separator.
- `dict_append(d, **kws)`
- `appendpath(prefix, path)`: Append `path` to the beginning of `prefix`.
- `allpath(name)`: Convert a `/`-separated pathname to one using the OS’s path separator.
- `dot_join(*args)`: Join arguments with a dot separator.
- `generate_config_py(target)`: Generate `config.py` file containing `system_info` information used during building the package.
- `get_cmd(cmdname[, _cache])`: Get command information.
- `terminal_has_colors()`: Check if terminal has colors.
- `red_text(s)`, `green_text(s)`, `yellow_text(s)`, `blue_text(s)`, `cyan_text(s)`: Print text in different colors.
- `cyg2win32(path)`: Convert path from Cygwin to Windows.
- `all_strings(lst)`: Return True if all items in `lst` are string objects.
- `has_f_sources(sources)`: Return True if sources contains Fortran files.
- `has_cxx_sources(sources)`: Return True if sources contains C++ files.
- `filter_sources(sources)`: Return four lists of filenames containing C, C++, Fortran, and Fortran 90 module sources, respectively.
- `get_dependencies(sources)`: Return four lists of filenames containing C, C++, Fortran, and Fortran 90 module sources, respectively.
- `is_local_src_dir(directory)`: Return true if directory is local directory.
- `get_ext_source_files(ext)`
- `get_script_files(scripts)`

```python
numpy.distutils.misc_util.get_numpy_include_dirs()
```

```python
numpy.distutils.misc_util.dict_append(d, **kws)
```
numpy.distutils.misc_util appended(path, path)

numpy.distutils.misc_util.allpath(name)
    Convert a /-separated pathname to one using the OS’s path separator.

numpy.distutils.misc_util.dot_join(*args)

numpy.distutils.misc_util.generate_config_py(target)
    Generate config.py file containing system_info information used during building the package.
    Usage:
        config['py_modules'].append((packagename, '__config__', generate_config_py))

numpy.distutils.misc_util.get_cmd(cmdname, _cache={})

numpy.distutils.misc_util.terminal_has_colors()

numpy.distutils.misc_util.red_text(s)

numpy.distutils.misc_util.green_text(s)

numpy.distutils.misc_util.yellow_text(s)

numpy.distutils.misc_util.blue_text(s)

numpy.distutils.misc_util.cyan_text(s)

numpy.distutils.misc_util.cyg2win32(path)

numpy.distutils.misc_util.all_strings(lst)
    Return True if all items in lst are string objects.

numpy.distutils.misc_util.has_f_sources(sources)
    Return True if sources contains Fortran files.

numpy.distutils.misc_util.has_cxx_sources(sources)
    Return True if sources contains C++ files.

numpy.distutils.misc_util.filter_sources(sources)
    Return four lists of filenames containing C, C++, Fortran, and Fortran 90 module sources, respectively.

numpy.distutils.misc_util.get_dependencies(sources)

numpy.distutils.misc_util.is_local_src_dir(directory)
    Return true if directory is local directory.

numpy.distutils.misc_util.get_ext_source_files(ext)

numpy.distutils.misc_util.get_script_files(scripts)
class numpy.distutils.misc_util.Configuration:

Construct a configuration instance for the given package name. If `parent_name` is not None, then construct the package as a sub-package of the `parent_name` package. If `top_path` and `package_path` are None then they are assumed equal to the path of the file this instance was created in. The setup.py files in the numpy distribution are good examples of how to use the `Configuration` instance.

```python
todict()
    Return a dictionary compatible with the keyword arguments of distutils setup function.
```

Examples

```python
>>> setup(**config.todict())
```

```python
get_distribution()
    Return the distutils distribution object for self.
```

get_subpackage(subpackage_name, subpackage_path=None, parent_name=None, caller_level=1)

Return list of subpackage configurations.

Parameters

- `subpackage_name`: str or None
  Name of the subpackage to get the configuration. ‘*’ in subpackage_name is handled as a wildcard.

- `subpackage_path`: str
  If None, then the path is assumed to be the local path plus the subpackage_name. If a setup.py file is not found in the subpackage_path, then a default configuration is used.

- `parent_name`: str
  Parent name.

add_subpackage(subpackage_name, subpackage_path=None, standalone=False)

Add a sub-package to the current Configuration instance.

This is useful in a setup.py script for adding sub-packages to a package.

Parameters

- `subpackage_name`: str
  name of the subpackage

- `subpackage_path`: str
  if given, the subpackage path such as the subpackage is in subpackage_path / subpackage_name. If None, the subpackage is assumed to be located in the local path / subpackage_name.

- `standalone`: bool

add_data_files(*files)

Add data files to configuration data_files.

Parameters

- `files`: sequence
  Argument(s) can be either
  - 2-sequence (<datadir prefix>, <path to data file(s)>)
  - paths to data files where python datadir prefix defaults to package dir.

4.1. Modules in numpy.distutils
Notes

The form of each element of the files sequence is very flexible allowing many combinations of where to get the files from the package and where they should ultimately be installed on the system. The most basic usage is for an element of the files argument sequence to be a simple filename. This will cause that file from the local path to be installed to the installation path of the self.name package (package path). The file argument can also be a relative path in which case the entire relative path will be installed into the package directory. Finally, the file can be an absolute path name in which case the file will be found at the absolute path name but installed to the package path.

This basic behavior can be augmented by passing a 2-tuple in as the file argument. The first element of the tuple should specify the relative path (under the package install directory) where the remaining sequence of files should be installed to (it has nothing to do with the file-names in the source distribution). The second element of the tuple is the sequence of files that should be installed. The files in this sequence can be filenames, relative paths, or absolute paths. For absolute paths the file will be installed in the top-level package installation directory (regardless of the first argument). Filenames and relative path names will be installed in the package install directory under the path name given as the first element of the tuple.

Rules for installation paths:

1. file.txt -> (., file.txt) -> parent/file.txt
2. foo/file.txt -> (foo, foo/file.txt) -> parent/foo/file.txt
4. *.txt -> parent/a.txt, parent/b.txt
5. foo/*.txt -> parent/boo/a.txt, parent/boo/b.txt
6. .txt -> (., *.txt) -> parent/c/a.txt, parent/d/b.txt
7. (sun, file.txt) -> parent/sun/file.txt
8. (sun, bar/file.txt) -> parent/sun/file.txt
9. (sun, /foo/bar/file.txt) -> parent/sun/file.txt
10. (sun, *.txt) -> parent/sun/a.txt, parent/sun/b.txt
11. (sun, bar/*, txt) -> parent/sun/a.txt, parent/sun/b.txt
12. (sun, /*.txt) -> parent/sun/c/a.txt, parent/d/b.txt

An additional feature is that the path to a data-file can actually be a function that takes no arguments and returns the actual path(s) to the data-files. This is useful when the data files are generated while building the package.

Examples

Add files to the list of data_files to be included with the package.

```python
>>> self.add_data_files('foo.dat',
... ['fun', ['gun.dat', 'nun/pun.dat', '/tmp/sun.dat']],
... 'bar/cat.dat',
... '/full/path/to/can.dat')
```

will install these data files to:

```xml
<package install directory>/
foo.dat
fun/
  gun.dat
nun/
```
add_data_dir(data_path)
Recursively add files under data_path to data_files list.

Recursively add files under data_path to the list of data_files to be installed (and distributed). The data_path can be either a relative path-name, or an absolute path-name, or a 2-tuple where the first argument shows where in the install directory the data directory should be installed to.

Parameters

data_path : seq or str
Argument can be either

• 2-sequence (<datadir suffix>, <path to data directory>)
• path to data directory where python datadir suffix defaults to package dir.

Notes

Rules for installation paths:
foo/bar -> (foo/bar, foo/bar) -> parent/foo/bar (gun, foo/bar) -> parent/gun foo/* -> (foo/a, foo/a),
(foo/b, foo/b) -> parent/foo/a, parent/foo/b (gun, foo/) -> (gun, foo/a), (gun, foo/b) -> gun (gun/, foo/)
-> parent/gun/a, parent/gun/b /foo/bar -> (bar, /foo/bar) -> parent/bar (gun, /foo/bar) -> parent/gun
(gun/*, sun/foo/bar) -> parent/fun/foo/gun/bar

Examples

For example suppose the source directory contains fun/foo.dat and fun/bar/car.dat:

```python
>>> self.add_data_dir('fun')
```

```python
>>> self.add_data_dir(('sun', 'fun'))
```

```python
>>> self.add_data_dir(('gun', '/full/path/to/fun'))
```

Will install data-files to the locations:

```bash
<package install directory>/
fun/
  foo.dat
  bar/
    car.dat
sun/
  foo.dat
  bar/
    car.dat
gun/
  foo.dat
car.dat
```

add_include_dirs(*paths)
Add paths to configuration include directories.
Add the given sequence of paths to the beginning of the include_dirs list. This list will be visible to all extension modules of the current package.

add_headers(*files)
Add installable headers to configuration.

Add the given sequence of files to the beginning of the headers list. By default, headers will be installed under `<python-include>/<self.name.replace(\'.\', '/')>/` directory. If an item of files is a tuple, then its first argument specifies the actual installation location relative to the `<python-include>` path.

Parameters
files : str or seq
Argument(s) can be either:
• 2-sequence `<includedir suffix>,<path to header file(s)>`
• path(s) to header file(s) where python includedir suffix will default to package name.

add_extension(name, sources, **kw)
Add extension to configuration.

Create and add an Extension instance to the ext_modules list. This method also takes the following optional keyword arguments that are passed on to the Extension constructor.

Parameters
name : str
name of the extension

sources : seq
list of the sources. The list of sources may contain functions (called source generators) which must take an extension instance and a build directory as inputs and return a source file or list of source files or None. If None is returned then no sources are generated. If the Extension instance has no sources after processing all source generators, then no extension module is built.

include_dirs :
define_macros :
defed_macros :
library_dirs :
libraries :
runtime_library_dirs :
extra_objects :
extra_compile_args :
extra_link_args :
extra_f77_compile_args :
extra_f90_compile_args :
export_symbols :
swig_opts :
depends :

The depends list contains paths to files or directories that the sources of the extension module depend on. If any path in the depends list is newer than the extension module, then the module will be rebuilt.

language :

f2py_options :

module_dirs :

extra_info : dict or list
dict or list of dict of keywords to be appended to keywords.

Notes
The self.paths(...) method is applied to all lists that may contain paths.

add_library (name, sources, **build_info)
Add library to configuration.

Parameters

name : str
Name of the extension.

sources : sequence
List of the sources. The list of sources may contain functions (called source generators) which must take an extension instance and a build directory as inputs and return a source file or list of source files or None. If None is returned then no sources are generated. If the Extension instance has no sources after processing all source generators, then no extension module is built.

build_info : dict, optional
The following keys are allowed:

• depends
• macros
• include_dirs
• extra_compiler_args
• extra_f77_compiler_args
• extra_f90_compiler_args
• f2py_options
• language

add_scripts (*files)
Add scripts to configuration.

Add the sequence of files to the beginning of the scripts list. Scripts will be installed under the <prefix>/bin/directory.

add_installed_library (name, sources, install_dir, build_info=None)
Similar to add_library, but the specified library is installed.

Most C libraries used with distutils are only used to build python extensions, but libraries built through this method will be installed so that they can be reused by third-party packages.

4.1. Modules in numpy.distutils
Parameters

name : str

Name of the installed library.

sources : sequence

List of the library’s source files. See add_library for details.

install_dir : str

Path to install the library, relative to the current sub-package.

build_info : dict, optional

The following keys are allowed:

• depends
• macros
• include_dirs
• extra_compiler_args
• extra_f77_compiler_args
• extra_f90_compiler_args
• f2py_options
• language

Returns

None

See also:

add_library, add_npy_pkg_config, get_info

Notes

The best way to encode the options required to link against the specified C libraries is to use a “libname.ini” file, and use get_info to retrieve the required options (see add_npy_pkg_config for more information).

add_npy_pkg_config(template, install_dir, subst_dict=None)

Generate and install a npy-pkg config file from a template.

The config file generated from template is installed in the given install directory, using subst_dict for variable substitution.

Parameters

template : str

The path of the template, relatively to the current package path.

install_dir : str

Where to install the npy-pkg config file, relatively to the current package path.

subst_dict : dict, optional

If given, any string of the form @key@ will be replaced by subst_dict[key] in the template file when installed. The install prefix is always available through the variable @prefix@, since the install prefix is not easy to get reliably from setup.py.
See also:
add_installed_library, get_info

Notes
This works for both standard installs and in-place builds, i.e. the @prefix@ refer to the source directory for in-place builds.

Examples

```python
cfg.add_npy_pkg_config('foo.ini.in', 'lib', {'foo': bar})
```

Assuming the foo.ini.in file has the following content:

```ini
[meta]
Name=foo
Version=1.0
Description=dummy description

[default]
Cflags=-I@prefix@/include
Libs=
```

The generated file will have the following content:

```ini
[meta]
Name=bar
Version=1.0
Description=dummy description

[default]
Cflags=-I@prefix_dir@/include
Libs=
```

and will be installed as foo.ini in the ‘lib’ subpath.

paths(*paths, **kws)
Apply glob to paths and prepend local_path if needed.

get_config_cmd()
Returns the numpy.distutils config command instance.

get_build_temp_dir()
Return a path to a temporary directory where temporary files should be placed.

have_f77c()
Check for availability of Fortran 77 compiler.

Notes
True if a Fortran 77 compiler is available (because a simple Fortran 77 code was able to be compiled successfully).

have_f90c()
Check for availability of Fortran 90 compiler.
Use it inside source generating function to ensure that setup distribution instance has been initialized.

**Notes**

True if a Fortran 90 compiler is available (because a simple Fortran 90 code was able to be compiled successfully)

**get_version** *(version_file=None, version_variable=None)*

Try to get version string of a package.

Return a version string of the current package or None if the version information could not be detected.

**Notes**

This method scans files named __version__.py, <packagename>_version.py, version.py, and __svn_version__.py for string variables version, __version__, and <packagename>_version, until a version number is found.

**make_svn_version_py** *(delete=True)*

Appends a data function to the data_files list that will generate __svn_version__.py file to the current package directory.

Generate package __svn_version__.py file from SVN revision number, it will be removed after python exits but will be available when sdist, etc commands are executed.

**Notes**

If __svn_version__.py existed before, nothing is done.

This is intended for working with source directories that are in an SVN repository.

**make_config_py** *(name=’__config__’)*

Generate package __config__.py file containing system_info information used during building the package.

This file is installed to the package installation directory.

**get_info** *(names)*

Get resources information.

Return information (from system_info.get_info) for all of the names in the argument list in a single dictionary.

### 4.1.2 Other modules

| **system_info.get_info** *(name[, notfound_action])** | **notfound_action:** |
| **system_info.get_standard_file** *(fname)* | **Returns a list of files named ‘fname’ from** |
| **cpuinfo.cpu** | **directory-location of this module)** |
| **log.set_verbosity** *(v[, force])** | **exec_command** |

**numpy.distutils.system_info.get_info** *(name, notfound_action=0)*

**notfound_action:**

0 - do nothing 1 - display warning message 2 - raise error

**numpy.distutils.system_info.get_standard_file** *(fname)*

Returns a list of files named ‘fname’ from 1) System-wide directory (directory-location of this module) 2)
NumPy Reference, Release 1.9.2

Users HOME directory (os.environ['HOME']) 3) Local directory

```python
numpy.distutils.cpuinfo.cpu = <numpy.distutils.cpuinfo.LinuxCPUInfo object at 0x4384e18c>
```

```python
numpy.distutils.log.set_verbosity(v, force=False)
```

exec_command

Implements exec_command function that is (almost) equivalent to commands.getstatusoutput function but on NT, DOS systems the returned status is actually correct (though, the returned status values may be different by a factor). In addition, exec_command takes keyword arguments for (re-)defining environment variables.

Provides functions:

```python
exec_command — execute command in a specified directory and
      in the modified environment.

find_executable — locate a command using info from environment
      variable PATH. Equivalent to posix which command.
```

Author: Pearu Peterson <pearu@cens.ioc.ee> Created: 11 January 2003

Requires: Python 2.x

Successfully tested on:

<table>
<thead>
<tr>
<th>os.name</th>
<th>sys.platform</th>
<th>comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>posix</td>
<td>linux2</td>
<td>Debian (sid) Linux, Python 2.1.3+, 2.2.3+, 2.3.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PyCrust 0.9.3, Idle 1.0.2</td>
</tr>
<tr>
<td>posix</td>
<td>linux2</td>
<td>Red Hat 9 Linux, Python 2.1.3, 2.2.2, 2.3.2 posix</td>
</tr>
<tr>
<td></td>
<td></td>
<td>darwin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Python 2.3(EE), Idle 1.0, PyCrust 0.7.2 Python 2.1.1 Idle 0.8</td>
</tr>
<tr>
<td>nt</td>
<td>win32</td>
<td>Windows 98, Python 2.1.1. Idle 0.8 nt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fail i.e. redefining environment variables may not work. FIXED: don’t use cygwin echo! Comment: also cmd /c echo will not work but redefining environment variables do work.</td>
</tr>
<tr>
<td>posix</td>
<td>cygwin</td>
<td>Cygwin 98-4.10, Python 2.3.3(cygming special) nt</td>
</tr>
</tbody>
</table>

Known bugs: - Tests, that send messages to stderr, fail when executed from MSYS prompt

because the messages are lost at some point.

Functions

| exec_command(command[, execute_in, ...]) | Return (status,output) of executed command. |
| find_executable(exe[, path, _cache])     | Return full path of a executable or None. |
| get_exception()                          |                                              |
| get_pythonexe()                          |                                              |
| is_sequence(seq)                         |                                              |
| make_temp_file([suffix, prefix, text])   |                                              |
| open_latin1(filename[, mode])            |                                              |
| quote_arg(arg)                           |                                              |
| splitcmdline(line)                       |                                              |
| temp_file_name()                         |                                              |
| test(**kws)                              |                                              |

Continued on next page
### 4.2 Building Installable C libraries

Conventional C libraries (installed through `add_library`) are not installed, and are just used during the build (they are statically linked). An installable C library is a pure C library, which does not depend on the python C runtime, and is installed such that it may be used by third-party packages. To build and install the C library, you just use the method `add_installed_library` instead of `add_library`, which takes the same arguments except for an additional `install_dir` argument:

```python
>>> config.add_installed_library('foo', sources=['foo.c'], install_dir='lib')
```

#### 4.2.1 npy-pkg-config files

To make the necessary build options available to third parties, you could use the `npy-pkg-config` mechanism implemented in `numpy.distutils`. This mechanism is based on a .ini file which contains all the options. A .ini file is very similar to .pc files as used by the pkg-config unix utility:

```
[meta]
Name: foo
Version: 1.0
Description: foo library

[variables]
prefix = /home/user/local
libdir = ${prefix}/lib
includedir = ${prefix}/include

[default]
cflags = -I${includedir}
libs = -L${libdir} -lfoo
```

Generally, the file needs to be generated during the build, since it needs some information known at build time only (e.g. prefix). This is mostly automatic if one uses the `Configuration` method `add_npy_pkg_config`. Assuming we have a template file `foo.ini.in` as follows:

```
[meta]
Name: foo
Version: @version@
Description: foo library

[variables]
prefix = @prefix@
libdir = ${prefix}/lib
includedir = ${prefix}/include

[default]
cflags = -I${includedir}
libs = -L${libdir} -lfoo
```

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and the following code in setup.py:

```python
>>> config.add_installed_library('foo', sources=['foo.c'], install_dir='lib')
>>> subst = {'version': '1.0'}
>>> config.add_npy_pkg_config('foo.ini.in', 'lib', subst_dict=subst)
```

This will install the file foo.ini into the directory package_dir/lib, and the foo.ini file will be generated from foo.ini.in, where each `@version@` will be replaced by `subst_dict['version']`. The dictionary has an additional prefix substitution rule automatically added, which contains the install prefix (since this is not easy to get from setup.py). npy-pkg-config files can also be installed at the same location as used for numpy, using the path returned from `get_npy_pkg_dir` function.

### 4.2.2 Reusing a C library from another package

Info are easily retrieved from the `get_info` function in `numpy.distutils.misc_util`:

```python
>>> info = get_info('npymath')
>>> config.add_extension('foo', sources=['foo.c'], extra_info=**info)
```

An additional list of paths to look for .ini files can be given to `get_info`.

### 4.3 Conversion of `.src` files

NumPy distutils supports automatic conversion of source files named `<somefile>.src`. This facility can be used to maintain very similar code blocks requiring only simple changes between blocks. During the build phase of setup, if a template file named `<somefile>.src` is encountered, a new file named `<somefile>` is constructed from the template and placed in the build directory to be used instead. Two forms of template conversion are supported. The first form occurs for files named named `<file>.ext.src` where ext is a recognized Fortran extension (f, f90, f95, f77, for, ftn, pyf). 

The second form is used for all other cases.

#### 4.3.1 Fortran files

This template converter will replicate all `function` and `subroutine` blocks in the file with names that contain `'<...>'` according to the rules in `'<...>'`. The number of comma-separated words in `'<...>'` determines the number of times the block is repeated. What these words are indicates what that repeat rule, `'<...>'`, should be replaced with in each block. All of the repeat rules in a block must contain the same number of comma-separated words indicating the number of times that block should be repeated. If the word in the repeat rule needs a comma, leftarrow, or rightarrow, then prepend it with a backslash `\`. If a word in the repeat rule matches `\<index>` then it will be replaced with the `<index>`-th word in the same repeat specification. There are two forms for the repeat rule: named and short.

**Named repeat rule**

A named repeat rule is useful when the same set of repeats must be used several times in a block. It is specified using `<rule1=item1, item2, item3...., itemN>`, where N is the number of times the block should be repeated. On each repeat of the block, the entire expression, `'<...>'` will be replaced first with item1, and then with item2, and so forth until N repeats are accomplished. Once a named repeat specification has been introduced, the same repeat rule may be used in the current block by referring only to the name (i.e. `<rule1>`).
Short repeat rule

A short repeat rule looks like <item1, item2, item3, ..., itemN>. The rule specifies that the entire expression, ‘<...>’ should be replaced first with item1, and then with item2, and so forth until N repeats are accomplished.

Pre-defined names

The following predefined named repeat rules are available:

- <prefix=s,d,c,z>
- <_c=s,d,c,z>
- <_t=real, double precision, complex, double complex>
- <ftype=real, double precision, complex, double complex>
- <ctype=float, double, complex_float, complex_double>
- <ftypereal=float, double precision, \0, \1>
- <ctypereal=float, double, \0, \1>

4.3.2 Other files

Non-Fortran files use a separate syntax for defining template blocks that should be repeated using a variable expansion similar to the named repeat rules of the Fortran-specific repeats. The template rules for these files are:

1. “/*begin repeat “on a line by itself marks the beginning of a segment that should be repeated.

2. Named variable expansions are defined using #name=item1, item2, item3, ..., itemN# and placed on successive lines. These variables are replaced in each repeat block with corresponding word. All named variables in the same repeat block must define the same number of words.

3. In specifying the repeat rule for a named variable, item*N is short-hand for item, item, ..., item repeated N times. In addition, parenthesis in combination with *N can be used for grouping several items that should be repeated. Thus, #name=(item1, item2)*4# is equivalent to #name=item1, item2, item1, item2, item1, item2, item1, item2#.

4. “*/ “on a line by itself marks the end of the the variable expansion naming. The next line is the first line that will be repeated using the named rules.

5. Inside the block to be repeated, the variables that should be expanded are specified as @name@.

6. “/*end repeat**/ “on a line by itself marks the previous line as the last line of the block to be repeated.
Beware of the man who won’t be bothered with details.
— William Feather, Sr.

The truth is out there.
— Chris Carter, The X Files

NumPy provides a C-API to enable users to extend the system and get access to the array object for use in other routines. The best way to truly understand the C-API is to read the source code. If you are unfamiliar with (C) source code, however, this can be a daunting experience at first. Be assured that the task becomes easier with practice, and you may be surprised at how simple the C-code can be to understand. Even if you don’t think you can write C-code from scratch, it is much easier to understand and modify already-written source code than to create it de novo.

Python extensions are especially straightforward to understand because they all have a very similar structure. Admittedly, NumPy is not a trivial extension to Python, and may take a little more snooping to grasp. This is especially true because of the code-generation techniques, which simplify maintenance of very similar code, but can make the code a little less readable to beginners. Still, with a little persistence, the code can be opened to your understanding. It is my hope, that this guide to the C-API can assist in the process of becoming familiar with the compiled-level work that can be done with NumPy in order to squeeze that last bit of necessary speed out of your code.

### 5.1 Python Types and C-Structures

Several new types are defined in the C-code. Most of these are accessible from Python, but a few are not exposed due to their limited use. Every new Python type has an associated PyObject * with an internal structure that includes a pointer to a “method table” that defines how the new object behaves in Python. When you receive a Python object into C code, you always get a pointer to a PyObject structure. Because a PyObject structure is very generic and defines only PyObject_HEAD, by itself it is not very interesting. However, different objects contain more details after the PyObject_HEAD (but you have to cast to the correct type to access them — or use accessor functions or macros).

#### 5.1.1 New Python Types Defined

Python types are the functional equivalent in C of classes in Python. By constructing a new Python type you make available a new object for Python. The ndarray object is an example of a new type defined in C. New types are defined in C by two basic steps:

1. creating a C-structure (usually named Py{Name}Object) that is binary-compatible with the PyObject structure itself but holds the additional information needed for that particular object;
2. populating the PyTypeObject table (pointed to by the ob_type member of the PyObject structure) with pointers to functions that implement the desired behavior for the type.

Instead of special method names which define behavior for Python classes, there are “function tables” which point to functions that implement the desired results. Since Python 2.2, the PyTypeObject itself has become dynamic which allows C types that can be “sub-typed” from other C-types in C, and sub-classed in Python. The children types inherit the attributes and methods from their parent(s).

There are two major new types: the ndarray (PyArray_Type) and the ufunc (PyUFunc_Type). Additionally play a supportive role: the PyArrayIter_Type, the PyArrayMultiIter_Type, and the PyArrayDescr_Type. The PyArrayIter_Type is the type for a flat iterator for an ndarray (the object that is returned when getting the flat attribute). The PyArrayMultiIter_Type is the type of the object returned when calling broadcast(). It handles iteration and broadcasting over a collection of nested sequences. Also, the PyArrayDescr_Type is the data-type-descriptor type whose instances describe the data. Finally, there are 21 new scalar-array types which are new Python scalars corresponding to each of the fundamental data types available for arrays. An additional 10 other types are place holders that allow the array scalars to fit into a hierarchy of actual Python types.

PyArray_Type

PyArray_Type

The Python type of the ndarray is PyArray_Type. In C, every ndarray is a pointer to a PyArrayObject structure. The ob_type member of this structure contains a pointer to the PyArray_Type typeobject.

PyArrayObject

The PyArrayObject C-structure contains all of the required information for an array. All instances of an ndarray (and its subclasses) will have this structure. For future compatibility, these structure members should normally be accessed using the provided macros. If you need a shorter name, then you can make use of NPY_AO which is defined to be equivalent to PyArrayObject.

typedef struct PyArrayObject {
    PyObject_HEAD
    char *data;
    int nd;
    npy_intp *dimensions;
    npy_intp *strides;
    PyObject *base;
    PyArray_Descr *descr;
    int flags;
    PyObject *weakreflist;
} PyArrayObject;

PyArrayObject.PyObject_HEAD

This is needed by all Python objects. It consists of (at least) a reference count member (ob_refcnt) and a pointer to the typeobject (ob_type). (Other elements may also be present if Python was compiled with special options see Include/object.h in the Python source tree for more information). The ob_type member points to a Python type object.

cchar *PyArrayObject.data

A pointer to the first element of the array. This pointer can (and normally should) be recast to the data type of the array.

int PyArrayObject.nd

An integer providing the number of dimensions for this array. When nd is 0, the array is sometimes called a rank-0 array. Such arrays have undefined dimensions and strides and cannot be accessed. NPY_MAXDIMS is the largest number of dimensions for any array.
npy_intp PyArrayObject.dimensions
An array of integers providing the shape in each dimension as long as nd ≥ 1. The integer is always large
enough to hold a pointer on the platform, so the dimension size is only limited by memory.

npy_intp *PyArrayObject.strides
An array of integers providing for each dimension the number of bytes that must be skipped to get to the next
element in that dimension.

PyObject *PyArrayObject.base
This member is used to hold a pointer to another Python object that is related to this array. There are two use
cases: 1) If this array does not own its own memory, then base points to the Python object that owns it (perhaps
another array object), 2) If this array has the NPY_ARRAY_UPDATEIFCOPY flag set, then this array is a
working copy of a “misbehaved” array. As soon as this array is deleted, the array pointed to by base will be
updated with the contents of this array.

PyArray_Descr *PyArrayObject.descr
A pointer to a data-type descriptor object (see below). The data-type descriptor object is an instance of a new
built-in type which allows a generic description of memory. There is a descriptor structure for each data type
supported. This descriptor structure contains useful information about the type as well as a pointer to a table of
function pointers to implement specific functionality.

int PyArrayObject.flags
Flags indicating how the memory pointed to by data is to be interpreted. Possible flags
are NPY_ARRAY_C_CONTIGUOUS, NPY_ARRAY_F_CONTIGUOUS, NPY_ARRAY_OWNDATA,
NPY_ARRAY_ALIGNED, NPY_ARRAY_WRITEABLE, and NPY_ARRAY_UPDATEIFCOPY.

PyObject *PyArrayObject.weakreflist
This member allows array objects to have weak references (using the weakref module).

PyArrayDescr_Type

PyArrayDescr_Type
The PyArrayDescr_Type is the built-in type of the data-type-descriptor objects used to describe how the
bytes comprising the array are to be interpreted. There are 21 statically-defined PyArray_Descr objects
for the built-in data-types. While these participate in reference counting, their reference count should never
reach zero. There is also a dynamic table of user-defined PyArray_Descr objects that is also main-
tained. Once a data-type-descriptor object is “registered” it should never be deallocated either. The function
PyArray_DescrFromType(...) can be used to retrieve a PyArray_Descr object from an enumerated
type-number (either built-in or user-defined).

PyArray_Descr
The format of the PyArray_Descr structure that lies at the heart of the PyArrayDescr_Type is

typedef struct {
    PyObject_HEAD
    PyTypeObject *typeobj;
    char kind;
    char type;
    char byteorder;
    char unused;
    int flags;
    int type_num;
    int elsize;
    int alignment;
    PyArray_ArrayDescr *subarray;
    PyObject *fields;
    PyArray_ArrFuncs *f;
} PyArray_Descr;
PyTypeObject *PyArray_Descr.typeobj
    Pointer to a typeobject that is the corresponding Python type for the elements of this array. For the built-in types, this points to the corresponding array scalar. For user-defined types, this should point to a user-defined type object. This type object can either inherit from array scalars or not. If it does not inherit from array scalars, then the NPY_USE_GETITEM and NPY_USE_SETITEM flags should be set in the flags member.

char PyArray_Descr.kind
    A character code indicating the kind of array (using the array interface typestring notation). A ‘b’ represents Boolean, a ‘i’ represents signed integer, a ‘u’ represents unsigned integer, ‘f’ represents floating point, ‘c’ represents complex floating point, ‘S’ represents 8-bit character string, ‘U’ represents 32-bit/character unicode string, and ‘V’ represents arbitrary.

char PyArray_Descr.type
    A traditional character code indicating the data type.

char PyArray_Descr.byteorder
    A character indicating the byte-order: ‘>’ (big-endian), ‘<’ (little-endian), ‘=’ (native), ‘!’ (irrelevant, ignore). All built-in data types have byteorder ‘=’.

int PyArray_Descr.flags
    A data-type bit-flag that determines if the data-type exhibits object-array like behavior. Each bit in this member is a flag which are named as:

    NPY_ITEM_REFCOUNT

    NPY_ITEM_HASOBJECT
        Indicates that items of this data-type must be reference counted (using Py_INCREF and Py_DECREF).

    NPY_LIST_PICKLE
        Indicates arrays of this data-type must be converted to a list before pickling.

    NPY_ITEM_IS_POINTER
        Indicates the item is a pointer to some other data-type

    NPY_NEEDS_INIT
        Indicates memory for this data-type must be initialized (set to 0) on creation.

    NPY_NEEDS_PYAPI
        Indicates this data-type requires the Python C-API during access (so don’t give up the GIL if array access is going to be needed).

    NPY_USE_GETITEM
        On array access use the f->getitem function pointer instead of the standard conversion to an array scalar. Must use if you don’t define an array scalar to go along with the data-type.

    NPY_USE_SETITEM
        When creating a 0-d array from an array scalar use f->setitem instead of the standard copy from an array scalar. Must use if you don’t define an array scalar to go along with the data-type.

    NPY_FROM_FIELDS
        The bits that are inherited for the parent data-type if these bits are set in any field of the data-type. Currently (NPY_NEEDS_INIT | NPY_LIST_PICKLE | NPY_ITEM_REFCOUNT | NPY_NEEDS_PYAPI).

    NPY_OBJECT_DTYPE_FLAGS
        Bits set for the object data-type: (NPY_LIST_PICKLE | NPY_USE_GETITEM | NPY_ITEM_IS_POINTER | NPY_REFCOUNT | NPY_NEEDS_INIT | NPY_NEEDS_PYAPI).

PyDataType_FLAGCHK(PyArray_Descr *dtype, int flags)
    Return true if all the given flags are set for the data-type object.
**PyDataType_REFCHK** (PyArray_Descr *dtype)
Equivalent to **PyDataType_FLAGCHK** (dtype, NPY_ITEM_REFCOUNT).

int PyArray_Descr.type_num
A number that uniquely identifies the data type. For new data-types, this number is assigned when the data-type is registered.

int PyArray_Descr.elsize
For data types that are always the same size (such as long), this holds the size of the data type. For flexible data types where different arrays can have a different elementsize, this should be 0.

int PyArray_Descr.alignment
A number providing alignment information for this data type. Specifically, it shows how far from the start of a 2-element structure (whose first element is a char), the compiler places an item of this type: `offsetof(struct {char c; type v;}, v)`

PyArray_ArrayDescr *PyArray_Descr.subarray
If this is non-NULL, then this data-type descriptor is a C-style contiguous array of another data-type descriptor. In other-words, each element that this descriptor describes is actually an array of some other base descriptor. This is most useful as the data-type descriptor for a field in another data-type descriptor. The fields member should be NULL if this is non-NULL (the fields member of the base descriptor can be non-NULL however). The PyArray_ArrayDescr structure is defined using

```c
typedef struct {
    PyArray_Descr *base;
    PyObject *shape;
} PyArray_ArrayDescr;
```

The elements of this structure are:

PyArray_Descr *PyArray_ArrayDescr.base
The data-type-descriptor object of the base-type.

PyObject *PyArray_ArrayDescr.shape
The shape (always C-style contiguous) of the sub-array as a Python tuple.

PyObject *PyArray_Descr.fields
If this is non-NULL, then this data-type-descriptor has fields described by a Python dictionary whose keys are names (and also titles if given) and whose values are tuples that describe the fields. Recall that a data-type-descriptor always describes a fixed-length set of bytes. A field is a named sub-region of that total, fixed-length collection. A field is described by a tuple composed of another data-type-descriptor and a byte offset. Optionally, the tuple may contain a title which is normally a Python string. These tuples are placed in this dictionary keyed by name (and also title if given).

PyArray_ArrFuncs *PyArray_Descr.f
A pointer to a structure containing functions that the type needs to implement internal features. These functions are not the same thing as the universal functions (ufuncs) described later. Their signatures can vary arbitrarily.

PyArray_ArrFuncs
Functions implementing internal features. Not all of these function pointers must be defined for a given type. The required members are nonzero, copyswap, copyswapn, setitem, getitem, and cast. These are assumed to be non-NULL and NULL entries will cause a program crash. The other functions may be NULL which will just mean reduced functionality for that data-type. (Also, the nonzero function will be filled in with a default function if it is NULL when you register a user-defined data-type).

```c
typedef struct {
    PyArray_VectorUnaryFunc *cast[NPY_NTYPES];
    PyArray_GetItemFunc *getitem;
    PyArray_SetItemFunc *setitem;
    PyArray_CopySwapNFunc *copyswapn;
} PyArray_ArrFuncs;
```
The concept of a behaved segment is used in the description of the function pointers. A behaved segment is one that is aligned and in native machine byte-order for the data-type. The nonzero, copyswap, copyswapn, getitem, and setitem functions can (and must) deal with misbehaved arrays. The other functions require behaved memory segments.

```c
void cast(void *from, void *to, npy_intp n, void *fromarr,
          void *toarr)
An array of function pointers to cast from the current type to all of the other builtin types. Each function casts a contiguous, aligned, and notswapped buffer pointed at by from to a contiguous, aligned, and notswapped buffer pointed at by to. The number of items to cast is given by n, and the arguments fromarr and toarr are interpreted as PyArrayObjects for flexible arrays to get itemsize information.

PyObject *getitem(void *data, void *arr)
A pointer to a function that returns a standard Python object from a single element of the array object arr pointed to by data. This function must be able to deal with “misbehaved” (misaligned and/or swapped) arrays correctly.

int setitem(PyObject *item, void *data, void *arr)
A pointer to a function that sets the Python object item into the array, arr, at the position pointed to by data. This function deals with “misbehaved” arrays. If successful, a zero is returned, otherwise, a negative one is returned (and a Python error set).

void copyswapn(void *dest, npy_intp dstride, void *src,
               npy_intp sstride, npy_intp n, int swap, void *arr)

void copyswap (void *dest, void *src, int swap, void *arr)
These members are both pointers to functions to copy data from src to dest and swap if indicated. The value of arr is only used for flexible (NPY_STRING, NPY_UNICODE, and NPY_VOID) arrays (and is obtained from arr->descr->elsize). The second function copies a single value, while the first loops over n values with the provided strides. These functions can deal with misbehaved src data. If src is NULL then no copy is performed. If swap is 0, then no byteswapping occurs. It is assumed that dest and src do not overlap. If they overlap, then use memmove (...) first followed by copyswap (n) with NULL valued src.

int compare (const void *d1, const void *d2, void *arr)
A pointer to a function that compares two elements of the array, arr, pointed to by d1 and d2. This function requires behaved (aligned and not swapped) arrays. The return value is 1 if *d1 > *d2, 0 if *
```
d1 == *d2, and -1 if *d1 < *d2. The array object arr is used to retrieve itemsize and field information for flexible arrays.

```c
int argmax(void* data, npy_intp n, npy_intp* max_ind,

void* arr)
```

A pointer to a function that retrieves the index of the largest of n elements in arr beginning at the element pointed to by data. This function requires that the memory segment be contiguous and behaved. The return value is always 0. The index of the largest element is returned in max_ind.

```c
void dotfunc(void* ip1, npy_intp is1, void* ip2, npy_intp is2,

void* op, npy_intp n, void* arr)
```

A pointer to a function that multiplies two n-length sequences together, adds them, and places the result in element pointed to by op of arr. The start of the two sequences are pointed to by ip1 and ip2. To get to the next element in each sequence requires a jump of is1 and is2 bytes, respectively. This function requires behaved (though not necessarily contiguous) memory.

```c
int scanfunc(FILE* fd, void* ip, void* sep, void* arr)
```

A pointer to a function that scans (scanf style) one element of the corresponding type from the file descriptor fd into the array memory pointed to by ip. The array is assumed to be behaved. If sep is not NULL, then a separator string is also scanned from the file before returning. The last argument arr is the array to be scanned into. A 0 is returned if the scan is successful. A negative number indicates something went wrong: -1 means the end of file was reached before the separator string could be scanned, -4 means that the end of file was reached before the element could be scanned, and -3 means that the element could not be interpreted from the format string. Requires a behaved array.

```c
int fromstr(char* str, void* ip, char** endptr, void* arr)
```

A pointer to a function that converts the string pointed to by str to one element of the corresponding type and places it in the memory location pointed to by ip. After the conversion is completed, endptr points to the rest of the string. The last argument arr is the array into which ip points (needed for variable-size data-types). Returns 0 on success or -1 on failure. Requires a behaved array.

```c
Bool nonzero(void* data, void* arr)
```

A pointer to a function that returns TRUE if the item of arr pointed to by data is nonzero. This function can deal with misbehaved arrays.

```c
void fill(void* data, npy_intp length, void* arr)
```

A pointer to a function that fills a contiguous array of given length with data. The first two elements of the array must already be filled-in. From these two values, a delta will be computed and the values from item 3 to the end will be computed by repeatedly adding this computed delta. The data buffer must be well-behaved.

```c
void fillwithscalar(void* buffer, npy_intp length,

void* value, void* arr)
```

A pointer to a function that fills a contiguous buffer of the given length with a single scalar value whose address is given. The final argument is the array which is needed to get the itemsize for variable-length arrays.

```c
int sort(void* start, npy_intp length, void* arr)
```

An array of function pointers to a particular sorting algorithms. A particular sorting algorithm is obtained using a key (so far NPY_QUICKSORT, NPY_HEAPSORT, and NPY_MERGESORT are defined). These sorts are done in-place assuming contiguous and aligned data.

```c
int argsort(void* start, npy_intp* result, npy_intp length,

void* arr)
```

5.1. Python Types and C-Structures
void *arr)
   An array of function pointers to sorting algorithms for this data type. The same sorting algorithms as for
   sort are available. The indices producing the sort are returned in result (which must be initialized with
   indices 0 to length-1 inclusive).

PyObject *castdict
   Either NULL or a dictionary containing low-level casting functions for user-defined data-types. Each
   function is wrapped in a PyObject * and keyed by the data-type number.

NPY_SCALARKIND scalarkind(PyArrayObject* arr)
   A function to determine how scalars of this type should be interpreted. The argument is NULL or a
   0-dimensional array containing the data (if that is needed to determine the kind of scalar). The return
   value must be of type NPY_SCALARKIND.

int **cancastscalarkindto
   Either NULL or an array of NPY_NSCALARKINDS pointers. These pointers should each be either NULL
   or a pointer to an array of integers (terminated by NPY_NOTYPE) indicating data-types that a scalar of
   this data-type of the specified kind can be cast to safely (this usually means without losing precision).

int *cancastto
   Either NULL or an array of integers (terminated by NPY_NOTYPE) indicated data-types that this data-type
   can be cast to safely (this usually means without losing precision).

int listpickle
   Unused.

The PyArray_Type typeobject implements many of the features of Python objects including the tp_as_number,
 tp_as_sequence, tp_as_mapping, and tp_as_buffer interfaces. The rich comparison (tp_richcompare) is also used
 along with new-style attribute lookup for methods (tp_methods) and properties (tp_getset). The PyArray_Type can
 also be sub-typed.

Tip: The tp_as_number methods use a generic approach to call whatever function has been registered for handling
 the operation. The function PyNumeric_SetOps(..) can be used to register functions to handle particular mathematical
 operations (for all arrays). When the umath module is imported, it sets the numeric operations for all arrays to the
 corresponding ufuncs. The tp_str and tp_repr methods can also be altered using PyString_SetStringFunction(...).

PyUFunc_Type

PyUFunc_Type
   The ufunc object is implemented by creation of the PyUFunc_Type. It is a very simple type that implements
   only basic getattribute behavior, printing behavior, and has call behavior which allows these objects to act
   like functions. The basic idea behind the ufunc is to hold a reference to fast 1-dimensional (vector) loops for
   each data type that supports the operation. These one-dimensional loops all have the same signature and are
   the key to creating a new ufunc. They are called by the generic looping code as appropriate to implement the
   N-dimensional function. There are also some generic 1-d loops defined for floating and complex floating arrays
   that allow you to define a ufunc using a single scalar function (e.g. atanh).

PyUFuncObject
   The core of the ufunc is the PyUFuncObject which contains all the information needed to call the underlying
   C-code loops that perform the actual work. It has the following structure:

   typedef struct {
      PyObject_HEAD
      int nin;
      int nout;
      int nargs;
      int identity;
   } PyUFuncObject;
PyUFuncGenericFunction *functions;
void **data;
int ntypes;
int check_return;
const char *name;
char *types;
const char *doc;
void *ptr;
PyObject *obj;
PyObject *userloops;
npy_uint32 *op_flags;
npy_uint32 *iter_flags;
}
PyUFuncObject;

PyUFuncObject.PyObject_HEAD

int PyUFuncObject.nin
The number of input arguments.

int PyUFuncObject.nout
The number of output arguments.

int PyUFuncObject.nargs
The total number of arguments (nin + nout). This must be less than NPY_MAXARGS.

int PyUFuncObject.identity
Either PyUFunc_One, PyUFunc_Zero, or PyUFunc_None to indicate the identity for this operation.
It is only used for a reduce-like call on an empty array.

void PyUFuncObject.functions(char** args, npy_intp* dims,
npy_intp* steps, void* extradata)
An array of function pointers — one for each data type supported by the ufunc. This is the vector loop
that is called to implement the underlying function dims [0] times. The first argument, args, is an array of
nargs pointers to behaved memory. Pointers to the data for the input arguments are first, followed by the
pointers to the data for the output arguments. How many bytes must be skipped to get to the next element
in the sequence is specified by the corresponding entry in the steps array. The last argument allows the
loop to receive extra information. This is commonly used so that a single, generic vector loop can be used
for multiple functions. In this case, the actual scalar function to call is passed in as extradata. The size of
this function pointer array is ntypes.

void **PyUFuncObject.data
Extra data to be passed to the 1-d vector loops or NULL if no extra-data is needed. This C-array must be
the same size (i.e. ntypes) as the functions array. NULL is used if extra_data is not needed. Several C-API
calls for UFuncs are just 1-d vector loops that make use of this extra data to receive a pointer to the actual
function to call.

int PyUFuncObject.ntypes
The number of supported data types for the ufunc. This number specifies how many different 1-d loops
(of the builtin data types) are available.

int PyUFuncObject.check_return
Obsolete and unused. However, it is set by the corresponding entry in the main ufunc creation routine:
PyUFunc_FromFuncAndData(…).

char *PyUFuncObject.name
A string name for the ufunc. This is used dynamically to build the __doc__ attribute of ufuncs.
Char *PyUFuncObject.types
An array of $nargs \times ntypes$ 8-bit type_numbers which contains the type signature for the function for each of the supported (builtin) data types. For each of the ntypes functions, the corresponding set of type numbers in this array shows how the args argument should be interpreted in the 1-d vector loop. These type numbers do not have to be the same type and mixed-type ufuncs are supported.

Char *PyUFuncObject.doc
Documentation for the ufunc. Should not contain the function signature as this is generated dynamically when __doc__ is retrieved.

Void *PyUFuncObject.ptr
Any dynamically allocated memory. Currently, this is used for dynamic ufuncs created from a python function to store room for the types, data, and name members.

PyObject *PyUFuncObject.obj
For ufuncs dynamically created from python functions, this member holds a reference to the underlying Python function.

PyObject *PyUFuncObject.userloops
A dictionary of user-defined 1-d vector loops (stored as CObject ptrs) for user-defined types. A loop may be registered by the user for any user-defined type. It is retrieved by type number. User defined type numbers are always larger than NPY_USERDEF.

Npy_uint32 PyUFuncObject.op_flags
Override the default operand flags for each ufunc operand.

Npy_uint32 PyUFuncObject.iter_flags
Override the default nditer flags for the ufunc.

PyArrayIter_Type

PyArrayIter_Type
This is an iterator object that makes it easy to loop over an N-dimensional array. It is the object returned from the flat attribute of an ndarray. It is also used extensively throughout the implementation internals to loop over an N-dimensional array. The tp_as_mapping interface is implemented so that the iterator object can be indexed (using 1-d indexing), and a few methods are implemented through the tp_methods table. This object implements the next method and can be used anywhere an iterator can be used in Python.

PyArrayIterObject
The C-structure corresponding to an object of PyArrayIter_Type is the PyArrayIterObject. The PyArrayIterObject is used to keep track of a pointer into an N-dimensional array. It contains associated information used to quickly march through the array. The pointer can be adjusted in three basic ways: 1) advance to the “next” position in the array in a C-style contiguous fashion, 2) advance to an arbitrary N-dimensional coordinate in the array, and 3) advance to an arbitrary one-dimensional index into the array. The members of the PyArrayIterObject structure are used in these calculations. Iterator objects keep their own dimension and strides information about an array. This can be adjusted as needed for “broadcasting,” or to loop over only specific dimensions.

typedef struct {
    PyObject_HEAD
    int nd_m1;
    npy_intp index;
    npy_intp size;
    npy_intp coordinates[NPY_MAXDIMS];
    npy_intp dims_m1[NPY_MAXDIMS];
    npy_intp strides[NPY_MAXDIMS];
    npy_intp backstrides[NPY_MAXDIMS];
    npy_intp factors[NPY_MAXDIMS];
}
NumPy Reference, Release 1.9.2

```c
PyArrayObject *ao;
char  *dataptr;
Bool    contiguous;
} PyArrayIterObject;
```

- **PyArrayIterObject.nd_m1**: $N - 1$ where $N$ is the number of dimensions in the underlying array.

- **PyArrayIterObject.index**: The current 1-d index into the array.

- **PyArrayIterObject.size**: The total size of the underlying array.

- **PyArrayIterObject.coordinates**: An $N$-dimensional index into the array.

- **PyArrayIterObject.dims_m1**: The size of the array minus 1 in each dimension.

- **PyArrayIterObject.strides**: The strides of the array. How many bytes needed to jump to the next element in each dimension.

- **PyArrayIterObject.backstrides**: How many bytes needed to jump from the end of a dimension back to its beginning. Note that $\text{backstrides}[k] = \text{strides}[k] \times \text{dims}_m1[k]$, but it is stored here as an optimization.

- **PyArrayIterObject.factors**: This array is used in computing an N-d index from a 1-d index. It contains needed products of the dimensions.

- **PyArrayIterObject.ao**: A pointer to the underlying ndarray this iterator was created to represent.

- **PyArrayIterObject.dataptr**: This member points to an element in the ndarray indicated by the index.

- **PyArrayIterObject.contiguous**: This flag is true if the underlying array is NPY_ARRAY_C_CONTIGUOUS. It is used to simplify calculations when possible.

How to use an array iterator on a C-level is explained more fully in later sections. Typically, you do not need to concern yourself with the internal structure of the iterator object, and merely interact with it through the use of the macros `PyArray_ITER_NEXT(it)`, `PyArray_ITER_GOTO(it, dest)`, or `PyArray_ITER_GOTO1D(it, index)`. All of these macros require the argument `it` to be a `PyArrayIterObject *`.

**PyArrayMultiIter_Type**

This type provides an iterator that encapsulates the concept of broadcasting. It allows $N$ arrays to be broadcast together so that the loop progresses in C-style contiguous fashion over the broadcasted array. The corresponding C-structure is the `PyArrayMultiIterObject` whose memory layout must begin any object, `obj`, passed in to the `PyArray_Broadcast(obj)` function. Broadcasting is performed by adjusting array iterators so that each iterator represents the broadcasted shape and size, but has its strides adjusted so that the correct element from the array is used at each iteration.

**PyArrayMultiIterObject**

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typedef struct {
    PyObject_HEAD
    int numiter;
    npy_intp size;
    npy_intp index;
    int nd;
    npy_intp dimensions[NPY_MAXDIMS];
    PyArrayIterObject *iters[NPY_MAXDIMS];
} PyArrayMultiIterObject;

PyArrayMultiIterObject.PyObject_HEAD

Needed at the start of every Python object (holds reference count and type identification).

int PyArrayMultiIterObject.numiter
The number of arrays that need to be broadcast to the same shape.

npy_intp PyArrayMultiIterObject.size
The total broadcasted size.

npy_intp PyArrayMultiIterObject.index
The current (1-d) index into the broadcasted result.

int PyArrayMultiIterObject.nd
The number of dimensions in the broadcasted result.

npy_intp *PyArrayMultiIterObject.dimensions
The shape of the broadcasted result (only nd slots are used).

PyArrayIterObject **PyArrayMultiIterObject.iters
An array of iterator objects that holds the iterators for the arrays to be broadcast together. On return, the iterators are adjusted for broadcasting.

PyArrayNeighborhoodIter_Type

PyArrayNeighborhoodIter_Type
This is an iterator object that makes it easy to loop over an N-dimensional neighborhood.

PyArrayNeighborhoodIterObject
The C-structure corresponding to an object of PyArrayNeighborhoodIter_Type is the PyArrayNeighborhoodIterObject.

PyArrayFlags_Type

PyArrayFlags_Type
When the flags attribute is retrieved from Python, a special builtin object of this type is constructed. This special type makes it easier to work with the different flags by accessing them as attributes or by accessing them as if the object were a dictionary with the flag names as entries.

ScalarArrayTypes

There is a Python type for each of the different built-in data types that can be present in the array Most of these are simple wrappers around the corresponding data type in C. The C-names for these types are Py{TYPE}ArrType_Type where {TYPE} can be

These type names are part of the C-API and can therefore be created in extension C-code. There is also a `PyIntpArrType_Type` and a `PyUIntpArrType_Type` that are simple substitutes for one of the integer types that can hold a pointer on the platform. The structure of these scalar objects is not exposed to C-code. The function `PyArray_ScalarAsCtype` (...) can be used to extract the C-type value from the array scalar and the function `PyArray_Scalar` (...) can be used to construct an array scalar from a C-value.

### 5.1.2 Other C-Structures

A few new C-structures were found to be useful in the development of NumPy. These C-structures are used in at least one C-API call and are therefore documented here. The main reason these structures were defined is to make it easy to use the Python ParseTuple C-API to convert from Python objects to a useful C-Object.

**PyArray_Dims**

This structure is very useful when shape and/or strides information is supposed to be interpreted. The structure is:

```c
typedef struct {
    npy_intp *ptr;
    int len;
} PyArray_Dims;
```

The members of this structure are

- `npy_intp *PyArray_Dims.ptr`  
  A pointer to a list of (npy_intp) integers which usually represent array shape or array strides.

- `int PyArray_Dims.len`  
  The length of the list of integers. It is assumed safe to access `ptr [0]` to `ptr [len-1]`.

**PyArray_Chunk**

This is equivalent to the buffer object structure in Python up to the ptr member. On 32-bit platforms (i.e. if `NPY_SIZEOF_INT == NPY_SIZEOF_INTP`) or in Python 2.5, the len member also matches an equivalent member of the buffer object. It is useful to represent a generic single-segment chunk of memory.

```c
typedef struct {
    PyObject_HEAD
    PyObject *base;
    void *ptr;
    npy_intp len;
    int flags;
} PyArray_Chunk;
```

The members are

- **PyArray_ChunkPyObject_HEAD**  
  Necessary for all Python objects. Included here so that the `PyArray_Chunk` structure matches that of the buffer object (at least to the len member).

- **PyObject *PyArray_Chunk.base**  
  The Python object this chunk of memory comes from. Needed so that memory can be accounted for properly.
PyArray_Chunk

- **void *PyArray_Chunk.ptr**
  A pointer to the start of the single-segment chunk of memory.

- **npy_intp PyArray_Chunk.len**
  The length of the segment in bytes.

- **int PyArray_Chunk.flags**
  Any data flags (e.g. NPY_ARRAY_WRITEABLE) that should be used to interpret the memory.

PyArrayInterface

See also:

The Array Interface

PyArrayInterface

The `PyArrayInterface` structure is defined so that NumPy and other extension modules can use the rapid array interface protocol. The `__array_struct__` method of an object that supports the rapid array interface protocol should return a `PyObject` that contains a pointer to a `PyArrayInterface` structure with the relevant details of the array. After the new array is created, the attribute should be `DECREF`d which will free the `PyArrayInterface` structure. Remember to `INCREF` the object (whose `__array_struct__` attribute was retrieved) and point the base member of the new `PyArrayObject` to this same object. In this way the memory for the array will be managed correctly.

```
typedef struct {
    int two;
    int nd;
    char typekind;
    int itemsize;
    int flags;
    npy_intp *shape;
    npy_intp *strides;
    void *data;
    PyObject *descr;
} PyArrayInterface;
```

- **int PyArrayInterface.two**
  the integer 2 as a sanity check.

- **int PyArrayInterface.nd**
  the number of dimensions in the array.

- **char PyArrayInterface.typekind**

- **int PyArrayInterface.itemsize**
  The number of bytes each item in the array requires.

- **int PyArrayInterface.flags**
  Any of the bits NPY_ARRAY_C_CONTIGUOUS (1), NPY_ARRAY_F_CONTIGUOUS (2), NPY_ARRAY_ALIGNED (0x100), NPY_ARRAY_NOTSWAPPED (0x200), or NPY_ARRAY_WRITEABLE (0x400) to indicate something about the data. The NPY_ARRAY_ALIGNED, NPY_ARRAY_C_CONTIGUOUS, and NPY_ARRAY_F_CONTIGUOUS flags can actually be determined from the other parameters. The flag NPY_ARR_HAS_DESCR (0x800) can also be set to indicate to objects consuming the version 3 array interface that the descr member of the structure is present (it will be ignored by objects consuming version 2 of the array interface).
npy_intp *PyArrayInterface.shape
   An array containing the size of the array in each dimension.

npy_intp *PyArrayInterface.strides
   An array containing the number of bytes to jump to get to the next element in each dimension.

void *PyArrayInterface.data
   A pointer to the first element of the array.

PyObject *PyArrayInterface.descr
   A Python object describing the data-type in more detail (same as the descr key in __array_interface__). This can be NULL if typekind and itemsize provide enough information. This field is also ignored unless ARR_HAS_DESCR flag is on in flags.

Internally used structures

Internally, the code uses some additional Python objects primarily for memory management. These types are not accessible directly from Python, and are not exposed to the C-API. They are included here only for completeness and assistance in understanding the code.

PyUFuncLoopObject
   A loose wrapper for a C-structure that contains the information needed for looping. This is useful if you are trying to understand the ufunc looping code. The PyUFuncLoopObject is the associated C-structure. It is defined in the ufuncobject.h header.

PyUFuncReduceObject
   A loose wrapper for the C-structure that contains the information needed for reduce-like methods of ufuncs. This is useful if you are trying to understand the reduce, accumulate, and reduce-at code. The PyUFuncReduceObject is the associated C-structure. It is defined in the ufuncobject.h header.

PyUFunc_Loop1d
   A simple linked-list of C-structures containing the information needed to define a 1-d loop for a ufunc for every defined signature of a user-defined data-type.

PyArrayMapIter_Type
   Advanced indexing is handled with this Python type. It is simply a loose wrapper around the C-structure containing the variables needed for advanced array indexing. The associated C-structure, PyArrayMapIterObject, is useful if you are trying to understand the advanced-index mapping code. It is defined in the arrayobject.h header. This type is not exposed to Python and could be replaced with a C-structure. As a Python type it takes advantage of reference-counted memory management.

5.2 System configuration

When NumPy is built, information about system configuration is recorded, and is made available for extension modules using NumPy’s C API. These are mostly defined in numpyconfig.h (included in ndarrayobject.h). The public symbols are prefixed by NPY_. Numpy also offers some functions for querying information about the platform in use.

For private use, Numpy also constructs a config.h in the NumPy include directory, which is not exported by Numpy (that is a python extension which use the numpy C API will not see those symbols), to avoid namespace pollution.

5.2.1 Data type sizes

The NPY_SIZEOF_{CTYPE} constants are defined so that sizeof information is available to the pre-processor.
NPY_SIZEOF_SHORT

NPY_SIZEOF_INT

NPY_SIZEOF_LONG

NPY_SIZEOF_LONGLONG
   sizeof(longlong) where longlong is defined appropriately on the platform.

NPY_SIZEOF_PY_LONG_LONG

NPY_SIZEOF_FLOAT

NPY_SIZEOF_DOUBLE

NPY_SIZEOF_LONG_DOUBLE

NPY_SIZEOF_PY_INTPTR_T
   Size of a pointer on this platform (sizeof(void *)) (A macro defines NPY_SIZEOF_INTP as well.)

5.2.2 Platform information

NPY_CPU_X86

NPY_CPU_AMD64

NPY_CPU_IA64

NPY_CPU_PPC

NPY_CPU_PPC64

NPY_CPU_SPARC

NPY_CPU_SPARC64

NPY_CPU_S390

NPY_CPU_PARISC
   New in version 1.3.0.
   CPU architecture of the platform; only one of the above is defined.
   Defined in numpy/npy_cpu.h

NPY_LITTLE_ENDIAN
NPY_BIG_ENDIAN

NPY_BYTE_ORDER
New in version 1.3.0.
Portable alternatives to the endian.h macros of GNU Libc. If big endian, NPY_BYTE_ORDER == NPY_BIG_ENDIAN, and similarly for little endian architectures.
Defined in numpy/npy_endian.h.

PyArray_GetEndianness()
New in version 1.3.0.
Returns the endianness of the current platform. One of NPY_CPU_BIG, NPY_CPU_LITTLE, or NPY_CPUUNKNOWN_ENDIAN.

5.3 Data Type API

The standard array can have 24 different data types (and has some support for adding your own types). These data types all have an enumerated type, an enumerated type-character, and a corresponding array scalar Python type object (placed in a hierarchy). There are also standard C typedefs to make it easier to manipulate elements of the given data type. For the numeric types, there are also bit-width equivalent C typedefs and named typenumbers that make it easier to select the precision desired.

**Warning:** The names for the types in C code follows C naming conventions more closely. The Python names for these types follow Python conventions. Thus, NPY_FLOAT picks up a 32-bit float in C, but numpy.float_ in Python corresponds to a 64-bit double. The bit-width names can be used in both Python and C for clarity.

5.3.1 Enumerated Types

There is a list of enumerated types defined providing the basic 24 data types plus some useful generic names. Whenever the code requires a type number, one of these enumerated types is requested. The types are all called NPY_{NAME}:

NPY_BOOL
The enumeration value for the boolean type, stored as one byte. It may only be set to the values 0 and 1.

NPY_BYTE

NPY_INT8
The enumeration value for an 8-bit/1-byte signed integer.

NPY_SHORT

NPY_INT16
The enumeration value for a 16-bit/2-byte signed integer.

NPY_INT

NPY_INT32
The enumeration value for a 32-bit/4-byte signed integer.

NPY_LONG
Equivalent to either NPY_INT or NPY_LONGLONG, depending on the platform.
NPY_LONGLONG

NPY_INT64
The enumeration value for a 64-bit/8-byte signed integer.

NPY_UBYTE

NPY_UINT8
The enumeration value for an 8-bit/1-byte unsigned integer.

NPY_USHORT

NPY_UINT16
The enumeration value for a 16-bit/2-byte unsigned integer.

NPY_UINT

NPY_UINT32
The enumeration value for a 32-bit/4-byte unsigned integer.

NPY_ULONG
Equivalent to either NPY_UINT or NPY_ULONGLONG, depending on the platform.

NPY_ULONGLONG

NPY_UINT64
The enumeration value for a 64-bit/8-byte unsigned integer.

NPY_HALF

NPY_FLOAT16
The enumeration value for a 16-bit/2-byte IEEE 754-2008 compatible floating point type.

NPY_FLOAT

NPY_FLOAT32
The enumeration value for a 32-bit/4-byte IEEE 754 compatible floating point type.

NPY_DOUBLE

NPY_FLOAT64
The enumeration value for a 64-bit/8-byte IEEE 754 compatible floating point type.

NPY_LONGDOUBLE
The enumeration value for a platform-specific floating point type which is at least as large as NPY_DOUBLE, but larger on many platforms.

NPY_CFLOAT

NPY_COMPLEX64
The enumeration value for a 64-bit/8-byte complex type made up of two NPY_FLOAT values.

NPY_CDOUBLE
NPY_COMPLEX128
The enumeration value for a 128-bit/16-byte complex type made up of two NPY_DOUBLE values.

NPY_CLONGDOUBLE
The enumeration value for a platform-specific complex floating point type which is made up of two NPY_LONGDOUBLE values.

NPY_DATETIME
The enumeration value for a data type which holds dates or datetimes with a precision based on selectable date or time units.

NPY_TIMEDELTA
The enumeration value for a data type which holds lengths of times in integers of selectable date or time units.

NPY_STRING
The enumeration value for ASCII strings of a selectable size. The strings have a fixed maximum size within a given array.

NPY_UNICODE
The enumeration value for UCS4 strings of a selectable size. The strings have a fixed maximum size within a given array.

NPY_OBJECT
The enumeration value for references to arbitrary Python objects.

NPY_VOID
Primarily used to hold struct dtypes, but can contain arbitrary binary data.

Some useful aliases of the above types are

NPY_INTP
The enumeration value for a signed integer type which is the same size as a (void *) pointer. This is the type used by all arrays of indices.

NPY_UINTP
The enumeration value for an unsigned integer type which is the same size as a (void *) pointer.

NPY_MASK
The enumeration value of the type used for masks, such as with the NPY_ITER_ARRAYMASK iterator flag. This is equivalent to NPY_UINT8.

NPY_DEFAULT_TYPE
The default type to use when no dtype is explicitly specified, for example when calling np.zero(shape). This is equivalent to NPY_DOUBLE.

Other useful related constants are

NPY_NTYPES
The total number of built-in NumPy types. The enumeration covers the range from 0 to NPY_NTYPES-1.

NPY_NOTYPE
A signal value guaranteed not to be a valid type enumeration number.

NPY_USERDEF
The start of type numbers used for Custom Data types.

The various character codes indicating certain types are also part of an enumerated list. References to type characters (should they be needed at all) should always use these enumerations. The form of them is NPY_{NAME}LTR where {NAME} can be

BOOL, BYTE, UBYTE, SHORT, USHORT, INT, UINT, LONG, ULONG, LONGLONG, ULONGLONG, HALF, FLOAT, DOUBLE, LONGDOUBLE, CFLOAT, CDOUBLE, CLONGDOUBLE, DATETIME, TIMEDELTA, OBJECT, STRING, VOID
INTP, UINTP
GENBOOL, SIGNED, UNSIGNED, FLOATING, COMPLEX

The latter group of \{NAME\}s corresponds to letters used in the array interface typestring specification.

5.3.2 Defines

Max and min values for integers

NPY_MAX_INT{bits}

NPY_MAX_UINT{bits}

NPY_MIN_INT{bits}
These are defined for \{bits\} = 8, 16, 32, 64, 128, and 256 and provide the maximum (minimum) value of the corresponding (unsigned) integer type. Note: the actual integer type may not be available on all platforms (i.e. 128-bit and 256-bit integers are rare).

NPY_MIN_{type}
This is defined for \{type\} = BYTE, SHORT, INT, LONG, LONGLONG, INTP

NPY_MAX_{type}
This is defined for all defined for \{type\} = BYTE, UBYTE, SHORT, USHORT, INT, UINT, LONG, ULONG, LONGLONG, ULONGLONG, INTP, UINTP

Number of bits in data types

All NPY_SIZEOF_{CTYPE} constants have corresponding NPY_BITSOF_{CTYPE} constants defined. The NPY_BITSOF_{CTYPE} constants provide the number of bits in the data type. Specifically, the available \{CTYPE\}s are

BOOL, CHAR, SHORT, INT, LONG, LONGLONG, FLOAT, DOUBLE, LONDDOUBLE

Bit-width references to enumerated typenums

All of the numeric data types (integer, floating point, and complex) have constants that are defined to be a specific enumerated type number. Exactly which enumerated type a bit-width type refers to is platform dependent. In particular, the constants available are PyArray_{NAME}{BITS} where \{NAME\} is INT, UINT, FLOAT, COMPLEX and \{BITS\} can be 8, 16, 32, 64, 80, 96, 128, 160, 192, 256, and 512. Obviously not all bit-widths are available on all platforms for all the kinds of numeric types. Commonly 8-, 16-, 32-, 64-bit integers; 32-, 64-bit floats; and 64-, 128-bit complex types are available.

Integer that can hold a pointer

The constants NPY_INTP and NPY_UINTP refer to an enumerated integer type that is large enough to hold a pointer on the platform. Index arrays should always be converted to NPY_INTP, because the dimension of the array is of type npy_intp.
5.3.3 C-type names

There are standard variable types for each of the numeric data types and the bool data type. Some of these are already available in the C-specification. You can create variables in extension code with these types.

Boolean

`npy_bool`
unsigned char; The constants `NPY_FALSE` and `NPY_TRUE` are also defined.

(Un)Signed Integer

Unsigned versions of the integers can be defined by pre-pending a 'u' to the front of the integer name.

`npy_(u)byte`
(unsigned) char

`npy_(u)short`
(unsigned) short

`npy_(u)int`
(unsigned) int

`npy_(u)long`
(unsigned) long int

`npy_(u)longlong`
(unsigned long long int)

`npy_(u)intp`
(unsigned) Py_intptr_t (an integer that is the size of a pointer on the platform).

(Complex) Floating point

`npy_(c)float`
float

`npy_(c)double`
double

`npy_(c)longdouble`
long double

complex types are structures with `.real` and `.imag` members (in that order).

Bit-width names

There are also typedefs for signed integers, unsigned integers, floating point, and complex floating point types of specific bit-widths. The available type names are

`npy_int{bits}, npy_uint{bits}, npy_float{bits}, and npy_complex{bits}`

where `{bits}` is the number of bits in the type and can be 8, 16, 32, 64, 128, and 256 for integer types; 16, 32, 64, 80, 96, 128, and 256 for floating-point types; and 32, 64, 128, 160, 192, and 512 for complex-valued types. Which bit-widths are available is platform dependent. The bolded bit-widths are usually available on all platforms.
5.3.4 Printf Formatting

For help in printing, the following strings are defined as the correct format specifier in printf and related commands.

NPY_LONGLONG_FMT, NPY_ULONGLONG_FMT, NPY_INTP_FMT, NPY_UINTP_FMT, NPY_LONGDOUBLE_FMT

5.4 Array API

The test of a first-rate intelligence is the ability to hold two opposed ideas in the mind at the same time, and still retain the ability to function.
— F. Scott Fitzgerald

For a successful technology, reality must take precedence over public relations, for Nature cannot be fooled.
— Richard P. Feynman

5.4.1 Array structure and data access

These macros all access the PyArrayObject structure members. The input argument, arr, can be any PyObject * that is directly interpretable as a PyArrayObject * (any instance of the PyArray_Type and its sub-types).

int PyArray_NDIM (PyArrayObject *arr)
The number of dimensions in the array.

npy_intp *PyArray_DIMS (PyArrayObject *arr)
Returns a pointer to the dimensions/shape of the array. The number of elements matches the number of dimensions of the array.

npy_intp *PyArray_SHAPE (PyArrayObject *arr)
New in version 1.7.
A synonym for PyArray_DIMS, named to be consistent with the ‘shape’ usage within Python.

void *PyArray_DATA (PyArrayObject *arr)

char *PyArray_BYTES (PyArrayObject *arr)
These two macros are similar and obtain the pointer to the data-buffer for the array. The first macro can (and should be) assigned to a particular pointer where the second is for generic processing. If you have not guaranteed a contiguous and/or aligned array then be sure you understand how to access the data in the array to avoid memory and/or alignment problems.

npy_intp *PyArray_STRIDES (PyArrayObject* arr)
Returns a pointer to the strides of the array. The number of elements matches the number of dimensions of the array.

npy_intp PyArray_DIM (PyArrayObject* arr, int n)
Return the shape in the n th dimension.

npy_intp PyArray_STRIDE (PyArrayObject* arr, int n)
Return the stride in the n th dimension.
PyObject *PyArray_BASE (PyArrayObject* arr)
This returns the base object of the array. In most cases, this means the object which owns the memory the array
is pointing at.

If you are constructing an array using the C API, and specifying your own memory, you should use the function
PyArray_SetBaseObject to set the base to an object which owns the memory.

If the NPY_ARRAY_UPDATEIFCOPY flag is set, it has a different meaning, namely base is the array into which
the current array will be copied upon destruction. This overloading of the base property for two functions is
likely to change in a future version of NumPy.

PyArray_Descr *PyArray_DESCR (PyArrayObject* arr)
Returns a borrowed reference to the dtype property of the array.

PyArray_Descr *PyArray_DTYPE (PyArrayObject* arr)
New in version 1.7.
A synonym for PyArray_DESCR, named to be consistent with the ’dtype’ usage within Python.

void PyArray_ENABLEFLAGS (PyArrayObject* arr, int flags)
New in version 1.7.
Enables the specified array flags. This function does no validation, and assumes that you know what you’re
doing.

void PyArray_CLEARFLAGS (PyArrayObject* arr, int flags)
New in version 1.7.
Clears the specified array flags. This function does no validation, and assumes that you know what you’re doing.

int PyArray_FLAGS (PyArrayObject* arr)

int PyArray_ITEMSIZE (PyArrayObject* arr)
Return the itemsize for the elements of this array.

int PyArray_TYPE (PyArrayObject* arr)
Return the (builtin) typenumber for the elements of this array.

PyObject *PyArray_GETITEM (PyArrayObject* arr, void* itemptr)
Get a Python object from the ndarray, arr, at the location pointed to by itemptr. Return NULL on failure.

int PyArray_SETITEM (PyArrayObject* arr, void* itemptr, PyObject* obj)
Convert obj and place it in the ndarray, arr, at the place pointed to by itemptr. Return -1 if an error occurs or 0
on success.

npy_intp PyArray_SIZE (PyArrayObject* arr)
Returns the total size (in number of elements) of the array.

npy_intp PyArray_Size (PyArrayObject* obj)
Returns 0 if obj is not a sub-class of bigndarray. Otherwise, returns the total number of elements in the array.
Safer version of PyArray_SIZE (obj).

npy_intp PyArray_NBYTES (PyArrayObject* arr)
Returns the total number of bytes consumed by the array.

Data access

These functions and macros provide easy access to elements of the ndarray from C. These work for all arrays. You
may need to take care when accessing the data in the array, however, if it is not in machine byte-order, misaligned, or
not writeable. In other words, be sure to respect the state of the flags unless you know what you are doing, or have
previously guaranteed an array that is writeable, aligned, and in machine byte-order using PyArray_FromAny. If
you wish to handle all types of arrays, the copyswap function for each type is useful for handling misbehaved arrays. Some platforms (e.g. Solaris) do not like misaligned data and will crash if you de-reference a misaligned pointer. Other platforms (e.g. x86 Linux) will just work more slowly with misaligned data.

```c
void* PyArray_GetPtr (PyArrayObject* aobj, npy_intp* ind)
Return a pointer to the data of the ndarray, aobj, at the N-dimensional index given by the c-array, ind, (which must be at least aobj->nd in size). You may want to typecast the returned pointer to the data type of the ndarray.
```

```c
void* PyArray_GETPTR1 (PyArrayObject* obj, npy_intp i)
void* PyArray_GETPTR2 (PyArrayObject* obj, npy_intp i, npy_intp j)
void* PyArray_GETPTR3 (PyArrayObject* obj, npy_intp i, npy_intp j, npy_intp k)
void* PyArray_GETPTR4 (PyArrayObject* obj, npy_intp i, npy_intp j, npy_intp k)
```

Quick, inline access to the element at the given coordinates in the ndarray, obj, which must have respectively 1, 2, 3, or 4 dimensions (this is not checked). The corresponding i, j, k, and l coordinates can be any integer but will be interpreted as npy_intp. You may want to typecast the returned pointer to the data type of the ndarray.

### 5.4.2 Creating arrays

#### From scratch

```c
PyObject* PyArray_NewFromDescr (PyTypeObject* subtype, PyArray_Descr* descr, int nd, npy_intp* dims, npy_intp* strides, void* data, int flags, PyObject* obj)
```

This function steals a reference to descr.

This is the main array creation function. Most new arrays are created with this flexible function.

The returned object is an object of Python-type subtype, which must be a subtype of PyArray_Type. The array has nd dimensions, described by dims. The data-type descriptor of the new array is descr.

If subtype is of an array subclass instead of the base &PyArray_Type, then obj is the object to pass to the __array_finalize__ method of the subclass.

If data is NULL, then new memory will be allocated and flags can be non-zero to indicate a Fortran-style contiguous array. If data is not NULL, then it is assumed to point to the memory to be used for the array and the flags argument is used as the new flags for the array (except the state of NPY_OWNDATA and NPY_ARRAY_UPDATEIFCOPY flags of the new array will be reset).

In addition, if data is non-NULL, then strides can also be provided. If strides is NULL, then the array strides are computed as C-style contiguous (default) or Fortran-style contiguous (flags is nonzero for data = NULL or flags & NPY_ARRAY_F_CONTIGUOUS is nonzero non-NULL data). Any provided dims and strides are copied into newly allocated dimension and strides arrays for the new array object.

```c
PyObject* PyArray_NewLikeArray (PyArrayObject* prototype, NPY_ORDER order, PyArray_Descr* descr, int subok)
```

New in version 1.6.

This function steals a reference to descr if it is not NULL.

This array creation routine allows for the convenient creation of a new array matching an existing array’s shapes and memory layout, possibly changing the layout and/or data type.
When \textit{order} is \texttt{NPY\_ANYORDER}, the result order is \texttt{NPY\_FORTRANORDER} if \textit{prototype} is a fortran array, \texttt{NPY\_CORDER} otherwise. When \textit{order} is \texttt{NPY\_KEEPORDER}, the result order matches that of \textit{prototype}, even when the axes of \textit{prototype} aren't in C or Fortran order.

If \textit{descr} is NULL, the data type of \textit{prototype} is used.

If \textit{subok} is 1, the newly created array will use the sub-type of \textit{prototype} to create the new array, otherwise it will create a base-class array.

\textit{PyObject*} \texttt{PyArray\_New} (\texttt{PyTypeObject* subtype}, \texttt{int nd}, \texttt{npy\_intp* dims}, \texttt{int type\_num}, \texttt{npy\_intp* strides}, \texttt{void* data}, \texttt{int itemsize}, \texttt{int flags}, \texttt{PyObject* obj})

This is similar to \texttt{PyArray\_DescrNew (...) except you specify the data-type descriptor with \textit{type\_num} and \textit{itemsize}, where \textit{type\_num} corresponds to a builtin (or user-defined) type. If the type always has the same number of bytes, then \textit{itemsize} is ignored. Otherwise, \textit{itemsize} specifies the particular size of this array.

\begin{center}
\textbf{Warning:} If data is passed to \texttt{PyArray\_NewFromDescr} or \texttt{PyArray\_New}, this memory must not be deallocated until the new array is deleted. If this data came from another Python object, this can be accomplished using \texttt{Py\_INCREF} on that object and setting the base member of the new array to point to that object. If strides are passed in they must be consistent with the dimensions, the \textit{itemsize}, and the data of the array.
\end{center}

\textit{PyObject*} \texttt{PyArray\_SimpleNew} (\texttt{int nd}, \texttt{npy\_intp* dims}, \texttt{int typenum})

Create a new unitialized array of type, \textit{typenum}, whose size in each of \textit{nd} dimensions is given by the integer array, \textit{dims}. This function cannot be used to create a flexible-type array (no \textit{itemsize} given).

\textit{PyObject*} \texttt{PyArray\_SimpleNewFromData} (\texttt{int nd}, \texttt{npy\_intp* dims}, \texttt{int typenum}, \texttt{void* data})

Create an array wrapper around \textit{data} pointed to by the given pointer. The array flags will have a default that the data area is well-behaved and C-style contiguous. The shape of the array is given by the \textit{dims} c-array of length \textit{nd}. The data-type of the array is indicated by \textit{typenum}.

\textit{PyObject*} \texttt{PyArray\_SimpleNewFromDescr} (\texttt{int nd}, \texttt{npy\_intp* dims}, \texttt{PyArray\_Descr* descr})

This function steals a reference to \textit{descr} if it is not NULL.

Create a new array with the provided data-type descriptor, \textit{descr}, of the shape determined by \textit{nd} and \textit{dims}.

\textit{PyArray\_FILLBYTE} (\texttt{PyObject* obj}, \texttt{int val})

Fill the array pointed to by \textit{obj} — which must be a (subclass of) bigndarray — with the contents of \textit{val} (evaluated as a byte). This macro calls memset, so \textit{obj} must be contiguous.

\textit{PyObject*} \texttt{PyArray\_Zeros} (\texttt{int nd}, \texttt{npy\_intp* dims}, \texttt{PyArray\_Descr* dtype}, \texttt{int fortran})

Construct a new \textit{nd} -dimensional array with shape given by \textit{dims} and data type given by \textit{dtype}. If \textit{fortran} is non-zero, then a Fortran-order array is created, otherwise a C-order array is created. Fill the memory with zeros (or the 0 object if \textit{dtype} corresponds to \texttt{NPY\_OBJECT}).

\textit{PyObject*} \texttt{PyArray\_ZEROS} (\texttt{int nd}, \texttt{npy\_intp* dims}, \texttt{int type\_num}, \texttt{int fortran})

Macro form of \texttt{PyArray\_Zeros} which takes a type-number instead of a data-type object.

\textit{PyObject*} \texttt{PyArray\_Empty} (\texttt{int nd}, \texttt{npy\_intp* dims}, \texttt{PyArray\_Descr* dtype}, \texttt{int fortran})

Construct a new \textit{nd} -dimensional array with shape given by \textit{dims} and data type given by \textit{dtype}. If \textit{fortran} is non-zero, then a Fortran-order array is created, otherwise a C-order array is created. The array is uninitialized unless the data type corresponds to \texttt{NPY\_OBJECT} in which case the array is filled with \texttt{Py\_None}.

\textit{PyObject*} \texttt{PyArray\_EMPTY} (\texttt{int nd}, \texttt{npy\_intp* dims}, \texttt{int typenum}, \texttt{int fortran})

Macro form of \texttt{PyArray\_Empty} which takes a type-number, \textit{typenum}, instead of a data-type object.

\textit{PyObject*} \texttt{PyArray\_Arange} (\texttt{double start}, \texttt{double stop}, \texttt{double step}, \texttt{int typenum})

Construct a new 1-dimensional array of data-type, \textit{typenum}, that ranges from \texttt{start} to \texttt{stop} (exclusive) in increments of \texttt{step}. Equivalent to \texttt{arange} (\texttt{start}, \texttt{stop}, \texttt{step}, \texttt{dtype}).

\textit{PyObject*} \texttt{PyArray\_ArangeObj} (\texttt{PyObject* start}, \texttt{PyObject* stop}, \texttt{PyObject* step}, \texttt{PyArray\_Descr* descr})

Construct a new 1-dimensional array of data-type determined by \textit{descr}, that ranges from \texttt{start} to \texttt{stop}
(exclusive) in increments of step. Equivalent to arange( start, stop, step, typenum ).

```c
int PyArray_SetBaseObject ( PyArrayObject* arr,PyObject* obj )
```

New in version 1.7.

This function **steals a reference** to obj and sets it as the base property of arr.

If you construct an array by passing in your own memory buffer as a parameter, you need to set the array’s base property to ensure the lifetime of the memory buffer is appropriate.

The return value is 0 on success, -1 on failure.

If the object provided is an array, this function traverses the chain of base pointers so that each array points to the owner of the memory directly. Once the base is set, it may not be changed to another value.

**From other objects**

```c
PyObject* PyArray_FromAny ( PyObject* op, PyArray_Descr* dtype, int min_depth, int max_depth, int requirements, PyObject* context )
```

This is the main function used to obtain an array from any nested sequence, or object that exposes the array interface, op. The parameters allow specification of the required dtype, the minimum (min_depth) and maximum (max_depth) number of dimensions acceptable, and other requirements for the array. The dtype argument needs to be a PyArray_Descr structure indicating the desired data-type (including required byteorder). The dtype argument may be NULL, indicating that any data-type (and byteorder) is acceptable. Unless FORCECAST is present in flags, this call will generate an error if the data type cannot be safely obtained from the object. If you want to use NULL for the dtype and ensure the array is not swapped then use PyArray_CheckFromAny.

A value of 0 for either of the depth parameters causes the parameter to be ignored. Any of the following array flags can be added (e.g. using |) to get the requirements argument. If your code can handle general (e.g. strided, byte-swapped, or unaligned arrays) then requirements may be 0. Also, if op is not already an array (or does not expose the array interface), then a new array will be created (and filled from op using the sequence protocol). The new array will have NPY_DEFAULT as its flags member. The context argument is passed to the __array__ method of op and is only used if the array is constructed that way. Almost always this parameter is NULL.

In versions 1.6 and earlier of NumPy, the following flags did not have the _ARRAY_ macro namespace in them. That form of the constant names is deprecated in 1.7.

**NPY_ARRAY_C_CONTIGUOUS**
Make sure the returned array is C-style contiguous

**NPY_ARRAY_F_CONTIGUOUS**
Make sure the returned array is Fortran-style contiguous.

**NPY_ARRAY_ALIGNED**
Make sure the returned array is aligned on proper boundaries for its data type. An aligned array has the data pointer and every strides factor as a multiple of the alignment factor for the data-type descriptor.

**NPY_ARRAY_WRITEABLE**
Make sure the returned array can be written to.

**NPY_ARRAY_ENSURECOPY**
Make sure a copy is made of op. If this flag is not present, data is not copied if it can be avoided.

**NPY_ARRAY_ENSUREARRAY**
Make sure the result is a base-class ndarray or bigndarray. By default, if op is an instance of a subclass of the bigndarray, an instance of that same subclass is returned. If this flag is set, an ndarray object will be returned instead.
NPY_AR

Force a cast to the output type even if it cannot be done safely. Without this flag, a data cast will occur only if it can be done safely, otherwise an error is raised.

NPY_ARRAY_UPDATEIFCOPY

If op is already an array, but does not satisfy the requirements, then a copy is made (which will satisfy the requirements). If this flag is present and a copy (of an object that is already an array) must be made, then the corresponding NPY_ARRAY_UPDATEIFCOPY flag is set in the returned copy and op is made to be read-only. When the returned copy is deleted (presumably after your calculations are complete), its contents will be copied back into op and the op array will be made writeable again. If op is not writeable to begin with, then an error is raised. If op is not already an array, then this flag has no effect.

NPY_ARRAY_BEHAVED

NPY_ARRAY_ALIGNED | NPY_ARRAY_WRITEABLE

NPY_ARRAY_CARRAY

NPY_ARRAY_C_CONTIGUOUS | NPY_ARRAY_BEHAVED

NPY_ARRAY_CARRAY_RO

NPY_ARRAY_C_CONTIGUOUS | NPY_ARRAY_ALIGNED

NPY_ARRAY_FARRAY

NPY_ARRAY_F_CONTIGUOUS | NPY_ARRAY_BEHAVED

NPY_ARRAY_FARRAY_RO

NPY_ARRAY_F_CONTIGUOUS | NPY_ARRAY_ALIGNED

NPY_ARRAY_DEFAULT

NPY_ARRAY_CARRAY

NPY_ARRAY_IN_ARRAY

NPY_ARRAY_CONTIGUOUS | NPY_ARRAY_ALIGNED

NPY_ARRAY_IN_FARRAY

NPY_ARRAY_F_CONTIGUOUS | NPY_ARRAY_ALIGNED

NPY_OUT_ARRAY

NPY_ARRAY_C_CONTIGUOUS | NPY_ARRAY_WRITEABLE | NPY_ARRAY_ALIGNED

NPY_ARRAY_OUT_FARRAY

NPY_ARRAY_F_CONTIGUOUS | NPY_ARRAY_WRITEABLE | NPY_ARRAY_ALIGNED

int PyArray_GetArrayParamsFromObject (PyObject* op, PyArray_Descr* requested_dtype,
                                 npy_bool writeable, PyArray_Descr** out_dtype,
                                 int* out_ndim, npy_intp* out_dims, PyArrayObject** out_arr, PyObject* context)

New in version 1.6.

Retrieves the array parameters for viewing/converting an arbitrary PyObject* to a NumPy array. This allows the “innate type and shape” of Python list-of-lists to be discovered without actually converting to an array. PyArray_FromAny calls this function to analyze its input.

In some cases, such as structured arrays and the __array__ interface, a data type needs to be used to make sense of the object. When this is needed, provide a Descr for ‘requested_dtype’, otherwise provide NULL. This

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reference is not stolen. Also, if the requested dtype doesn’t modify the interpretation of the input, out_dtype will still get the “innate” dtype of the object, not the dtype passed in ‘requested_dtype’.

If writing to the value in ‘op’ is desired, set the boolean ‘writeable’ to 1. This raises an error when ‘op’ is a scalar, list of lists, or other non-writeable ‘op’. This differs from passing NPY_ARRAY_WRITEABLE to PyArray_FromAny, where the writeable array may be a copy of the input.

When success (0 return value) is returned, either out_arr is filled with a non-NULL PyArrayObject and the rest of the parameters are untouched, or out_arr is filled with NULL, and the rest of the parameters are filled.

Typical usage:

```c
PyArrayObject *arr = NULL;
PyArray_Descr *dtype = NULL;
int ndim = 0;
npy_intp dims[NPY_MAXDIMS];

if (PyArray_GetArrayParamsFromObject(op, NULL, 1, &dtype, &ndim, &dims, &arr, NULL) < 0) {
    return NULL;
}
if (arr == NULL) {
    ... validate/change dtype, validate flags, ndim, etc ...
    // Could make custom strides here too
    arr = PyArray_NewFromDescr(&PyArray_Type, dtype, ndim, dims, NULL,
                               fortran ? NPY_ARRAY_F_CONTIGUOUS : 0,
                               NULL);

    if (arr == NULL) {
        return NULL;
    }
    if (PyArray_CopyObject(arr, op) < 0) {
        Py_DECREF(arr);
        return NULL;
    }
} else {
    ... in this case the other parameters weren’t filled, just
    validate and possibly copy arr itself ...
}
... use arr ...
```

**PyObject* PyArray_CheckFromAny**(PyObject* op, PyArray_Descr* dtype, int min_depth, int max_depth, int requirements, PyObject* context)

Nearly identical to PyArray_FromAny (...) except requirements can contain NPY_ARRAY_NOTSWAPPED (over-riding the specification in dtype) and NPY_ARRAY_ELEMENTSTRIDES which indicates that the array should be aligned in the sense that the strides are multiples of the element size.

In versions 1.6 and earlier of NumPy, the following flags did not have the _ARRAY_ macro namespace in them. That form of the constant names is deprecated in 1.7.

**NPY_ARRAY_NOTSWAPPED**

Make sure the returned array has a data-type descriptor that is in machine byte-order, over-riding any specification in the dtype argument. Normally, the byte-order requirement is determined by the dtype argument. If this flag is set and the dtype argument does not indicate a machine byte-order descriptor (or is NULL and the object is already an array with a data-type descriptor that is not in machine byte-order), then a new data-type descriptor is created and used with its byte-order field set to native.

**NPY_ARRAY_BEHAVED_NS**

NPY_ARRAYAligned | NPY_ARRAY_WRITEABLE | NPY_ARRAY_NOTSWAPPED
NPY_ARRAY_ELEMENTSTRIDES
Make sure the returned array has strides that are multiples of the element size.

PyObject* PyArray_FromArray (PyObject* * op, PyArray_Descr* newtype, int requirements)
Special case of PyArray_FromAny for when op is already an array but it needs to be of a specific newtype (including byte-order) or has certain requirements.

PyObject* PyArray_FromStructInterface (PyObject* op)
Returns a (C-style) contiguous and behaved function array from any nested sequence or array-interface exporting object, and makes sure that the array is a base-class ndarray. It special cases array scalars, but otherwise calls PyArray_FromAny ( op, NULL, 0, 0, NPY_ARRAY_ENSUREARRAY).

PyObject* PyArray_FromString (char* string, npy_intp slen, PyArray_Descr* dtype, npy_intp num, char* sep)
Construct a one-dimensional ndarray of a single type from a binary or (ASCII) text string of length slen. The data-type of the array to-be-created is given by dtype. If num is -1, then copy the entire string and return an appropriately sized array, otherwise, num is the number of items to copy from the string. If sep is NULL (or ""), then interpret the string as bytes of binary data, otherwise convert the sub-strings separated by sep to items of data-type dtype. Some data-types may not be readable in text mode and an error will be raised if that occurs. All errors return NULL.

PyObject* PyArray_FromFile (FILE* fp, PyArray_Descr* dtype, npy_intp num, char* sep)
Construct a one-dimensional ndarray of a single type from a binary or text file. The open file pointer is fp, the data-type of the array to be created is given by dtype. This must match the data in the file. If num is -1, then read until the end of the file and return an appropriately sized array, otherwise, num is the number of items to read. If sep is NULL (or ""), then read from the file in binary mode, otherwise read from the file in text mode with sep providing the item separator. Some array types cannot be read in text mode and an error will be raised.

PyObject* PyArray_FromBuffer (PyObject* buf, PyArray_Descr* dtype, npy_intp count, npy_intp offset)
Construct a one-dimensional ndarray of a single type from an object, buf, that exports the (single-segment) buffer protocol (or has an attribute __buffer__ that returns an object that exports the buffer protocol). A writeable buffer will be tried first followed by a read-only buffer. The NPY_ARRAY_WRITEABLE flag of the

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returned array will reflect which one was successful. The data is assumed to start at offset bytes from the start of the memory location for the object. The type of the data in the buffer will be interpreted depending on the data-type descriptor, dtype. If count is negative then it will be determined from the size of the buffer and the requested itemsize, otherwise, count represents how many elements should be converted from the buffer.

```c
int PyArray_CopyInto (PyArrayObject* dest, PyArrayObject* src)
```

Copy from the source array, src, into the destination array, dest, performing a data-type conversion if necessary. If an error occurs return -1 (otherwise 0). The shape of src must be broadcastable to the shape of dest. The data areas of dest and src must not overlap.

```c
int PyArray_MoveInto (PyArrayObject* dest, PyArrayObject* src)
```

Move data from the source array, src, into the destination array, dest, performing a data-type conversion if necessary. If an error occurs return -1 (otherwise 0). The shape of src must be broadcastable to the shape of dest. The data areas of dest and src may overlap.

```c
PyArrayObject* PyArray_GETCONTIGUOUS (PyObject* op)
```

If op is already (C-style) contiguous and well-behaved then just return a reference, otherwise return a (contiguous and well-behaved) copy of the array. The parameter op must be a (sub-class of an) ndarray and no checking for that is done.

```c
PyObject* PyArray_GETCONTIGUOUS (PyObject* obj)
```

Convert obj to an ndarray. The argument can be any nested sequence or object that exports the array interface. This is a macro form of PyArray_FromAny using NULL, 0, 0, 0 for the other arguments. Your code must be able to handle any data-type descriptor and any combination of data-flags to use this macro.

```c
PyObject* PyArray_GETCONTIGUOUS (PyObject* obj, int requirements)
```

Similar to PyArray_GETCONTIGUOUS except it can take an argument of requirements indicating properties the resulting array must have. Available requirements that can be enforced are NPY_ARRAY_C_CONTIGUOUS, NPY_ARRAY_F_CONTIGUOUS, NPY_ARRAY_ALIGNED, NPY_ARRAY_WRITEABLE, NPY_ARRAY_NOTSWAPPED, NPY_ARRAY_ENSURECOPY, NPY_ARRAY_UPDATEIFCOPY, NPY_ARRAY_FORCECAST, and NPY_ARRAY_ENSUREARRAY. Standard combinations of flags can also be used:

```c
PyObject* PyArray_GETCONTIGUOUS (PyObject* obj, int typenum)
```

Similar to PyArray_GETCONTIGUOUS except it can take an argument of typenum specifying the type-number the returned array.

```c
PyObject* PyArray_GETCONTIGUOUS (PyObject* obj, int typenum, int min, int max)
```

Combination of PyArray_GETCONTIGUOUS and PyArray_SETCONTIGUOUS allowing both a typenum and a flags argument to be provided.

```c
PyObject* PyArray_GETCONTIGUOUS (PyObject* obj, int typenum, int min, int max, int requirements)
```

Similar to PyArray_GETCONTIGUOUS except the data-type is specified using a typenum. PyArray_DescrFromType (typenum) is passed directly to PyArray_FromAny. This macro also adds NPY_DEFAULT to requirements if NPY_ARRAY_ENSURECOPY is passed in as requirements.

```c
PyObject* PyArray_VALIDATE (PyObject* obj, int* axis, int requirements)
```

Encapsulate the functionality of functions and methods that take the axis= keyword and work properly with None as the axis argument. The input array is obj, while *axis is a converted integer (so that >=MAXDIMS is the None value), and requirements gives the needed properties of obj. The output is a converted version of the input so that requirements are met and if needed a flattening has occurred. On output negative values of *axis are converted and the new value is checked to ensure consistency with the shape of obj.
5.4.3 Dealing with types

General check of Python Type

**PyArray_Check** (op)
Evaluates true if `op` is a Python object whose type is a sub-type of `PyArray_Type`.

**PyArray_CheckExact** (op)
Evaluates true if `op` is a Python object with type `PyArray_Type`.

**PyArray_HasArrayInterface** (op, out)
If `op` implements any part of the array interface, then `out` will contain a new reference to the newly created `ndarray` using the interface or `out` will contain `NULL` if an error during conversion occurs. Otherwise, `out` will contain a borrowed reference to `Py_NotImplemented` and no error condition is set.

**PyArray_HasArrayInterfaceType** (op, type, context, out)
If `op` implements any part of the array interface, then `out` will contain a new reference to the newly created `ndarray` using the interface or `out` will contain `NULL` if an error during conversion occurs. Otherwise, `out` will contain a borrowed reference to `Py_NotImplemented` and no error condition is set. This version allows setting of the type and context in the part of the array interface that looks for the `__array__` attribute.

**PyArray_IsZeroDim** (op)
Evaluates true if `op` is an instance of (a subclass of) `PyArray_Type` and has 0 dimensions.

**PyArray_IsScalar** (op, cls)
Evaluates true if `op` is an instance of `Py{cls}ArrType_Type`.

**PyArray_CheckScalar** (op)
Evaluates true if `op` is either an array scalar (an instance of a sub-type of `PyGenericArr_Type`), or an instance of (a sub-class of) `PyArray_Type` whose dimensionality is 0.

**PyArray_IsPythonScalar** (op)
Evaluates true if `op` is a builtin Python “scalar” object (int, float, complex, str, unicode, long, bool).

**PyArray_IsAnyScalar** (op)
Evaluates true if `op` is either a Python scalar or an array scalar (an instance of a sub-type of `PyGenericArr_Type`).

Data-type checking

For the typenum macros, the argument is an integer representing an enumerated array data type. For the array type checking macros the argument must be a `PyObject *` that can be directly interpreted as a `PyArrayObject *`.

**PyTypeNum_ISUNSIGNED** (num)

**PyDataType_ISUNSIGNED** (descr)

**PyArray_ISUNSIGNED** (obj)
Type represents an unsigned integer.

**PyTypeNum_ISSIGNED** (num)

**PyDataType_ISSIGNED** (descr)

**PyArray_ISSIGNED** (obj)
Type represents a signed integer.
NumPy Reference, Release 1.9.2

PyTypeNum_ISINTEGER (num)

PyDataType_ISINTEGER (descr)

PyArray_ISINTEGER (obj)
          Type represents any integer.
PyTypeNum_ISFLOAT (num)

PyDataType_ISFLOAT (descr)

PyArray_ISFLOAT (obj)
          Type represents any floating point number.
PyTypeNum_ISCOMPLEX (num)

PyDataType_ISCOMPLEX (descr)

PyArray_ISCOMPLEX (obj)
          Type represents any complex floating point number.
PyTypeNum_ISNUMBER (num)

PyDataType_ISNUMBER (descr)

PyArray_ISNUMBER (obj)
          Type represents any integer, floating point, or complex floating point number.
PyTypeNum_ISSTRING (num)

PyDataType_ISSTRING (descr)

PyArray_ISSTRING (obj)
          Type represents a string data type.
PyTypeNum_ISPYTHON (num)

PyDataType_ISPYTHON (descr)

PyArray_ISPYTHON (obj)
          Type represents an enumerated type corresponding to one of the standard Python scalar (bool, int, float, or complex).
PyTypeNum_ISFLEXIBLE (num)

PyDataType_ISFLEXIBLE (descr)

PyArray_ISFLEXIBLE (obj)
          Type represents one of the flexible array types (NPY_STRING, NPY_UNICODE, or NPY_VOID).
Type represents a user-defined type.

PyArray_ISEXTENDED (obj)
Type is either flexible or user-defined.

PyArray_ISOBJECT (obj)
Type represents object data type.

PyArray_HASFIELDS (obj)
Type has fields associated with it.

PyArray_ISNOTSWAPPED (m)
Evaluates true if the data area of the ndarray m is in machine byte-order according to the array’s data-type descriptor.

PyArray_ISBYTESWAPPED (m)
Evaluates true if the data area of the ndarray m is not in machine byte-order according to the array’s data-type descriptor.

Bool PyArray_EquivTypes (PyArray_Descr* type1, PyArray_Descr* type2)
Return NPY_TRUE if type1 and type2 actually represent equivalent types for this platform (the fortran member of each type is ignored). For example, on 32-bit platforms, NPY_LONG and NPY_INT are equivalent. Otherwise return NPY_FALSE.

Bool PyArray_EquivArrTypes (PyArrayObject* a1, PyArrayObject * a2)
Return NPY_TRUE if a1 and a2 are arrays with equivalent types for this platform.

Bool PyArray_EquivTypenums (int typenum1, int typenum2)
Special case of PyArray_EquivTypes (...) that does not accept flexible data types but may be easier to call.

int PyArray_EquivByteorders ( (byteorder) b1, (byteorder) b2)
True if byteorder characters (NPY_LITTLE, NPY_BIG, NPY_NATIVE, NPY_IGNORE) are either equal or
equivalent as to their specification of a native byte order. Thus, on a little-endian machine NPY_LITTLE and NPY_NATIVE are equivalent where they are not equivalent on a big-endian machine.

Converting data types

PyObject* PyArray_Cast (PyArrayObject* arr, int typenum)
Mainly for backwards compatibility to the Numeric C-API and for simple casts to non-flexible types. Return a new array object with the elements of arr cast to the data-type typenum which must be one of the enumerated types and not a flexible type.

PyObject* PyArray_CastToType (PyArrayObject* arr, PyArray_Descr* type, int fortran)
Return a new array of the type specified, casting the elements of arr as appropriate. The fortran argument specifies the ordering of the output array.

int PyArray_CastTo (PyArrayObject* out, PyArrayObject* in)
As of 1.6, this function simply calls PyArray_CopyInto, which handles the casting.

Cast the elements of the array in into the array out. The output array should be writeable, have an integer-multiple of the number of elements in the input array (more than one copy can be placed in out), and have a data type that is one of the builtin types. Returns 0 on success and -1 if an error occurs.

PyObject_VectorUnaryFunc* PyArray_GetCastFunc (PyArray_Descr* from, int totype)
Return the low-level casting function to cast from the given descriptor to the builtin type number. If no casting function exists return NULL and set an error. Using this function instead of direct access to from->f->cast will allow support of any user-defined casting functions added to a descriptors casting dictionary.

int PyArray_CanCastSafely (int fromtype, int totype)
Returns non-zero if an array of data type fromtype can be cast to an array of data type totype without losing information. An exception is that 64-bit integers are allowed to be cast to 64-bit floating point values even though this can lose precision on large integers so as not to proliferate the use of long doubles without explicit requests. Flexible array types are not checked according to their lengths with this function.

int PyArray_CanCastTo (PyArray_Descr* fromtype, PyArray_Descr* totype)
New in version 1.6.
Returns non-zero if an array of data type fromtype (which can include flexible types) can be cast safely to an array of data type totype (which can include flexible types) according to the casting rule casting. For simple types with NPY_SAFE_CASTING, this is basically a wrapper around PyArray_CanCastSafely, but for flexible types such as strings or unicode, it produces results taking into account their sizes. Integer and float types can only be cast to a string or unicode type using NPY_SAFE_CASTING if the string or unicode type is big enough to hold the max value of the integer/float type being cast from.

int PyArray_CanCastArrayTo (PyArrayObject* arr, PyArray_Descr* totype, NPY_CASTING casting)
New in version 1.6.
Returns non-zero if arr can be cast to totype according to the casting rule given in casting. If arr is an array scalar, its value is taken into account, and non-zero is also returned when the value will not overflow or be truncated to an integer when converting to a smaller type.

This is almost the same as the result of PyArray_CanCastTypeTo(PyArray_MinScalarType(arr), totype, casting), but it also handles a special case arising because the set of uint values is not a subset of the int values for types with the same number of bits.
PyArray_Descr* **PyArray_MinScalarType** (PyArrayObject* arr)
New in version 1.6.
If arr is an array, returns its data type descriptor, but if arr is an array scalar (has 0 dimensions), it finds the data type of smallest size to which the value may be converted without overflow or truncation to an integer.
This function will not demote complex to float or anything to boolean, but will demote a signed integer to an unsigned integer when the scalar value is positive.

PyArray_Descr* **PyArray_PromoteTypes** (PyArray_Descr* type1, PyArray_Descr* type2)
New in version 1.6.
Finds the data type of smallest size and kind to which type1 and type2 may be safely converted. This function is symmetric and associative. A string or unicode result will be the proper size for storing the max value of the input types converted to a string or unicode.

PyArray_Descr* **PyArray_ResultType** (npy_intp narrs, PyArrayObject**arrs, npy_intp ndtypes, PyArray_Descr**dtypes)
New in version 1.6.
This applies type promotion to all the inputs, using the NumPy rules for combining scalars and arrays, to determine the output type of a set of operands. This is the same result type that ufuncs produce. The specific algorithm used is as follows.
Categories are determined by first checking which of boolean, integer (int/uint), or floating point (float/complex) the maximum kind of all the arrays and the scalars are.
If there are only scalars or the maximum category of the scalars is higher than the maximum category of the arrays, the data types are combined with PyArray_PromoteTypes to produce the return value.
Otherwise, PyArray_MinScalarType is called on each array, and the resulting data types are all combined with PyArray_PromoteTypes to produce the return value.
The set of int values is not a subset of the uint values for types with the same number of bits, something not reflected in PyArray_MinScalarType, but handled as a special case in PyArray_ResultType.

int **PyArray_ObjectType** (PyObject* op, int mintype)
This function is superceded by PyArray_MinScalarType and/or PyArray_ResultType.
This function is useful for determining a common type that two or more arrays can be converted to. It only works for non-flexible array types as no itemsize information is passed. The mintype argument represents the minimum type acceptable, and op represents the object that will be converted to an array. The return value is the enumerated typenumber that represents the data-type that op should have.

void **PyArray_ArrayType** (PyObject* op, PyArray_Descr* mintype, PyArray_Descr* outtype)
This function is superceded by PyArray_ResultType.
This function works similarly to PyArray_ObjectType (...) except it handles flexible arrays. The mintype argument can have an itemsize member and the outtype argument will have an itemsize member at least as big but perhaps bigger depending on the object op.

PyArrayObject** **PyArray_ConvertToCommonType** (PyObject* op, int* n)
The functionality this provides is largely superceded by iterator NpyIter introduced in 1.6, with flag NPY_ITER_COMMON_DTYPE or with the same dtype parameter for all operands.
Convert a sequence of Python objects contained in op to an array of ndarrays each having the same data type. The type is selected based on the typenumber (larger type number is chosen over a smaller one) ignoring objects that are only scalars. The length of the sequence is returned in n, and an n -length array of PyArrayObject pointers is the return value (or NULL if an error occurs). The returned array must be freed by the caller of this routine (using PyDataMem_FREE ) and all the array objects in it DECREF ’d or a memory-leak will occur.
The example template-code below shows a typically usage:
mps = PyArray_ConvertToCommonType(obj, &n);
if (mps==NULL) return NULL;
{
for (i=0; i<n; i++) Py_DECREF(mps[i]);
PyDataMem_FREE(mps);
{return}
}

char* PyArray_Zero (PyArrayObject* arr)
A pointer to newly created memory of size arr ->itemsize that holds the representation of 0 for that type. The returned pointer, ret, must be freed using PyDataMem_FREE (ret) when it is not needed anymore.

char* PyArray_One (PyArrayObject* arr)
A pointer to newly created memory of size arr ->itemsize that holds the representation of 1 for that type. The returned pointer, ret, must be freed using PyDataMem_FREE (ret) when it is not needed anymore.

int PyArray_ValidType (int typenum)
Returns NPY_TRUE if typenum represents a valid type-number (builtin or user-defined or character code). Otherwise, this function returns NPY_FALSE.

New data types

void PyArray_InitArrFuncs (PyArray_ArrFuncs* f)
Initialize all function pointers and members to NULL.

int PyArray_RegisterDataType (PyArray_Descr* dtype)
Register a data-type as a new user-defined data type for arrays. The type must have most of its entries filled in. This is not always checked and errors can produce segfaults. In particular, the typeobj member of the dtype structure must be filled with a Python type that has a fixed-size element-size that corresponds to the elsize member of dtype. Also the f member must have the required functions: nonzero, copy, copy swapped, getitem, setitem, and cast (some of the cast functions may be NULL if no support is desired). To avoid confusion, you should choose a unique character typecode but this is not enforced and not relied on internally.

A user-defined type number is returned that uniquely identifies the type. A pointer to the new structure can then be obtained from PyArray_DescrFromType using the returned type number. A -1 is returned if an error occurs. If this dtype has already been registered (checked only by the address of the pointer), then return the previously-assigned type-number.

int PyArray_RegisterCastFunc (PyArray_Descr* descr, int totype, PyArray_VectorUnaryFunc* castfunc)
Register a low-level casting function, castfunc, to convert from the data-type, descr, to the given data-type number, totype. Any old casting function is over-written. A 0 is returned on success or a -1 on failure.

int PyArray_RegisterCanCast (PyArray_Descr* descr, int totype, NPY_SCALARKIND scalar)
Register the data-type number, totype, as castable from data-type object, descr, of the given scalar kind. Use scalar = NPY_NOSCALAR to register that an array of data-type descr can be cast safely to a data-type whose type number is totype.

Special functions for NPY_OBJECT

int PyArray_INCREF (PyArrayObject* op)
Used for an array, op, that contains any Python objects. It increments the reference count of every object in the array according to the data-type of op. A -1 is returned if an error occurs, otherwise 0 is returned.

void PyArray_Item_INCREF (char* ptr, PyArray_Descr* dtype)
A function to INCREF all the objects at the location ptr according to the data-type dtype. If ptr is the start of a
record with an object at any offset, then this will (recursively) increment the reference count of all object-like items in the record.

```c
int PyArray_XDECREF (PyArrayObject* op)
```

Used for an array, `op`, that contains any Python objects. It decrements the reference count of every object in the array according to the data-type of `op`. Normal return value is 0. A -1 is returned if an error occurs.

```c
void PyArray_Item_XDECREF (char* ptr, PyArray_Descr* dtype)
```

A function to XDECREF all the object-like items at the location `ptr` as recorded in the data-type, `dtype`. This works recursively so that if `dtype` itself has fields with data-types that contain object-like items, all the object-like fields will be XDECREF’d.

```c
void PyArray_FillObjectArray (PyArrayObject* arr, PyObject* obj)
```

Fill a newly created array with a single value `obj` at all locations in the structure with object data-types. No checking is performed but `arr` must be of data-type `NPY_OBJECT` and be single-segment and uninitialized (no previous objects in position). Use `PyArray_DECREF (arr)` if you need to decrement all the items in the object array prior to calling this function.

### 5.4.4 Array flags

The `flags` attribute of the `PyArrayObject` structure contains important information about the memory used by the array (pointed to by the data member). This flag information must be kept accurate or strange results and even segfaults may result.

There are 6 (binary) flags that describe the memory area used by the data buffer. These constants are defined in `arrayobject.h` and determine the bit-position of the flag. Python exposes a nice attribute-based interface as well as a dictionary-like interface for getting (and, if appropriate, setting) these flags.

Memory areas of all kinds can be pointed to by an ndarray, necessitating these flags. If you get an arbitrary `PyArrayObject` in C-code, you need to be aware of the flags that are set. If you need to guarantee a certain kind of array (like `NPY_ARRAY_C_CONTIGUOUS` and `NPY_ARRAY_BEHAVED`), then pass these requirements into the `PyArray_FromAny` function.

#### Basic Array Flags

An ndarray can have a data segment that is not a simple contiguous chunk of well-behaved memory you can manipulate. It may not be aligned with word boundaries (very important on some platforms). It might have its data in a different byte-order than the machine recognizes. It might not be writeable. It might be in Fortran-contiguous order. The array flags are used to indicate what can be said about data associated with an array.

In versions 1.6 and earlier of NumPy, the following flags did not have the _ARRAY_ macro namespace in them. That form of the constant names is deprecated in 1.7.

- **NPY_ARRAY_C_CONTIGUOUS**
  The data area is in C-style contiguous order (last index varies the fastest).

- **NPY_ARRAY_F_CONTIGUOUS**
  The data area is in Fortran-style contiguous order (first index varies the fastest).

**Note:** Arrays can be both C-style and Fortran-style contiguous simultaneously. This is clear for 1-dimensional arrays, but can also be true for higher dimensional arrays.

Even for contiguous arrays a stride for a given dimension `arr.strides[dim]` may be arbitrary if `arr.shape[dim] == 1` or the array has no elements. It does *not* generally hold that `self.strides[-1] == self.itemsize` for C-style contiguous arrays or `self.strides[0] == self.itemsize` for Fortran-style contiguous arrays is true. The correct way to access the `itemsize` of an array from the C API is `PyArray_ITEMSIZE(arr)`.

**5.4. Array API**

1371
See also:

*Internal memory layout of an ndarray*

**NPY_ARRAY_OWNDATA**
The data area is owned by this array.

**NPY_ARRAY_ALIGNED**
The data area and all array elements are aligned appropriately.

**NPY_ARRAY_WRITEABLE**
The data area can be written to.

Notice that the above 3 flags are are defined so that a new, well-behaved array has these flags defined as true.

**NPY_ARRAY_UPDATEIFCOPY**
The data area represents a (well-behaved) copy whose information should be transferred back to the original when this array is deleted.

This is a special flag that is set if this array represents a copy made because a user required certain flags in `PyArray_FromAny` and a copy had to be made of some other array (and the user asked for this flag to be set in such a situation). The base attribute then points to the “misbehaved” array (which is set read_only). When the array with this flag set is deallocated, it will copy its contents back to the “misbehaved” array (casting if necessary) and will reset the “misbehaved” array to `NPY_ARRAY_WRITEABLE`. If the “misbehaved” array was not `NPY_ARRAY_WRITEABLE` to begin with then `PyArray_FromAny` would have returned an error because `NPY_ARRAY_UPDATEIFCOPY` would not have been possible.

`PyArray_UpdateFlags` (obj, flags) will update the obj->flags for flags which can be any of `NPY_ARRAY_C_CONTIGUOUS`, `NPY_ARRAY_F_CONTIGUOUS`, `NPY_ARRAY_ALIGNED`, or `NPY_ARRAY_WRITEABLE`.

**Combinations of array flags**

**NPY_ARRAY_BEHAVED**

- `NPY_ARRAY_ALIGNED | NPY_ARRAY_WRITEABLE`

**NPY_ARRAY_CARRAY**

- `NPY_ARRAY_C_CONTIGUOUS | NPY_ARRAY_BEHAVED`

**NPY_ARRAY_CARRAY_RO**

- `NPY_ARRAY_C_CONTIGUOUS | NPY_ARRAY_ALIGNED`

**NPY_ARRAY_FARRAY**

- `NPY_ARRAY_F_CONTIGUOUS | NPY_ARRAY_BEHAVED`

**NPY_ARRAY_FARRAY_RO**

- `NPY_ARRAY_F_CONTIGUOUS | NPY_ARRAY_ALIGNED`

**NPY_ARRAY_DEFAULT**

- `NPY_ARRAY_CARRAY`

**NPY_ARRAY_UPDATE_ALL**

- `NPY_ARRAY_C_CONTIGUOUS | NPY_ARRAY_F_CONTIGUOUS | NPY_ARRAY_ALIGNED`

**Flag-like constants**

These constants are used in `PyArray_FromAny` (and its macro forms) to specify desired properties of the new array.
NPY_ARRAY_FORCECAST
Cast to the desired type, even if it can’t be done without losing information.

NPY_ARRAY_ENSURECOPY
Make sure the resulting array is a copy of the original.

NPY_ARRAY_ENSUREARRAY
Make sure the resulting object is an actual ndarray (or bigndarray), and not a sub-class.

NPY_ARRAY_NOTSWAPPED
Only used in PyArray_CheckFromAny to over-ride the byteorder of the data-type object passed in.

NPY_ARRAY_BEAHVED_NS
NPY_ARRAY_ALIGNED | NPY_ARRAY_WRITEABLE | NPY_ARRAY_NOTSWAPPED

Flag checking

For all of these macros arr must be an instance of a (subclass of) PyArray_Type, but no checking is done.

PyArray_CHKFLAGS (arr, flags)
The first parameter, arr, must be an ndarray or subclass. The parameter, flags, should be an integer consisting of bitwise combinations of the possible flags an array can have:
NPY_ARRAY_C_CONTIGUOUS, NPY_ARRAY_F_CONTIGUOUS, NPY_ARRAY_OWNDATA, NPY_ARRAY_ALIGNED, NPY_ARRAY_WRITEABLE, NPY_ARRAY_UPDATEIFCOPY.

PyArray_IS_C_CONTIGUOUS (arr)
Evaluates true if arr is C-style contiguous.

PyArray_IS_F_CONTIGUOUS (arr)
Evaluates true if arr is Fortran-style contiguous.

PyArray_ISFORTRAN (arr)
Evaluates true if arr is Fortran-style contiguous and not C-style contiguous. PyArray_IS_F_CONTIGUOUS is the correct way to test for Fortran-style contiguity.

PyArray_ISWRITEABLE (arr)
Evaluates true if the data area of arr can be written to

PyArray_ISALIGNED (arr)
Evaluates true if the data area of arr is properly aligned on the machine.

PyArray_ISBEHAVED (arr)
Evaluates true if the data area of arr is aligned and writeable and in machine byte-order according to its descriptor.

PyArray_ISBEHAVED_RO (arr)
Evaluates true if the data area of arr is aligned and in machine byte-order.

PyArray_ISCARRAY (arr)
Evaluates true if the data area of arr is C-style contiguous, and PyArray_ISBEHAVED (arr) is true.

PyArray_ISFARRAY (arr)
Evaluates true if the data area of arr is Fortran-style contiguous and PyArray_ISBEHAVED (arr) is true.

PyArray_ISCARRAY_RO (arr)
Evaluates true if the data area of arr is C-style contiguous, aligned, and in machine byte-order.

PyArray_ISFARRAY_RO (arr)
Evaluates true if the data area of arr is Fortran-style contiguous, aligned, and in machine byte-order.

PyArray_ISONESEGMENT (arr)
Evaluates true if the data area of arr consists of a single (C-style or Fortran-style) contiguous segment.
void **PyArray_UpdateFlags**(PyArrayObject* \*arr, int flagmask)

The NPY_ARRAY_C_CONTIGUOUS, NPY_ARRAYAligned, and NPY_ARRAY_F_CONTIGUOUS array flags can be “calculated” from the array object itself. This routine updates one or more of these flags of \*arr as specified in flagmask by performing the required calculation.

**Warning:** It is important to keep the flags updated (using PyArray_UpdateFlags can help) whenever a manipulation with an array is performed that might cause them to change. Later calculations in NumPy that rely on the state of these flags do not repeat the calculation to update them.

### 5.4.5 Array method alternative API

#### Conversion

PyObject** PyArray_GetField**(PyArrayObject* \*self, PyArray_Descr* dtype, int offset)

Equivalent to ndarray.getfield(\*self, dtype, offset). Return a new array of the given dtype using the data in the current array at a specified offset in bytes. The offset plus the itemsize of the new array type must be less than self->descr->elsize or an error is raised. The same shape and strides as the original array are used. Therefore, this function has the effect of returning a field from a record array. But, it can also be used to select specific bytes or groups of bytes from any array type.

int **PyArray_SetField**(PyArrayObject* \*self, PyArray_Descr* dtype, int offset, PyObject* \*val)

Equivalent to ndarray.setfield(\*self, val, dtype, offset ). Set the field starting at offset in bytes and of the given dtype to val. The offset plus dtype->elsize must be less than self->descr->elsize or an error is raised. Otherwise, the val argument is converted to an array and copied into the field pointed to. If necessary, the elements of val are repeated to fill the destination array. But, the number of elements in the destination must be an integer multiple of the number of elements in val.

PyObject** PyArray_BYTESwap**(PyArrayObject* \*self, Bool inplace)

Equivalent to ndarray.byteswap(\*self, inplace). Return an array whose data area is byteswapped. If inplace is non-zero, then do the byteswap inplace and return a reference to self. Otherwise, create a byteswapped copy and leave self unchanged.

PyObject** PyArray_NewCopy**(PyArrayObject* old, NPY_ORDER order)

Equivalent to ndarray.copy(\*self, fortran). Make a copy of the old array. The returned array is always aligned and writeable with data interpreted as the same as the old array. If order is NPY_CORDER, then a C-style contiguous array is returned. If order is NPY_FORTRANORDER, then a Fortran-style contiguous array is returned. If order is NPY_ANYORDER, then the array returned is Fortran-style contiguous only if the old one is; otherwise, it is C-style contiguous.

PyObject** PyArray_ToList**(PyArrayObject* \*self)

Equivalent to ndarray.tolist(\*self). Return a nested Python list from self.

PyObject** PyArray_ToString**(PyArrayObject* \*self, NPY_ORDER order)

Equivalent to ndarray.tobytes(\*self, order). Return the bytes of this array in a Python string.

PyObject** PyArray_ToFile**(PyArrayObject* \*self, FILE* \*fp, char* sep, char* format)

Write the contents of self to the file pointer \*fp in C-style contiguous fashion. Write the data as binary bytes if sep is the string "" or NULL. Otherwise, write the contents of self as text using the sep string as the item separator. Each item will be printed to the file. If the format string is not NULL or "", then it is a Python print statement format string showing how the items are to be written.

int **PyArray_Dump**(PyObject* \*self, PyObject* \*file, int protocol)

Pickle the object in self to the given file (either a string or a Python file object). If file is a Python string it is considered to be the name of a file which is then opened in binary mode. The given protocol is used (if protocol is negative, or the highest available is used). This is a simple wrapper around cPickle.dump(\*self, \*file, protocol).
PyObject* `PyArray_Dumps` (PyObject* `self`, int `protocol`)
Pick the object in `self` to a Python string and return it. Use the Pickle `protocol` provided (or the highest available if `protocol` is negative).

int `PyArray_FillWithScalar` (PyArrayObject* `arr`, PyObject* `obj`)
Fill the array, `arr`, with the given scalar object, `obj`. The object is first converted to the data type of `arr`, and then copied into every location. A -1 is returned if an error occurs, otherwise 0 is returned.

PyObject* `PyArray_View` (PyArrayObject* `self`, PyArray_Descr* `dtype`, PyTypeObject *`ptype`)
Equivalent to `ndarray.view` (`self`, `dtype`). Return a new view of the array `self` as possibly a different data-type, `dtype`, and different array subclass `ptype`.

If `dtype` is NULL, then the returned array will have the same data type as `self`. The new data-type must be consistent with the size of `self`. Either the itemsizes must be identical, or `self` must be single-segment and the total number of bytes must be the same. In the latter case the dimensions of the returned array will be altered in the last (or first for Fortran-style contiguous arrays) dimension. The data area of the returned array and `self` is exactly the same.

Shape Manipulation

PyObject* `PyArray_Newshape` (PyArrayObject* `self`, PyArray_Dims* `newshape`, NPY_ORDER `order`)
Result will be a new array (pointing to the same memory location as `self` if possible), but having a shape given by `newshape`. If the new shape is not compatible with the strides of `self`, then a copy of the array with the new specified shape will be returned.

PyObject* `PyArray_Reshape` (PyArrayObject* `self`, PyObject* `shape`)
Equivalent to `ndarray.reshape` (`self`, `shape`) where `shape` is a sequence. Converts `shape` to a `PyArray_Dims` structure and calls `PyArray_Newshape` internally. For back-ward compatibility – Not recommended

PyObject* `PyArray_Squeeze` (PyArrayObject* `self`)
Equivalent to `ndarray.squeeze` (`self`). Return a new view of `self` with all of the dimensions of length 1 removed from the shape.

**Warning**: matrix objects are always 2-dimensional. Therefore, `PyArray_Squeeze` has no effect on arrays of matrix sub-class.

PyObject* `PyArray_SwapAxes` (PyArrayObject* `self`, int `a1`, int `a2`)
Equivalent to `ndarray.swapaxes` (`self`, `a1`, `a2`). The returned array is a new view of the data in `self` with the given axes, `a1` and `a2`, swapped.

PyObject* `PyArray_Resize` (PyArrayObject* `self`, PyArray_Dims* `newshape`, int `refcheck`, NPY_ORDER `fortran`)
Equivalent to `ndarray.resize` (`self`, `newshape`, `refcheck = refcheck`, `order = fortran`) . This function only works on single-segment arrays. It changes the shape of `self` inplace and will reallocate the memory for `self` if `newshape` has a different total number of elements then the old shape. If reallocation is necessary, then `self` must own its data, have `self - > base == NULL`, have `self - > weakrefs == NULL`, and (unless `refcheck` is 0) not be referenced by any other array. A reference to the new array is returned. The fortran argument can be NPY_ANYORDER, NPY_CORDER, or NPY_FORTRANORDER. It currently has no effect. Eventually it could be used to determine how the resize operation should view the data when constructing a differently-dimensioned array.

PyObject* `PyArrayTranspose` (PyArrayObject* `self`, PyArray_Dims* `permute`)
Equivalent to `ndarray.transpose` (`self`, `permute`). Permute the axes of the ndarray object `self` according to the data structure `permute` and return the result. If `permute` is NULL, then the resulting array has its axes reversed. For example if `self` has shape 10 x 20 x 30, and `permute`.ptr is (0,2,1) the shape of the result is 10 x 30 x 20. If `permute` is NULL, the shape of the result is 30 x 20 x 10.
NumPy Reference, Release 1.9.2

PyObject* **PyArray_Flatten** (PyArrayObject* *self*, NPY_ORDER *order*)
Equivalent to ndarray.flatten (*self*, *order*). Return a 1-d copy of the array. If *order* is NPY_FORTRANORDER the elements are scanned out in Fortran order (first-dimension varies the fastest). If *order* is NPY_CORDER, the elements of *self* are scanned in C-order (last dimension varies the fastest). If order NPY_ANYORDER, then the result of PyArray_ISFORTRAN (*self*) is used to determine which order to flatten.

PyObject* **PyArray_Ravel** (PyArrayObject* *self*, NPY_ORDER *order*)
Equivalent to *self*.ravel(*order*). Same basic functionality as PyArray_Flatten (*self*, *order*) except if *order* is 0 and *self* is C-style contiguous, the shape is altered but no copy is performed.

**Item selection and manipulation**

PyObject* **PyArray_TakeFrom** (PyArrayObject* *self*, PyObject* *indices*, int *axis*, PyArrayObject* *ret*, NPY_CLIPMODE *clipmode*)
Equivalent to ndarray.take (*self*, *indices*, *axis*, *ret*, *clipmode*) except *axis* =None in Python is obtained by setting *axis* = NPY_MAXDIMS in C. Extract the items from *self* indicated by the integer-valued *indices* along the given *axis*. The clipmode argument can be NPY_RAISE, NPY_WRAP, or NPY_CLIP to indicate what to do with out-of-bound indices. The *ret* argument can specify an output array rather than having one created internally.

PyObject* **PyArray_PutTo** (PyArrayObject* *self*, PyObject* *values*, PyObject* *indices*, NPY_CLIPMODE *clipmode*)
Equivalent to *self*.put(*values*, *indices*, *clipmode*). Put values into *self* at the corresponding (flattened) *indices*. If *values* is too small it will be repeated as necessary.

PyObject* **PyArray_PutMask** (PyArrayObject* *self*, PyObject* *values*, PyObject* *mask*)
Place the *values* in *self* wherever corresponding positions (using a flattened context) in *mask* are true. The *mask* and *self* arrays must have the same total number of elements. If *values* is too small, it will be repeated as necessary.

PyObject* **PyArray_Repeat** (PyArrayObject* *self*, PyObject* *op*, int *axis*)
Equivalent to ndarray.repeat (*self*, *op*, *axis*). Copy the elements of *self* *op* times along the given *axis*. Either *op* is a scalar integer or a sequence of length *self* ->dimensions[ *axis* ] indicating how many times to repeat each item along the axis.

PyObject* **PyArray_Choose** (PyArrayObject* *self*, PyObject* *op*, PyArrayObject* *ret*, NPY_CLIPMODE *clipmode*)
Equivalent to ndarray.choose (*self*, *op*, *ret*, *clipmode*). Create a new array by selecting elements from the sequence of arrays in *op* based on the integer values in *self*. The arrays must all be broadcastable to the same shape and the entries in *self* should be between 0 and len(*op*). The output is placed in *ret* unless it is NULL in which case a new output is created. The *clipmode* argument determines behavior for when entries in *self* are not between 0 and len(*op*).

NPY_RAISE
raise a ValueError;

NPY_WRAP
wrap values < 0 by adding len(*op*) and values >=len(*op*) by subtracting len(*op*) until they are in range;

NPY_CLIP
all values are clipped to the region [0, len(*op*) ].

PyObject* **PyArray_Sort** (PyArrayObject* *self*, int *axis*)
Equivalent to ndarray.sort (*self*, *axis*). Return an array with the items of *self* sorted along *axis*.

PyObject* **PyArray_ArgSort** (PyArrayObject* *self*, int *axis*)
Equivalent to ndarray.argsort (*self*, *axis*). Return an array of indices such that selection of these indices along the given *axis* would return a sorted version of *self*. If *self* ->descr is a data-type with fields defined,
then self->descr->names is used to determine the sort order. A comparison where the first field is equal will use
the second field and so on. To alter the sort order of a record array, create a new data-type with a different order
of names and construct a view of the array with that new data-type.

PyObject* PyArray_LexSort (PyObject* sort_keys, int axis)
Given a sequence of arrays (sort_keys) of the same shape, return an array of indices (similar to
PyArray_ArgSort (...)) that would sort the arrays lexicographically. A lexicographic sort specifies
that when two keys are found to be equal, the order is based on comparison of subsequent keys. A merge
sort (which leaves equal entries unmoved) is required to be defined for the types. The sort is accomplished
by sorting the indices first using the first sort_key and then using the second sort_key and so forth. This is
equivalent to the lexsort(sort_keys, axis) Python command. Because of the way the merge-sort works, be sure
to understand the order the sort_keys must be in (reversed from the order you would use when comparing two
elements).

If these arrays are all collected in a record array, then PyArray_Sort (...) can also be used to sort the array
directly.

PyObject* PyArray_SearchSorted (PyArrayObject* self, PyObject* values)
Equivalent to ndarray.searchsorted (self, values). Assuming self is a 1-d array in ascending order
representing bin boundaries then the output is an array the same shape as values of bin numbers, giving the bin
into which each item in values would be placed. No checking is done on whether or not self is in ascending
order.

int PyArray_Partition (PyArrayObject *self, PyArrayObject * ktharray, int axis,
                      NPY_SELECTKIND which)
Equivalent to ndarray.partition (self, ktharray, axis, kind). Partitions the array so that the values of the
element indexed by ktharray are in the positions they would be if the array is fully sorted and places all elements
smaller than the kth before and all elements equal or greater after the kth element. The ordering of all elements
within the partitions is undefined. If self->descr is a data-type with fields defined, then self->descr->names is
used to determine the sort order. A comparison where the first field is equal will use the second field and so on.
To alter the sort order of a record array, create a new data-type with a different order of names and construct a
view of the array with that new data-type. Returns zero on success and -1 on failure.

PyObject* PyArray_ArgPartition (PyArrayObject *op, PyArrayObject * ktharray, int axis,
                               NPY_SELECTKIND which)
Equivalent to ndarray.argpartition (self, ktharray, axis, kind). Return an array of indices such that
selection of these indices along the given axis would return a partitioned version of self.

PyObject* PyArray_Diagonal (PyArrayObject* self, int offset, int axis1, int axis2)
Equivalent to ndarray.diagonal (self, offset, axis1, axis2 ). Return the offset diagonals of the 2-d arrays
defined by axis1 and axis2.

npy_intp PyArray_CountNonzero (PyArrayObject* self)
New in version 1.6.
Counts the number of non-zero elements in the array object self.

PyObject* PyArray_Nonzero (PyArrayObject* self)
Equivalent to ndarray.nonzero (self). Returns a tuple of index arrays that select elements of self that are
nonzero. If (nd= PyArray_NDIM (self))==1, then a single index array is returned. The index arrays have
data type NPY_INTP. If a tuple is returned (nd \neq 1), then its length is nd.

PyObject* PyArray_Compress (PyArrayObject* self, PyObject* condition, int axis, PyArrayObject* out)
Equivalent to ndarray.compress (self, condition, axis ). Return the elements along axis corresponding to
elements of condition that are true.

Calculation
Tip: Pass in NPY_MAXDIMS for axis in order to achieve the same effect that is obtained by passing in axis = None in Python (treating the array as a 1-d array).

PyObject PyArray_ArgMax (PyArrayObject* self, int axis, PyArrayObject* out)
   Equivalent to ndarray.argmax (self, axis). Return the index of the largest element of self along axis.

PyObject PyArray_ArgMin (PyArrayObject* self, int axis, PyArrayObject* out)
   Equivalent to ndarray.argmin (self, axis). Return the index of the smallest element of self along axis.

Note: The out argument specifies where to place the result. If out is NULL, then the output array is created, otherwise the output is placed in out which must be the correct size and type. A new reference to the output array is always returned even when out is not NULL. The caller of the routine has the responsibility to DECREF out if not NULL or a memory-leak will occur.

PyObject PyArray_Max (PyArrayObject* self, int axis, PyArrayObject* out)
   Equivalent to ndarray.max (self, axis). Return the largest element of self along the given axis.

PyObject PyArray_Min (PyArrayObject* self, int axis, PyArrayObject* out)
   Equivalent to ndarray.min (self, axis). Return the smallest element of self along the given axis.

PyObject PyArray_Ptp (PyArrayObject* self, int axis, PyArrayObject* out)
   Equivalent to ndarray.ptp (self, axis). Return the difference between the largest element of self along axis and the smallest element of self along axis.

Note: The rtype argument specifies the data-type the reduction should take place over. This is important if the data-type of the array is not “large” enough to handle the output. By default, all integer data-types are made at least as large as NPY_LONG for the “add” and “multiply” ufuncs (which form the basis for mean, sum, cumsum, prod, and cumprod functions).

PyObject PyArray_Mean (PyArrayObject* self, int axis, int rtype, PyArrayObject* out)
   Equivalent to ndarray.mean (self, axis, rtype). Returns the mean of the elements along the given axis, using the enumerated type rtype as the data type to sum in. Default sum behavior is obtained using NPY_NOTYPE for rtype.

PyObject PyArray_Trace (PyArrayObject* self, int offset, int axis1, int axis2, int rtype, PyArrayObject* out)
   Equivalent to ndarray.trace (self, offset, axis1, axis2, rtype). Return the sum (using rtype as the data type of summation) over the offset diagonal elements of the 2-d arrays defined by axis1 and axis2 variables. A positive offset chooses diagonals above the main diagonal. A negative offset selects diagonals below the main diagonal.

PyObject PyArray_Clip (PyArrayObject* self, PyObject* min, PyObject* max)
   Equivalent to ndarray.clip (self, min, max). Clip an array, self, so that values larger than max are fixed to max and values less than min are fixed to min.

PyObject PyArray_Conjugate (PyArrayObject* self)
   Equivalent to ndarray.conjugate (self). Return the complex conjugate of self. If self is not of complex data type, then return self with an reference.

PyObject PyArray_Round (PyArrayObject* self, int decimals, PyArrayObject* out)
   Equivalent to ndarray.round (self, decimals, out). Returns the array with elements rounded to the nearest decimal place. The decimal place is defined as the $10^{-\text{decimal}}$ digit so that negative decimals cause rounding to the nearest 10’s, 100’s, etc. If out is NULL, then the output array is created, otherwise the output is placed in out which must be the correct size and type.

PyObject PyArray_Std (PyArrayObject* self, int axis, int rtype, PyArrayObject* out)
   Equivalent to ndarray.std (self, axis, rtype). Return the standard deviation using data along axis converted to data type rtype.
PyObject* PyArray_Sum (PyArrayObject* self, int axis, int rtype, PyArrayObject* out)
Equivalent to ndarray.sum (self, axis, rtype). Return 1-d vector sums of elements in self along axis. Perform the sum after converting data to data type rtype.

PyObject* PyArray_CumSum (PyArrayObject* self, int axis, int rtype, PyArrayObject* out)
Equivalent to ndarray.cumsum (self, axis, rtype). Return cumulative 1-d sums of elements in self along axis. Perform the sum after converting data to data type rtype.

PyObject* PyArray_Prod (PyArrayObject* self, int axis, int rtype, PyArrayObject* out)
Equivalent to ndarray.prod (self, axis, rtype). Return 1-d products of elements in self along axis. Perform the product after converting data to data type rtype.

PyObject* PyArray_CumProd (PyArrayObject* self, int axis, int rtype, PyArrayObject* out)
Equivalent to ndarray.cumprod (self, axis, rtype). Return 1-d cumulative products of elements in self along axis. Perform the product after converting data to data type rtype.

PyObject* PyArray_All (PyArrayObject* self, int axis, PyArrayObject* out)
Equivalent to ndarray.all (self, axis). Return an array with True elements for every 1-d sub-array of self defined by axis in which all the elements are True.

PyObject* PyArray_Any (PyArrayObject* self, int axis, PyArrayObject* out)
Equivalent to ndarray.any (self, axis). Return an array with True elements for every 1-d sub-array of self defined by axis in which any of the elements are True.

5.4.6 Functions

Array Functions

int PyArray_AsCArray (PyObject** op, void* ptr, npy_intp* dims, int nd, int typenum, int itemsize)
Sometimes it is useful to access a multidimensional array as a C-style multi-dimensional array so that algorithms can be implemented using C’s a[i][j][k] syntax. This routine returns a pointer, ptr, that simulates this kind of C-style array, for 1-, 2-, and 3-d ndarrays.

Parameters

- **op** – The address to any Python object. This Python object will be replaced with an equivalent well-behaved, C-style contiguous, ndarray of the given data type specified by the last two arguments. Be sure that stealing a reference in this way to the input object is justified.
- **ptr** – The address to a (ctype* for 1-d, ctype** for 2-d or ctype*** for 3-d) variable where ctype is the equivalent C-type for the data type. On return, ptr will be addressable as a 1-d, 2-d, or 3-d array.
- **dims** – An output array that contains the shape of the array object. This array gives boundaries on any looping that will take place.
- **nd** – The dimensionality of the array (1, 2, or 3).
- **typenum** – The expected data type of the array.
- **itemsize** – This argument is only needed when typenum represents a flexible array. Otherwise it should be 0.

Note: The simulation of a C-style array is not complete for 2-d and 3-d arrays. For example, the simulated arrays of pointers cannot be passed to subroutines expecting specific, statically-defined 2-d and 3-d arrays. To pass to functions requiring those kind of inputs, you must statically define the required array and copy data.
int **PyArray_Free (PyObject *op, void *ptr)
    Must be called with the same objects and memory locations returned from PyArray_AsCArray (...). This function cleans up memory that otherwise would get leaked.

PyObject* PyArray_Concatenate (PyObject* obj, int axis)
    Join the sequence of objects in obj together along axis into a single array. If the dimensions or types are not compatible an error is raised.

PyObject* PyArray_InnerProduct (PyObject* obj1, PyObject* obj2)
    Compute a product-sum over the last dimensions of obj1 and obj2. Neither array is conjugated.

PyObject* PyArray_MatrixProduct (PyObject* obj1, PyObject* obj)
    Compute a product-sum over the last dimension of obj1 and the second-to-last dimension of obj2. For 2-d arrays this is a matrix-product. Neither array is conjugated.

PyObject* PyArray_MatrixProduct2 (PyObject* obj1, PyObject* obj, PyObject* out)
    New in version 1.6.
    Same as PyArray_MatrixProduct, but store the result in out. The output array must have the correct shape, type, and be C-contiguous, or an exception is raised.

PyObject* PyArray_EinsteinSum (char* subscripts, npy_intp *nop, PyArrayObject** op_in,
                                 PyArray_Descr* dtype, NPY_ORDER order, NPY_CASTING casting,
                                 PyArrayObject* out)
    New in version 1.6.
    Applies the einstein summation convention to the array operands provided, returning a new array or placing the result in out. The string in subscripts is a comma separated list of index letters. The number of operands is in nop, and op_in is an array containing those operands. The data type of the output can be forced with dtype, the output order can be forced with order (NPY_KEEPORDER is recommended), and when dtype is specified, casting indicates how permissive the data conversion should be.
    See the einsum function for more details.

PyObject* PyArray_CopyAndTranspose (PyObject *op)
    A specialized copy and transpose function that works only for 2-d arrays. The returned array is a transposed copy of op.

PyObject* PyArray_Correlate (PyObject* op1, PyObject* op2, int mode)
    Compute the 1-d correlation of the 1-d arrays op1 and op2. The correlation is computed at each output point by multiplying op1 by a shifted version of op2 and summing the result. As a result of the shift, needed values outside of the defined range of op1 and op2 are interpreted as zero. The mode determines how many shifts to return: 0 - return only shifts that did not need to assume zero- values; 1 - return an object that is the same size as op1, 2 - return all possible shifts (any overlap at all is accepted).

Notes
    This does not compute the usual correlation: if op2 is larger than op1, the arguments are swapped, and the conjugate is never taken for complex arrays. See PyArray_Correlate2 for the usual signal processing correlation.

PyObject* PyArray_Correlate2 (PyObject* op1, PyObject* op2, int mode)
    Updated version of PyArray_Correlate, which uses the usual definition of correlation for 1d arrays. The correlation is computed at each output point by multiplying op1 by a shifted version of op2 and summing the result. As a result of the shift, needed values outside of the defined range of op1 and op2 are interpreted as zero. The mode determines how many shifts to return: 0 - return only shifts that did not need to assume zero- values; 1 - return an object that is the same size as op1, 2 - return all possible shifts (any overlap at all is accepted).

Notes
    Compute z as follows:
\[ z[k] = \sum_n \text{op1}[n] \times \text{conj}(\text{op2}[n+k]) \]

**PyObject** `PyArray_Where (PyObject* condition, PyObject* x, PyObject* y)`

If both `x` and `y` are NULL, then return `PyArray_Nonzero (condition)`. Otherwise, both `x` and `y` must be given and the object returned is shaped like `condition` and has elements of `x` and `y` where `condition` is respectively True or False.

**Other functions**

_Bool* `PyArray_CheckStrides (int elsise, int nd, npy_intp numbytes, npy_intp* dims, npy_intp* newstrides)`

Determine if `newstrides` is a strides array consistent with the memory of an `nd`-dimensional array with shape `dims` and element-size, `elsize`. The `newstrides` array is checked to see if jumping by the provided number of bytes in each direction will ever mean jumping more than `numbytes` which is the assumed size of the available memory segment. If `numbytes` is 0, then an equivalent `numbytes` is computed assuming `nd`, `dims`, and `elsize` refer to a single-segment array. Return `NPY_TRUE` if `newstrides` is acceptable, otherwise return `NPY_FALSE`.

*npy_intp* `PyArray_MultiplyList (npy_intp* seq, int n)`

Both of these routines multiply an `n`-length array, `seq`, of integers and return the result. No overflow checking is performed.

`int` `PyArray_MultiplyIntList (int* seq, int n)`

`int` `PyArray_CompareLists (npy_intp* l1, npy_intp* l2, int n)`

Given two `n`-length arrays of integers, `l1`, and `l2`, return 1 if the lists are identical; otherwise, return 0.

### 5.4.7 Auxiliary Data With Object Semantics

New in version 1.7.0.

**NpyAuxData**

When working with more complex dtypes which are composed of other dtypes, such as the struct dtype, creating inner loops that manipulate the dtypes requires carrying along additional data. NumPy supports this idea through a struct [NpyAuxData](#), mandating a few conventions so that it is possible to do this.

Defining an [NpyAuxData](#) is similar to defining a class in C++, but the object semantics have to be tracked manually since the API is in C. Here’s an example for a function which doubles up an element using an element copier function as a primitive:

```c
typedef struct {
    NpyAuxData base;
    ElementCopier_Func *func;
    NpyAuxData *funcdata;
} eldoubler_aux_data;

void free_element_doubler_aux_data(NpyAuxData *data)
{
    eldoubler_aux_data *d = (eldoubler_aux_data *)data;
    /* Free the memory owned by this auxdata */
    NPY_AUXDATA_FREE(d->funcdata);
    PyArray_free(d);
}

NpyAuxData *clone_element_doubler_aux_data(NpyAuxData *data)
```

5.4. Array API
eldoubler_aux_data *ret = PyArray_malloc(sizeof(eldoubler_aux_data));
if (ret == NULL) {
    return NULL;
}
/* Raw copy of all data */
memcpy(ret, data, sizeof(eldoubler_aux_data));
/* Fix up the owned auxdata so we have our own copy */
ret->funcdata = NPY_AUXDATA_CLONE(ret->funcdata);
if (ret->funcdata == NULL) {
    PyArray_free(ret);
    return NULL;
}
return (NpyAuxData *)ret;

NpyAuxData *create_element_doubler_aux_data(
ElementCopier_Func *func,
NpyAuxData *funcdata)
{
eldoubler_aux_data *ret = PyArray_malloc(sizeof(eldoubler_aux_data));
if (ret == NULL) {
    PyErr_NoMemory();
    return NULL;
}
memset(&ret, 0, sizeof(eldoubler_aux_data));
ret->base->free = &free_element_doubler_aux_data;
ret->base->clone = &clone_element_doubler_aux_data;
ret->func = func;
ret->funcdata = funcdata;
return (NpyAuxData *)ret;
}

NpyAuxData_FreeFunc
The function pointer type for NpyAuxData free functions.

NpyAuxData_CloneFunc
The function pointer type for NpyAuxData clone functions. These functions should never set the Python exception on error, because they may be called from a multi-threaded context.

NPY_AUXDATA_FREE (auxdata)
A macro which calls the auxdata’s free function appropriately, does nothing if auxdata is NULL.

NPY_AUXDATA_CLONE (auxdata)
A macro which calls the auxdata’s clone function appropriately, returning a deep copy of the auxiliary data.

5.4.8 Array Iterators
As of Numpy 1.6, these array iterators are superceded by the new array iterator, NpyIter.
An array iterator is a simple way to access the elements of an N-dimensional array quickly and efficiently. Section 2 provides more description and examples of this useful approach to looping over an array.

PyObject* PyArray_IterNew (PyObject* arr)
Return an array iterator object from the array, `arr`. This is equivalent to `arr.flat`. The array iterator object makes it easy to loop over an N-dimensional non-contiguous array in C-style contiguous fashion.

```python
PyObject* PyArray_IterAllButAxis(PyObject* arr, int* axis)
```

Return an array iterator that will iterate over all axes but the one provided in `*axis`. The returned iterator cannot be used with `PyArray_ITER_GOTO1D`. This iterator could be used to write something similar to what ufuncs do wherein the loop over the largest axis is done by a separate sub-routine. If `*axis` is negative then `*axis` will be set to the axis having the smallest stride and that axis will be used.

```python
PyObject * PyArray_BroadcastToShape (PyObject* arr, npy_intp *dimensions, int nd)
```

Return an array iterator that is broadcast to iterate as an array of the shape provided by `dimensions` and `nd`.

```python
int PyArrayIter_Check (PyObject* op)
```

Evaluates true if `op` is an array iterator (or instance of a subclass of the array iterator type).

```python
void PyArray_ITER_RESET (PyObject* iterator)
```

Reset an iterator to the beginning of the array.

```python
void PyArray_ITER_NEXT (PyObject* iterator)
```

Increment the index and the dataptr members of the iterator to point to the next element of the array. If the array is not (C-style) contiguous, also increment the N-dimensional coordinates array.

```python
void * PyArray_ITER_DATA (PyObject* iterator)
```

A pointer to the current element of the array.

```python
void PyArray_ITER_GOTO (PyObject* iterator, npy_intp* destination)
```

Set the iterator index, dataptr, and coordinates members to the location in the array indicated by the N-dimensional c-array, `destination`, which must have size at least `iterator->nd_m1+1`.

```python
PyArray_ITER_GOTO1D (PyObject* iterator, npy_intp index)
```

Set the iterator index and dataptr to the location in the array indicated by the integer `index` which points to an element in the C-styled flattened array.

```python
int PyArray_ITER_NOTDONE (PyObject* iterator)
```

Evaluates TRUE as long as the iterator has not looped through all of the elements, otherwise it evaluates FALSE.

### 5.4.9 Broadcasting (multi-iterators)

```python
PyObject* PyArray_MultiIterNew (int num, ...)
```

A simplified interface to broadcasting. This function takes the number of arrays to broadcast and then `num` extra (`PyObject *`) arguments. These arguments are converted to arrays and iterators are created. `PyArray_Broadcast` is then called on the resulting multi-iterator object. The resulting, broadcasted multi-iterator object is then returned. A broadcasted operation can then be performed using a single loop and using `PyArray_MultiIter_NEXT()`.

```python
void PyArray_MultiIter_RESET (PyObject* multi)
```

Reset all the iterators to the beginning in a multi-iterator object, `multi`.

```python
void PyArray_MultiIter_NEXT (PyObject* multi)
```

Advance each iterator in a multi-iterator object, `multi`, to its next (broadcasted) element.

```python
void * PyArray_MultiIter_DATA (PyObject* multi, int i)
```

Return the data-pointer of the `i`th iterator in a multi-iterator object.

```python
void PyArray_MultiIter_NEXTi (PyObject* multi, int i)
```

Advance the pointer of only the `i`th iterator.

```python
void PyArray_MultiIter_GOTO (PyObject* multi, npy_intp* destination)
```

Advance each iterator in a multi-iterator object, `multi`, to the given `N`-dimensional `destination` where `N` is the number of dimensions in the broadcasted array.

### 5.4. Array API
void **PyArray_MultiIter_GOTO1D** (PyObject* multi, npy_intp index)

Advance each iterator in a multi-iterator object, multi, to the corresponding location of the index into the flattened broadcasted array.

int **PyArray_MultiIter_NOTDONE** (PyObject* multi)

Evaluates TRUE as long as the multi-iterator has not looped through all of the elements (of the broadcasted result), otherwise it evaluates FALSE.

int **PyArray_Broadcast** (PyArrayMultiIterObject* mit)

This function encapsulates the broadcasting rules. The mit container should already contain iterators for all the arrays that need to be broadcast. On return, these iterators will be adjusted so that iteration over each simultaneously will accomplish the broadcasting. A negative number is returned if an error occurs.

int **PyArray_RemoveSmallest** (PyArrayMultiIterObject* mit)

This function takes a multi-iterator object that has been previously “broadcasted,” finds the dimension with the smallest “sum of strides” in the broadcasted result and adapt all the iterators so as not to iterate over that dimension (by effectively making them of length-1 in that dimension). The corresponding dimension is returned unless mit ->nd is 0, then -1 is returned. This function is useful for constructing ufunc-like routines that broadcast their inputs correctly and then call a strided 1-d version of the routine as the inner-loop. This 1-d version is usually optimized for speed and for this reason the loop should be performed over the axis that won’t require large stride jumps.

### 5.4.10 Neighborhood iterator

New in version 1.4.0.

Neighborhood iterators are subclasses of the iterator object, and can be used to iter over a neighborhood of a point. For example, you may want to iterate over every voxel of a 3d image, and for every such voxel, iterate over an hypercube. Neighborhood iterator automatically handle boundaries, thus making this kind of code much easier to write than manual boundaries handling, at the cost of a slight overhead.

PyObject* **PyArray_NeighborhoodIterNew** (PyArrayIterObject* iter, npy_intp bounds, int mode, PyArrayObject* fill_value)

This function creates a new neighborhood iterator from an existing iterator. The neighborhood will be computed relatively to the position currently pointed by iter, the bounds define the shape of the neighborhood iterator, and the mode argument the boundaries handling mode.

The bounds argument is expected to be a (2 * iter->ao->nd) arrays, such as the range bound[2*i] -> bounds[2*i+1] defines the range where to walk for dimension i (both bounds are included in the walked coordinates). The bounds should be ordered for each dimension (bounds[2*i] <= bounds[2*i+1]).

The mode should be one of:

- **NPY_NEIGHBORHOOD_ITER_ZERO_PADDING**: zero padding. Outside bounds values will be 0.
- **NPY_NEIGHBORHOOD_ITER_ONE_PADDING**: one padding. Outside bounds values will be 1.
- **NPY_NEIGHBORHOOD_ITER_CONSTANT_PADDING**: constant padding. Outside bounds values will be the same as the first item in fill_value.
- **NPY_NEIGHBORHOOD_ITER_MIRROR_PADDING**: mirror padding. Outside bounds values will be as if the array items were mirrored. For example, for the array [1, 2, 3, 4], x[-2] will be 2, x[-2] will be 1, x[4] will be 4, x[5] will be 1, etc...
- **NPY_NEIGHBORHOOD_ITER_CIRCULAR_PADDING**: circular padding. Outside bounds values will be as if the array was repeated. For example, for the array [1, 2, 3, 4], x[-2] will be 3, x[-2] will be 4, x[4] will be 1, x[5] will be 2, etc...
If the mode is constant filling (NPY_NEIGHBORHOOD_ITER_CONSTANT_PADDING), fill_value should point to an array object which holds the filling value (the first item will be the filling value if the array contains more than one item). For other cases, fill_value may be NULL.

- The iterator holds a reference to iter
- Return NULL on failure (in which case the reference count of iter is not changed)
- iter itself can be a Neighborhood iterator: this can be useful for e.g automatic boundaries handling
- the object returned by this function should be safe to use as a normal iterator
- If the position of iter is changed, any subsequent call to PyArrayNeighborhoodIter_Next is undefined behavior, and PyArrayNeighborhoodIter_Reset must be called.

```python
PyArrayIterObject \*iter;
PyArrayNeighborhoodIterObject \*neigh_iter;
iter = PyArray_IterNew(x);
//For a 3x3 kernel
bounds = {-1, 1, -1, 1};
neigh_iter = (PyArrayNeighborhoodIterObject*)PyArrayNeighborhoodIter_New(
    iter, bounds, NPY_NEIGHBORHOOD_ITER_ZERO_PADDING, NULL);
for(i = 0; i < iter->size; ++i) {
    for (j = 0; j < neigh_iter->size; ++j) {
        // Walk around the item currently pointed by iter->dataptr
        PyArrayNeighborhoodIter_Next(neigh_iter);
    }
    // Move to the next point of iter
    PyArrayIter_Next(iter);
    PyArrayNeighborhoodIter_Reset(neigh_iter);
}
```

```python
int PyArrayNeighborhoodIter_Reset (PyArrayNeighborhoodIterObject* iter)
    Reset the iterator position to the first point of the neighborhood. This should be called whenever the iter argument given at PyArray_NeighborhoodIterObject is changed (see example)

int PyArrayNeighborhoodIter_Next (PyArrayNeighborhoodIterObject* iter)
    After this call, iter->dataptr points to the next point of the neighborhood. Calling this function after every point of the neighborhood has been visited is undefined.
```

### 5.4.11 Array Scalars

**PyObject* PyArray_Return (PyArrayObject* arr)**

This function checks to see if *arr* is a 0-dimensional array and, if so, returns the appropriate array scalar. It should be used whenever 0-dimensional arrays could be returned to Python.

**PyObject* PyArray_Scalar (void* data, PyArray_Descr* dtype, PyObject* itemsize)**

Return an array scalar object of the given enumerated typenum and itemsize by copying from memory pointed to by data. If swap is nonzero then this function will byteswap the data if appropriate to the data-type because array scalars are always in correct machine-byte order.

**PyObject* PyArray_ToScalar (void* data, PyArrayObject* arr)**

Return an array scalar object of the type and itemsize indicated by the array object *arr* copied from the memory pointed to by data and swapping if the data in *arr* is not in machine byte-order.

5.4. Array API
PyObject* PyArray_FromScalar (PyObject* scalar, PyArray_Descr* outcode)

Return a 0-dimensional array of type determined by outcode from scalar which should be an array-scalar object. If outcode is NULL, then the type is determined from scalar.

void PyArray_ScalarAsCtype (PyObject* scalar, void* ctypeptr)

Return in ctypeptr a pointer to the actual value in an array scalar. There is no error checking so scalar must be an array-scalar object, and ctypeptr must have enough space to hold the correct type. For flexible-sized types, a pointer to the data is copied into the memory of ctypeptr, for all other types, the actual data is copied into the address pointed to by ctypeptr.

void PyArray_CastScalarToCtype (PyObject* scalar, void* ctypeptr, PyArray_Descr* outcode)

Return the data (cast to the data type indicated by outcode) from the array-scalar, scalar, into the memory pointed to by ctypeptr (which must be large enough to handle the incoming memory).

PyObject* PyArray_TypeObjectFromType (int type)

Returns a scalar type-object from a type-number, type. Equivalent to PyArray_DescrFromType (type)->typeobj except for reference counting and error-checking. Returns a new reference to the typeobject on success or NULL on failure.

NPY_SCALARKIND PyArray_ScalarKind (int typenum, PyArrayObject** arr)

See the function PyArray_MinScalarType for an alternative mechanism introduced in NumPy 1.6.0.

Return the kind of scalar represented by typenum and the array in *arr (if arr is not NULL). The array is assumed to be rank-0 and only used if typenum represents a signed integer. If arr is not NULL and the first element is negative then NPY_INTNEG_SCALAR is returned, otherwise NPY_INTPOS_SCALAR is returned. The possible return values are NPY_{kind}_SCALAR where {kind} can be INTPOS, INTNEG, FLOAT, COMPLEX, BOOL, or OBJECT. NPY_NOSCALAR is also an enumerated value NPY_SCALARKIND variables can take on.

int PyArray_CanCoerceScalar (char thistype, char neededtype, NPY_SCALARKIND scalar)

See the function PyArray_ResultType for details of NumPy type promotion, updated in NumPy 1.6.0.

Implements the rules for scalar coercion. Scalars are only silently coerced from thistype to needed-type if this function returns nonzero. If scalar is NPY_NOSCALAR, then this function is equivalent to PyArray_CanCastSafely. The rule is that scalars of the same KIND can be coerced into arrays of the same KIND. This rule means that high-precision scalars will never cause low-precision arrays of the same KIND to be upcast.

5.4.12 Data-type descriptors

Warning: Data-type objects must be reference counted so be aware of the action on the data-type reference of different C-API calls. The standard rule is that when a data-type object is returned it is a new reference. Functions that take PyArray_Descr * objects and return arrays steal references to the data-type their inputs unless otherwise noted. Therefore, you must own a reference to any data-type object used as input to such a function.

int PyArray_DescrCheck (PyObject* obj)

Evaluates as true if obj is a data-type object (PyArray_Descr *).

PyArray_Descr* PyArray_DescrNew (PyArray_Descr* obj)

Return a new data-type object copied from obj (the fields reference is just updated so that the new object points to the same fields dictionary if any).

PyArray_Descr* PyArray_DescrNewFromType (int typenum)

Create a new data-type object from the built-in (or user-registered) data-type indicated by typenum. All builtin types should not have any of their fields changed. This creates a new copy of the PyArray_Descr structure.
so that you can fill it in as appropriate. This function is especially needed for flexible data-types which need to have a new elsize member in order to be meaningful in array construction.

**PyArray_Descr** PyArray_DescrNewByteorder (PyArray_Descr* obj, char newendian)

Create a new data-type object with the byteorder set according to newendian. All referenced data-type objects (in subdescr and fields members of the data-type object) are also changed (recursively). If a byteorder of NPY_IGNORE is encountered it is left alone. If newendian is NPY_SWAP, then all byte-orders are swapped. Other valid newendian values are NPY_NATIVE, NPY_LITTLE, and NPY_BIG which all cause the returned data-typed descriptor (and all its referenced data-type descriptors) to have the corresponding byte-order.

**PyArray_Descr** PyArray_DescrFromObject (PyObject* op, PyArray_Descr* mintype)

Determine an appropriate data-type object from the object op (which should be a “nested” sequence object) and the minimum data-type descriptor mintype (which can be NULL). Similar in behavior to array(op).dtype. Don’t confuse this function with PyArray_DescrConverter. This function essentially looks at all the objects in the (nested) sequence and determines the data-type from the elements it finds.

**PyArray_Descr** PyArray_DescrFromScalar (PyObject* scalar)

Return a data-type object from an array-scalar object. No checking is done to be sure that scalar is an array scalar. If no suitable data-type can be determined, then a data-type of NPY_OBJECT is returned by default.

**PyArray_Descr** PyArray_DescrFromType (int typenum)

Returns a data-type object corresponding to typenum. The typenum can be one of the enumerated types, a character code for one of the enumerated types, or a user-defined type.

int PyArray_DescrConverter (PyObject* obj, PyArray_Descr** dtype)

Convert any compatible Python object, obj, to a data-type object in dtype. A large number of Python objects can be converted to data-type objects. See Data type objects (dtype) for a complete description. This version of the converter converts None objects to a NPY_DEFAULT_TYPE data-type object. This function can be used with the “O&” character code in PyArg_ParseTuple processing.

int PyArray_DescrConverter2 (PyObject* obj, PyArray_Descr** dtype)

Convert any compatible Python object, obj, to a data-type object in dtype. This version of the converter converts None objects so that the returned data-type is NULL. This function can also be used with the “O&” character in PyArg_ParseTuple processing.

int PyArray_DescrAlignConverter (PyObject* obj, PyArray_Descr** dtype)

Like PyArray_DescrConverter except it aligns C-struct-like objects on word-boundaries as the compiler would.

int PyArray_DescrAlignConverter2 (PyObject* obj, PyArray_Descr** dtype)

Like PyArray_DescrConverter2 except it aligns C-struct-like objects on word-boundaries as the compiler would.

PyObject *PyArray_FieldNames (PyObject* dict)

Take the fields dictionary, dict, such as the one attached to a data-type object and construct an ordered-list of field names as is stored in the names field of the PyArray_Descr object.

### 5.4.13 Conversion Utilities

**For use with PyArg_ParseTuple**

All of these functions can be used in PyArg_ParseTuple (...) with the “O&” format specifier to automatically convert any Python object to the required C-object. All of these functions return NPY_SUCCEED if successful and NPY_FAIL if not. The first argument to all of these function is a Python object. The second argument is the address of the C-type to convert the Python object to.

---

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Warning: Be sure to understand what steps you should take to manage the memory when using these conversion functions. These functions can require freeing memory, and/or altering the reference counts of specific objects based on your use.

int PyArray_Converter (PyObject* obj, PyObject** address)
Convert any Python object to a PyArrayObject. If PyArray_Check (obj) is TRUE then its reference count is incremented and a reference placed in address. If obj is not an array, then convert it to an array using PyArray_FromAny. No matter what is returned, you must DECREF the object returned by this routine in address when you are done with it.

int PyArray_OutputConverter (PyObject* obj, PyArrayObject** address)
This is a default converter for output arrays given to functions. If obj is Py_None or NULL, then *address will be NULL but the call will succeed. If PyArray_Check (obj) is TRUE then it is returned in *address without incrementing its reference count.

int PyArray_IntpConverter (PyObject* obj, PyArray_Dims* seq)
Convert any Python sequence, obj, smaller than NPY_MAXDIMS to a C-array of npy_intp. The Python object could also be a single number. The seq variable is a pointer to a structure with members ptr and len. On successful return, seq->ptr contains a pointer to memory that must be freed to avoid a memory leak. The restriction on memory size allows this converter to be conveniently used for sequences intended to be interpreted as array shapes.

int PyArray_BufferConverter (PyObject* obj, PyArray_Chunk* buf)
Convert any Python object, obj, with a (single-segment) buffer interface to a variable with members that detail the object’s use of its chunk of memory. The buf variable is a pointer to a structure with members ptr and len. On return, the base member is set to obj (or its base if obj is already a buffer object pointing to another object). If you need to hold on to the memory be sure to INCREF the base member. The chunk of memory is pointed to by buf->ptr member and has length buf->len. The flags member of buf is NPY_BEHAVED_RO with the NPY_ARRAY_WRITEABLE flag set if obj has a writeable buffer interface.

int PyArray_AxisConverter (PyObject *obj, int* axis)
Convert a Python object, obj, representing an axis argument to the proper value for passing to the functions that take an integer axis. Specifically, if obj is None, axis is set to NPY_MAXDIMS which is interpreted correctly by the C-API functions that take axis arguments.

int PyArray_BoolConverter (PyObject* obj, Bool* value)
Convert any Python object, obj, to NPY_TRUE or NPY_FALSE, and place the result in value.

int PyArray_ByteorderConverter (PyObject* obj, char* endian)

int PyArray_SortkindConverter (PyObject* obj, NPY_SORTKIND* sort)
Convert Python strings into one of NPY_QUICKSORT (starts with ‘q’ or ‘Q’), NPY_HEAPSORT (starts with ‘h’ or ‘H’), or NPY_MERGESORT (starts with ‘m’ or ‘M’).

int PyArray_SearchsideConverter (PyObject* obj, NPY_SEARCHSIDE* side)
Convert Python strings into one of NPY_SEARCHLEFT (starts with ‘l’ or ‘L’), or NPY_SEARCHRIGHT (starts with ‘r’ or ‘R’).

int PyArray_OrderConverter (PyObject* obj, NPY_ORDER* order)
Convert the Python strings ‘C’, ‘F’, ‘A’, and ‘K’ into the NPY_ORDER enumeration NPY_CORDER, NPY_FORTRANORDER, NPY_ANYORDER, and NPY_KEEPORDER.

int PyArray_CastingConverter (PyObject* obj, NPY_CASTING* casting)
Convert the Python strings ‘no’, ‘equiv’, ‘safe’, ‘same_kind’, and ‘unsafe’ into the NPY_CASTING enumeration NPY_NO_CASTING, NPY_EQUIV_CASTING, NPY_SAFE_CASTING, NPYSAME_KIND_CASTING,
int PyArray_ClipmodeConverter (PyObject* object, NPY_CLIPMODE* val)

Convert the Python strings ‘clip’, ‘wrap’, and ‘raise’ into the NPY_CLIPMODE enumeration NPY_CLIP, NPY_WRAP, and NPY_RAISE.

int PyArray_ConvertClipmodeSequence (PyObject* object, NPY_CLIPMODE* modes, int n)

Converts either a sequence of clipmodes or a single clipmode into a C array of NPY_CLIPMODE values. The number of clipmodes n must be known before calling this function. This function is provided to help functions allow a different clipmode for each dimension.

Other conversions

int PyArray_PyIntAsInt (PyObject* op)

Convert all kinds of Python objects (including arrays and array scalars) to a standard integer. On error, -1 is returned and an exception set. You may find useful the macro:

#define error_converting(x) (((x) == -1) && PyErr_Occurred())

npy_intp PyArray_PyIntAsIntp (PyObject* op)

Convert all kinds of Python objects (including arrays and array scalars) to a (platform-pointer-sized) integer. On error, -1 is returned and an exception set.

int PyArray_IntpFromSequence (PyObject* seq, npy_intp* vals, int maxvals)

Convert any Python sequence (or single Python number) passed in as seq to (up to) maxvals pointer-sized integers and place them in the vals array. The sequence can be smaller then maxvals as the number of converted objects is returned.

int PyArray_TypestrConvert (int itemsize, int gentype)

Convert typestring characters (with itemsize) to basic enumerated data types. The typestring character corresponding to signed and unsigned integers, floating point numbers, and complex-floating point numbers are recognized and converted. Other values of gentype are returned. This function can be used to convert, for example, the string ‘f4’ to NPY_FLOAT32.

5.4.14 Miscellaneous

Importing the API

In order to make use of the C-API from another extension module, the import_array() command must be used. If the extension module is self-contained in a single .c file, then that is all that needs to be done. If, however, the extension module involves multiple files where the C-API is needed then some additional steps must be taken.

void import_array (void)

This function must be called in the initialization section of a module that will make use of the C-API. It imports the module where the function-pointer table is stored and points the correct variable to it.

PY_ARRAY_UNIQUE_SYMBOL

NO_IMPORT_ARRAY

Using these #defines you can use the C-API in multiple files for a single extension module. In each file you must define PY_ARRAY_UNIQUE_SYMBOL to some name that will hold the C-API (e.g. myextension_ARRAY_API). This must be done before including the numpy/arrayobject.h file. In the module initialization routine you call import_array(). In addition, in the files that do not have the module initialization sub_routine define NO_IMPORT_ARRAY prior to including numpy/arrayobject.h.
Suppose I have two files coolmodule.c and coolhelper.c which need to be compiled and linked into a single extension module. Suppose coolmodule.c contains the required initcool module initialization function (with the import_array() function called). Then, coolmodule.c would have at the top:

```c
#define PY_ARRAY_UNIQUE_SYMBOL cool_ARRAY_API
#include numpy/arrayobject.h
```

On the other hand, coolhelper.c would contain at the top:

```c
#define NO_IMPORT_ARRAY
#define PY_ARRAY_UNIQUE_SYMBOL cool_ARRAY_API
#include numpy/arrayobject.h
```

You can also put the common two last lines into an extension-local header file as long as you make sure that NO_IMPORT_ARRAY is #defined before #including that file.

### Checking the API Version

Because python extensions are not used in the same way as usual libraries on most platforms, some errors cannot be automatically detected at build time or even runtime. For example, if you build an extension using a function available only for numpy >= 1.3.0, and you import the extension later with numpy 1.2, you will not get an import error (but almost certainly a segmentation fault when calling the function). That’s why several functions are provided to check for numpy versions. The macros `NPY_VERSION` and `NPY_FEATURE_VERSION` corresponds to the numpy version used to build the extension, whereas the versions returned by the functions `PyArray_GetNDArrayCVersion` and `PyArray_GetNDArrayCFeatureVersion` corresponds to the runtime numpy’s version.

The rules for ABI and API compatibilities can be summarized as follows:

- Whenever `NPY_VERSION` != `PyArray_GetNDArrayCVersion`, the extension has to be recompiled (ABI incompatibility).
- `NPY_VERSION` == `PyArray_GetNDArrayCVersion` and `NPY_FEATURE_VERSION` <= `PyArray_GetNDArrayCFeatureVersion` means backward compatible changes.

ABI incompatibility is automatically detected in every numpy’s version. API incompatibility detection was added in numpy 1.4.0. If you want to supported many different numpy versions with one extension binary, you have to build your extension with the lowest `NPY_FEATURE_VERSION` as possible.

```c
unsigned int PyArray_GetNDArrayCVersion (void)
```

This just returns the value `NPY_VERSION`. `NPY_VERSION` changes whenever a backward incompatible change at the ABI level. Because it is in the C-API, however, comparing the output of this function from the value defined in the current header gives a way to test if the C-API has changed thus requiring a re-compilation of extension modules that use the C-API. This is automatically checked in the function `import_array`.

```c
unsigned int PyArray_GetNDArrayCFeatureVersion (void)
```

New in version 1.4.0.

This just returns the value `NPY_FEATURE_VERSION`. `NPY_FEATURE_VERSION` changes whenever the API changes (e.g. a function is added). A changed value does not always require a recompile.

### Internal Flexibility

```c
int PyArray_SetNumericOps (PyObject* dict)
```

NumPy stores an internal table of Python callable objects that are used to implement arithmetic operations for arrays as well as certain array calculation methods. This function allows the user to replace any or all of these Python objects with their own versions. The keys of the dictionary, `dict`, are the named functions to replace and the paired value is the Python callable object to use. Care should be taken that the function used to replace an
internal array operation does not itself call back to that internal array operation (unless you have designed the
function to handle that), or an unchecked infinite recursion can result (possibly causing program crash). The
key names that represent operations that can be replaced are:

add, subtract, multiply, divide, remainder, power, square, reciprocal, ones_like, sqrt, negative,
absolute, invert, left_shift, right_shift, bitwise_and, bitwise_xor, bitwise_or, less, less_equal,
equal, not_equal, greater, greater_equal, floor_divide, true_divide, logical_or, logical_and,
floor, ceil, maximum, minimum, rint.

These functions are included here because they are used at least once in the array object’s methods. The function
returns -1 (without setting a Python Error) if one of the objects being assigned is not callable.

PyObject* PyArray_GetNumericOps (void)
Return a Python dictionary containing the callable Python objects stored in the the internal arithmetic operation
table. The keys of this dictionary are given in the explanation for PyArray_SetNumericOps.

void PyArray_SetStringFunction (PyObject* op, int repr)
This function allows you to alter the tp_str and tp_repr methods of the array object to any Python function. Thus
you can alter what happens for all arrays when str(arr) or repr(arr) is called from Python. The function to be
called is passed in as op. If repr is non-zero, then this function will be called in response to repr(arr), otherwise
the function will be called in response to str(arr). No check on whether or not op is callable is performed. The
callable passed in to op should expect an array argument and should return a string to be printed.

Memory management

char* PyDataMem_NEW (size_t nbytes)

PyDataMem_FREE (char* ptr)

char* PyDataMem_RENEW (void* ptr, size_t newbytes)
Macros to allocate, free, and reallocate memory. These macros are used internally to create arrays.
npy_intp* PyDimMem_NEW (nd)

PyDimMem_FREE (npy_intp* ptr)

npy_intp* PyDimMem_RENEW (npy_intp* ptr, npy_intp newnd)
Macros to allocate, free, and reallocate dimension and strides memory.

PyArray_malloc (nbytes)

PyArray_free (ptr)

PyArray_realloc (ptr, nbytes)
These macros use different memory allocators, depending on the constant NPY_USE_PYMEM. The system
malloc is used when NPY_USE_PYMEM is 0, if NPY_USE_PYMEM is 1, then the Python memory allocator is used.

Threading support

These macros are only meaningful if NPY_ALLOW_THREADS evaluates True during compilation of the extension
module. Otherwise, these macros are equivalent to whitespace. Python uses a single Global Interpreter Lock (GIL)
for each Python process so that only a single thread may execute at a time (even on multi-cpu machines).
calling out to a compiled function that may take time to compute (and does not have side-effects for other threads like
updated global variables), the GIL should be released so that other Python threads can run while the time-consuming
calculations are performed. This can be accomplished using two groups of macros. Typically, if one macro in a group
is used in a code block, all of them must be used in the same code block. Currently, \texttt{NPY\_ALLOW\_THREADS} is
defined to the python-defined \texttt{WITH\_THREADS} constant unless the environment variable \texttt{NPY\_NOSMP} is set in which
case \texttt{NPY\_ALLOW\_THREADS} is defined to be 0.

**Group 1**

This group is used to call code that may take some time but does not use any Python C-API calls. Thus,
the GIL should be released during its calculation.

\begin{verbatim}
NPY\_BEGIN\_ALLOW\_THREADS
Equivalent to \texttt{Py\_BEGIN\_ALLOW\_THREADS} except it uses \texttt{NPY\_ALLOW\_THREADS} to determine
if the macro if replaced with white-space or not.
\end{verbatim}

\begin{verbatim}
NPY\_END\_ALLOW\_THREADS
Equivalent to \texttt{Py\_END\_ALLOW\_THREADS} except it uses \texttt{NPY\_ALLOW\_THREADS} to determine if
the macro if replaced with white-space or not.
\end{verbatim}

\begin{verbatim}
NPY\_BEGIN\_THREADS\_DEF
Place in the variable declaration area. This macro sets up the variable needed for storing the Python
state.
\end{verbatim}

\begin{verbatim}
NPY\_BEGIN\_THREADS
Place right before code that does not need the Python interpreter (no Python C-API calls). This
macro saves the Python state and releases the GIL.
\end{verbatim}

\begin{verbatim}
NPY\_END\_THREADS
Place right after code that does not need the Python interpreter. This macro acquires the GIL and
restores the Python state from the saved variable.
\end{verbatim}

\begin{verbatim}
NPY\_BEGIN\_THREADS\_DESCR \texttt{(PyArray\_Descr \*dtype)}
Useful to release the GIL only if \texttt{dtype} does not contain arbitrary Python objects which may need
the Python interpreter during execution of the loop. Equivalent to
\end{verbatim}

\begin{verbatim}
NPY\_END\_THREADS\_DESCR \texttt{(PyArray\_Descr \*dtype)}
Useful to regain the GIL in situations where it was released using the BEGIN form of this macro.
\end{verbatim}

**Group 2**

This group is used to re-acquire the Python GIL after it has been released. For example, suppose the
GIL has been released (using the previous calls), and then some path in the code (perhaps in a different
subroutine) requires use of the Python C-API, then these macros are useful to acquire the GIL. These
macros accomplish essentially a reverse of the previous three (acquire the LOCK saving what state it had)
and then re-release it with the saved state.

\begin{verbatim}
NPY\_ALLOW\_C\_API\_DEF
Place in the variable declaration area to set up the necessary variable.
\end{verbatim}

\begin{verbatim}
NPY\_ALLOW\_C\_API
Place before code that needs to call the Python C-API (when it is known that the GIL has already
been released).
\end{verbatim}

\begin{verbatim}
NPY\_DISABLE\_C\_API
Place after code that needs to call the Python C-API (to re-release the GIL).
\end{verbatim}

**Tip:** Never use semicolons after the threading support macros.
Priority

**NPY_PRIORITY**
Default priority for arrays.

**NPY_SUBTYPE_PRIORITY**
Default subtype priority.

**NPY_SCALAR_PRIORITY**
Default scalar priority (very small)

double *PyArray_GetPriority*(PyObject* obj, double def)

Return the __array_priority__ attribute (converted to a double) of obj or def if no attribute of that name exists. Fast returns that avoid the attribute lookup are provided for objects of type PyArray_Type.

Default buffers

**NPY_BUFSIZE**
Default size of the user-settable internal buffers.

**NPY_MIN_BUFSIZE**
Smallest size of user-settable internal buffers.

**NPY_MAX_BUFSIZE**
Largest size allowed for the user-settable buffers.

Other constants

**NPY_NUM_FLOATTYPE**
The number of floating-point types

**NPY_MAXDIMS**
The maximum number of dimensions allowed in arrays.

**NPY_VERSION**
The current version of the ndarray object (check to see if this variable is defined to guarantee the numpy/arrayobject.h header is being used).

**NPY_FALSE**
Defined as 0 for use with Bool.

**NPY_TRUE**
Defined as 1 for use with Bool.

**NPY_FAIL**
The return value of failed converter functions which are called using the “O&” syntax in PyArg_ParseTuple-like functions.

**NPY_SUCCEED**
The return value of successful converter functions which are called using the “O&” syntax in PyArg_ParseTuple-like functions.

Miscellaneous Macros

**PyArray_SAMESHAPE** (a1, a2)
Evaluates as True if arrays a1 and a2 have the same shape.
PyArray_MAX (a, b)
   Returns the maximum of \(a\) and \(b\). If \((a)\) or \((b)\) are expressions they are evaluated twice.

PyArray_MIN (a, b)
   Returns the minimum of \(a\) and \(b\). If \((a)\) or \((b)\) are expressions they are evaluated twice.

PyArray_CLT (a, b)

PyArray_CGT (a, b)

PyArray_CLE (a, b)

PyArray_CGE (a, b)

PyArray_CEQ (a, b)

PyArray_CNE (a, b)
   Implements the complex comparisons between two complex numbers (structures with a real and imag member) using NumPy’s definition of the ordering which is lexicographic: comparing the real parts first and then the complex parts if the real parts are equal.

PyArray_REFCOUNT (PyObject* op)
   Returns the reference count of any Python object.

PyArray_XDECREF_ERR (PyObject *obj)
   DECREF’s an array object which may have the NPY_ARRAY_UPDATEIFCOPY flag set without causing the contents to be copied back into the original array. Resets the NPY_ARRAY_WRITEABLE flag on the base object. This is useful for recovering from an error condition when NPY_ARRAY_UPDATEIFCOPY is used.

Enumerated Types

NPY_SORTKIND
   A special variable-type which can take on the values NPY_{KIND} where \{KIND\} is
   QUICKSORT, HEAPSORT, MERGESORT

NPY_NSORTS
   Defined to be the number of sorts.

NPY_SCALARKIND
   A special variable type indicating the number of “kinds” of scalars distinguished in determining scalar-coercion rules. This variable can take on the values NPY_{KIND} where \{KIND\} can be
   NOSCALAR, BOOL_SCALAR, INTPOS_SCALAR, INTNEG_SCALAR, FLOAT_SCALAR, COMPLEX_SCALAR, OBJECT_SCALAR

NPY_NSCALARKINDS
   Defined to be the number of scalar kinds (not including NPY_NOSCALAR).

NPY_ORDER
   An enumeration type indicating the element order that an array should be interpreted in. When a brand new array is created, generally only NPY_CORDER and NPY_FORTRANORDER are used, whereas when one or more inputs are provided, the order can be based on them.

NPY_ANYORDER
   Fortran order if all the inputs are Fortran, C otherwise.
NPY_CORDER
C order.

NPY_FORTRANORDER
Fortran order.

NPY_KEEPORDER
An order as close to the order of the inputs as possible, even if the input is in neither C nor Fortran order.

NPY_CLIPMODE
A variable type indicating the kind of clipping that should be applied in certain functions.

NPY_RAISE
The default for most operations, raises an exception if an index is out of bounds.

NPY_CLIP
Clips an index to the valid range if it is out of bounds.

NPY_WRAP
Wraps an index to the valid range if it is out of bounds.

NPY_CASTING
New in version 1.6.
An enumeration type indicating how permissive data conversions should be. This is used by the iterator added in NumPy 1.6, and is intended to be used more broadly in a future version.

NPY_NO_CASTING
Only allow identical types.

NPY_EQUIV_CASTING
Allow identical and casts involving byte swapping.

NPY_SAFE_CASTING
Only allow casts which will not cause values to be rounded, truncated, or otherwise changed.

NPYSAME_KIND_CASTING
Allow any safe casts, and casts between types of the same kind. For example, float64 -> float32 is permitted with this rule.

NPY_UNSAFE_CASTING
Allow any cast, no matter what kind of data loss may occur.

5.5 Array Iterator API

New in version 1.6.

5.5.1 Array Iterator

The array iterator encapsulates many of the key features in ufuncs, allowing user code to support features like output parameters, preservation of memory layouts, and buffering of data with the wrong alignment or type, without requiring difficult coding.

This page documents the API for the iterator. The C-API naming convention chosen is based on the one in the numpy-refactor branch, so will integrate naturally into the refactored code base. The iterator is named NpyIter and functions are named NpyIter_*.

There is an introductory guide to array iteration which may be of interest for those using this C API. In many instances, testing out ideas by creating the iterator in Python is a good idea before writing the C iteration code.
5.5.2 Converting from Previous NumPy Iterators

The existing iterator API includes functions like PyArrayIter_Check, PyArray_Iters and PyArray_ITER_. The multi-iterator array includes PyArray_MultiIter*, PyArray_Broadcast, and PyArray_RemoveSmallest. The new iterator design replaces all of this functionality with a single object and associated API. One goal of the new API is that all uses of the existing iterator should be replaceable with the new iterator without significant effort. In 1.6, the major exception to this is the neighborhood iterator, which does not have corresponding features in this iterator.

Here is a conversion table for which functions to use with the new iterator:

<table>
<thead>
<tr>
<th>Iterator Functions</th>
<th>New API</th>
</tr>
</thead>
<tbody>
<tr>
<td>PyArray_IterNew</td>
<td>NpyIter_New</td>
</tr>
<tr>
<td>PyArray_IterAllButAxis</td>
<td>NpyIter_New + axes parameter or Iterator flag</td>
</tr>
<tr>
<td>PyArray_BroadcastToShape</td>
<td>NOT SUPPORTED (Use the support for multiple operands instead.)</td>
</tr>
<tr>
<td>PyArray_IterCheck</td>
<td>NpyIter_Reset</td>
</tr>
<tr>
<td>PyArray_ITER_RESET</td>
<td>Function pointer from NpyIter_GetIterNext</td>
</tr>
<tr>
<td>PyArray_ITER_NEXT</td>
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</tr>
<tr>
<td>PyArray_ITER_DATA</td>
<td>NpyIter_GotoMultiIndex</td>
</tr>
<tr>
<td>PyArray_ITER_GOTO</td>
<td>NpyIter_GotoIndex or NpyIter_GotoIterIndex</td>
</tr>
<tr>
<td>PyArray_ITER_GOTO1D</td>
<td>Return value of iternext function pointer</td>
</tr>
<tr>
<td>PyArray_ITER_NOTDONE</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multi-iterator Functions</th>
<th>New API</th>
</tr>
</thead>
<tbody>
<tr>
<td>PyArray_MultiIterNew</td>
<td>NpyIter_MultiNew</td>
</tr>
<tr>
<td>PyArray_MultiIter_RESET</td>
<td>NpyIter_Reset</td>
</tr>
<tr>
<td>PyArray_MultiIter_NEXT</td>
<td>Function pointer from NpyIter_GetIterNext</td>
</tr>
<tr>
<td>PyArray_MultiIter_DATA</td>
<td>NpyIter_GetDataPtrArray</td>
</tr>
<tr>
<td>PyArray_MultiIter_NEXT1</td>
<td>NOT SUPPORTED (always lock-step iteration)</td>
</tr>
<tr>
<td>PyArray_MultiIter_GOTO</td>
<td>NpyIter_GotoMultiIndex</td>
</tr>
<tr>
<td>PyArray_MultiIter_GOTO1D</td>
<td>NpyIter_GotoIndex or NpyIter_GotoIterIndex</td>
</tr>
<tr>
<td>PyArray_MultiIter_NOTDONE</td>
<td>Return value of iternext function pointer</td>
</tr>
<tr>
<td>PyArray_Broadcast</td>
<td>Handled by NpyIter_MultiNew</td>
</tr>
<tr>
<td>PyArray_RemoveSmallest</td>
<td>Iterator flag NPY_ITER_EXTERNAL_LOOP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Functions</th>
<th>New API</th>
</tr>
</thead>
<tbody>
<tr>
<td>PyArray_ConvertToCommonType</td>
<td></td>
</tr>
</tbody>
</table>

5.5.3 Simple Iteration Example

The best way to become familiar with the iterator is to look at its usage within the NumPy codebase itself. For example, here is a slightly tweaked version of the code for `PyArray_CountNonzero`, which counts the number of non-zero elements in an array.

```c
npy_intp PyArray_CountNonzero(PyArrayObject* self) {
    /* Nonzero boolean function */
    PyArray_NonzeroFunc* nonzero = PyArray_DESCR(self)->f->nonzero;

    NpyIter* iter;
    NpyIter_IterNextFunc* iternext;
    char** dataptr;
    npy_intp* strideptr,* innersizeptr;

    /* Handle zero-sized arrays specially */
    if (PyArray_SIZE(self) == 0) {
        return 0;
    }
```
/* Create and use an iterator to count the nonzeros. */
* flag NPY_ITER_READONLY
* - The array is never written to.
* flag NPY_ITER_EXTERNAL_LOOP
* - Inner loop is done outside the iterator for efficiency.
* flag NPY_ITER_REFS_OK
* - Reference types are acceptable.
* order NPY_KEEPORDER
* - Visit elements in memory order, regardless of strides.
* This is good for performance when the specific order
* elements are visited is unimportant.
* casting NPY_NO_CASTING
* - No casting is required for this operation.
*/
iter = NpyIter_New(self, NPY_ITER_READONLY|
                   NPY_ITER_EXTERNAL_LOOP|
                   NPY_ITER_REFS_OK,
                   NPY_KEEPORDER, NPY_NO_CASTING,
                   NULL);
if (iter == NULL) {
    return -1;
}

/* The iternext function gets stored in a local variable
   so it can be called repeatedly in an efficient manner. */
iternext = NpyIter_GetIterNext(iter, NULL);
if (iternext == NULL) {
    NpyIter_Deallocate(iter);
    return -1;
}

/* The location of the data pointer which the iterator may update */
dataptr = NpyIter_GetDataPtrArray(iter);
/* The location of the stride which the iterator may update */
strideptr = NpyIter_GetInnerStrideArray(iter);
/* The location of the inner loop size which the iterator may update */
innersizeptr = NpyIter_GetInnerLoopSizePtr(iter);

/* The iteration loop */
do {
    /* Get the inner loop data/stride/count values */
    char* data = *dataptr;
npy_intp stride = *strideptr;
npy_intp count = *innersizeptr;

    /* This is a typical inner loop for NPY_ITER_EXTERNAL_LOOP */
    while (count--) {
        if (nonzero(data, self)) {
            ++nonzero_count;
        }
        data += stride;
    }
/* Increment the iterator to the next inner loop */
5.5.4 Simple Multi-Iteration Example

Here is a simple copy function using the iterator. The order parameter is used to control the memory layout of the allocated result, typically NPY_KEEPORDER is desired.

```c
PyObject *CopyArray(PyObject *arr, NPY_ORDER order)
{
    NpyIter *iter;
    NpyIter_IterNextFunc *iternext;
    PyObject *op[2], *ret;
    npy_uint32 flags;
    npy_uint32 op_flags[2];
    npy_intp itemsize, *innersizeptr, innerstride;
    char **dataptrarray;

    /*
    * No inner iteration - inner loop is handled by CopyArray code
    */
    flags = NPY_ITER_EXTERNAL_LOOP;
    /*
    * Tell the constructor to automatically allocate the output.
    * The data type of the output will match that of the input.
    */
    op[0] = arr;
    op[1] = NULL;
    op_flags[0] = NPY_ITER_READONLY;
    op_flags[1] = NPY_ITER_WRITEONLY | NPY_ITER_ALLOCATE;

    /* Construct the iterator */
    iter = NpyIter_MultiNew(2, op, flags, order, NPY_NO_CASTING,
                             op_flags, NULL);
    if (iter == NULL) {
        return NULL;
    }

    /*
    * Make a copy of the iternext function pointer and
    * a few other variables the inner loop needs.
    */
    iternext = NpyIter_GetIterNext(iter, NULL);
    innerstride = NpyIter_GetInnerStrideArray(iter)[0];
    itemsize = NpyIter_GetDescrArray(iter)[0]->elsize;
    /*
    * The inner loop size and data pointers may change during the
    * loop, so just cache the addresses.
    */
    innersizeptr = NpyIter_GetInnerLoopSizePtr(iter);
    dataptrarray = NpyIter.GetDataPtrArray(iter);
    /*
    */
```
Note that because the iterator allocated the output, it matches the iteration order and is packed tightly, so we don’t need to check it like the input.

```c
if (innerstride == itemsize) {
    do {
        memcpy(dataptrarray[1], dataptrarray[0],
               itemsize * (*innersizeptr));
    } while (iternext(iter));
} else {
    /* For efficiency, should specialize this based on item size... */
    npy_intp i;
    do {
        npy_intp size = *innersizeptr;
        char *src = dataptrarray[0], *dst = dataptrarray[1];
        for (i = 0; i < size; i++, src += innerstride, dst += itemsize) {
            memcpy(dst, src, itemsize);
        }
    } while (iternext(iter));
}
```

/* Get the result from the iterator object array */
ret = NpyIter_GetOperandArray(iter)[1];
Py_INCREF(ret);
if (NpyIter_Deallocate(iter) != NPY_SUCCEED) {
    Py_DECREF(ret);
    return NULL;
}
return ret;

### 5.5.5 Iterator Data Types

The iterator layout is an internal detail, and user code only sees an incomplete struct.

**NpyIter**
This is an opaque pointer type for the iterator. Access to its contents can only be done through the iterator API.

**NpyIter_Type**
This is the type which exposes the iterator to Python. Currently, no API is exposed which provides access to the values of a Python-created iterator. If an iterator is created in Python, it must be used in Python and vice versa. Such an API will likely be created in a future version.

**NpyIter_IterNextFunc**
This is a function pointer for the iteration loop, returned by `NpyIter_GetIterNext`.

**NpyIter_GetMultiIndexFunc**
This is a function pointer for getting the current iterator multi-index, returned by `NpyIter_GetGetMultiIndex`.
5.5.6 Construction and Destruction

NpyIter* **NpyIter_New** (PyArrayObject* *op*, npy_uint32 *flags*, NPY_ORDER *order*, NPY_CASTING *casting*, PyArray_Descr* *dtype*)

Creates an iterator for the given numpy array object *op*.

Flags that may be passed in *flags* are any combination of the global and per-operand flags documented in NpyIter_MultiNew, except for NPY_ITER_ALLOCATE.

Any of the NPY_ORDER enum values may be passed to *order*. For efficient iteration, NPY_KEEPORDER is the best option, and the other orders enforce the particular iteration pattern.

Any of the NPY_CASTING enum values may be passed to *casting*. The values include NPY_NO_CASTING, NPY_EQUIV_CASTING, NPY_SAFE_CASTING, NPY_SAME_KIND_CASTING, and NPY_UNSAFE_CASTING. To allow the casts to occur, copying or buffering must also be enabled.

If *dtype* isn’t NULL, then it requires that data type. If copying is allowed, it will make a temporary copy if the data is castable. If NPY_ITER_UPDATEIFCOPY is enabled, it will also copy the data back with another cast upon iterator destruction.

Returns NULL if there is an error, otherwise returns the allocated iterator.

To make an iterator similar to the old iterator, this should work.

```
iter = NpyIter_New(op, NPY_ITER_READWRITE,
                   NPY_CORDER, NPY_NO_CASTING, NULL);
```

If you want to edit an array with aligned double code, but the order doesn’t matter, you would use this.

```
dtype = PyArray_DescrFromType(NPY_DOUBLE);
iter = NpyIter_New(op, NPY_ITER_READWRITE,
                   NPY_ITER_BUFFERED|
                   NPY_ITER_NBO|
                   NPY_ITER_ALIGNED,
                   NPY_KEEPORDER,
                   NPY_SAME_KIND_CASTING,
                   dtype);
Py_DECREF(dtype);
```

NpyIter* **NpyIter_MultiNew** (npy_intp *nop*, PyObject** *op*, npy_uint32 *flags*, NPY_ORDER *order*, NPY_CASTING *casting*, npy_uint32* *op_flags*, PyArray_Descr** *op_dtypes*)

Creates an iterator for broadcasting the *nop* array objects provided in *op*, using regular NumPy broadcasting rules.

Any of the NPY_ORDER enum values may be passed to *order*. For efficient iteration, NPY_KEEPORDER is the best option, and the other orders enforce the particular iteration pattern. When using NPY_KEEPORDER, if you also want to ensure that the iteration is not reversed along an axis, you should pass the flag NPY_ITER_DONT_NEGATE_STRIDES.

Any of the NPY_CASTING enum values may be passed to *casting*. The values include NPY_NO_CASTING, NPY_EQUIV_CASTING, NPY_SAFE_CASTING, NPY_SAME_KIND_CASTING, and NPY_UNSAFE_CASTING. To allow the casts to occur, copying or buffering must also be enabled.

If *op_dtypes* isn’t NULL, it specifies a data type or NULL for each *op[i]*.

Returns NULL if there is an error, otherwise returns the allocated iterator.

Flags that may be passed in *flags*, applying to the whole iterator, are:
NPY_ITER_C_INDEX
Causes the iterator to track a raveled flat index matching C order. This option cannot be used with NPY_ITER_F_INDEX.

NPY_ITER_F_INDEX
Causes the iterator to track a raveled flat index matching Fortran order. This option cannot be used with NPY_ITER_C_INDEX.

NPY_ITER_MULTI_INDEX
Causes the iterator to track a multi-index. This prevents the iterator from coalescing axes to produce bigger inner loops. If the loop is also not buffered and no index is being tracked (NpyIter_RemoveAxis can be called), then the iterator size can be −1 to indicate that the iterator is too large. This can happen due to complex broadcasting and will result in errors being created when the setting the iterator range, removing the multi index, or getting the next function. However, it is possible to remove axes again and use the iterator normally if the size is small enough after removal.

NPY_ITER_EXTERNAL_LOOP
Causes the iterator to skip iteration of the innermost loop, requiring the user of the iterator to handle it.

This flag is incompatible with NPY_ITER_C_INDEX, NPY_ITER_F_INDEX, and NPY_ITER_MULTI_INDEX.

NPY_ITER_DONT_NEGATE_STRIDES
This only affects the iterator when NPY_KEEPORDER is specified for the order parameter. By default with NPY_KEEPORDER, the iterator reverses axes which have negative strides, so that memory is traversed in a forward direction. This disables this step. Use this flag if you want to use the underlying memory-ordering of the axes, but don’t want an axis reversed. This is the behavior of numpy.ravel(a, order='K'), for instance.

NPY_ITER_COMMON_DTYPE
Causes the iterator to convert all the operands to a common data type, calculated based on the ufunc type promotion rules. Copying or buffering must be enabled.

If the common data type is known ahead of time, don’t use this flag. Instead, set the requested dtype for all the operands.

NPY_ITER_REFS_OK
Indicates that arrays with reference types (object arrays or structured arrays containing an object type) may be accepted and used in the iterator. If this flag is enabled, the caller must be sure to check whether :cfunc:`NpyIter_IterationNeedsAPI`(iter) is true, in which case it may not release the GIL during iteration.

NPY_ITER_ZEROSIZE_OK
Indicates that arrays with a size of zero should be permitted. Since the typical iteration loop does not naturally work with zero-sized arrays, you must check that the IterSize is larger than zero before entering the iteration loop. Currently only the operands are checked, not a forced shape.

NPY_ITER_REDUCE_OK
Permits writeable operands with a dimension with zero stride and size greater than one. Note that such operands must be read/write.

When buffering is enabled, this also switches to a special buffering mode which reduces the loop length as necessary to not trample on values being reduced.

Note that if you want to do a reduction on an automatically allocated output, you must use NpyIter_GetOperandArray to get its reference, then set every value to the reduction unit before doing the iteration loop. In the case of a buffered reduction, this means you must also
specify the flag NPY_ITER_DELAY_BUFALLOC, then reset the iterator after initializing the allocated operand to prepare the buffers.

**NPY_ITER_RANGED**

Enables support for iteration of sub-ranges of the full iterindex range \([0, NpyIter_IterSize(iter))\). Use the function NpyIter_ResetToIterIndexRange to specify a range for iteration.

This flag can only be used with NPY_ITER_EXTERNAL_LOOP when NPY_ITER_BUFFERED is enabled. This is because without buffering, the inner loop is always the size of the innermost iteration dimension, and allowing it to get cut up would require special handling, effectively making it more like the buffered version.

**NPY_ITER_BUFFERED**

Causes the iterator to store buffering data, and use buffering to satisfy data type, alignment, and byte-order requirements. To buffer an operand, do not specify the NPY_ITER_COPY or NPY_ITER_UPDATEIFCOPY flags, because they will override buffering. Buffering is especially useful for Python code using the iterator, allowing for larger chunks of data at once to amortize the Python interpreter overhead.

If used with NPY_ITER_EXTERNAL_LOOP, the inner loop for the caller may get larger chunks than would be possible without buffering, because of how the strides are laid out.

Note that if an operand is given the flag NPY_ITER_COPY or NPY_ITER_UPDATEIFCOPY, a copy will be made in preference to buffering. Buffering will still occur when the array was broadcast so elements need to be duplicated to get a constant stride.

In normal buffering, the size of each inner loop is equal to the buffer size, or possibly larger if NPY_ITER_GROWINNER is specified. If NPY_ITER_REDUCE_OK is enabled and a reduction occurs, the inner loops may become smaller depending on the structure of the reduction.

**NPY_ITER_GROWINNER**

When buffering is enabled, this allows the size of the inner loop to grow when buffering isn’t necessary. This option is best used if you’re doing a straight pass through all the data, rather than anything with small cache-friendly arrays of temporary values for each inner loop.

**NPY_ITER_DELAY_BUFALLOC**

When buffering is enabled, this delays allocation of the buffers until NpyIter_Reset or another reset function is called. This flag exists to avoid wasteful copying of buffer data when making multiple copies of a buffered iterator for multi-threaded iteration.

Another use of this flag is for setting up reduction operations. After the iterator is created, and a reduction output is allocated automatically by the iterator (be sure to use READWRITE access), its value may be initialized to the reduction unit. Use NpyIter_GetOperandArray to get the object. Then, call NpyIter_Reset to allocate and fill the buffers with their initial values.

Flags that may be passed in op_flags[i], where 0 ≤ i < nop:

**NPY_ITER_READWRITE**

**NPY_ITER_READONLY**

**NPY_ITER_WRITEONLY**

Indicate how the user of the iterator will read or write to op[i]. Exactly one of these flags must be specified per operand.

**NPY_ITER_COPY**

Allow a copy of op[i] to be made if it does not meet the data type or alignment requirements as specified by the constructor flags and parameters.
**NPY_ITER_UPDATEIFCOPY**

Triggers `NPY_ITER_COPY`, and when an array operand is flagged for writing and is copied, causes the data in a copy to be copied back to `op[i]` when the iterator is destroyed.

If the operand is flagged as write-only and a copy is needed, an uninitialized temporary array will be created and then copied back to `op[i]` on destruction, instead of doing the unnecessary copy operation.

**NPY_ITER_NBO**

**NPY_ITER_ALIGNED**

**NPY_ITER_CONTIG**

Causes the iterator to provide data for `op[i]` that is in native byte order, aligned according to the dtype requirements, contiguous, or any combination.

By default, the iterator produces pointers into the arrays provided, which may be aligned or unaligned, and with any byte order. If copying or buffering is not enabled and the operand data doesn’t satisfy the constraints, an error will be raised.

The contiguous constraint applies only to the inner loop, successive inner loops may have arbitrary pointer changes.

If the requested data type is in non-native byte order, the NBO flag overrides it and the requested data type is converted to be in native byte order.

**NPY_ITER_ALLOCATE**

This is for output arrays, and requires that the flag `NPY_ITER_WRITEONLY` or `NPY_ITER_READWRITE` be set. If `op[i]` is NULL, creates a new array with the final broadcast dimensions, and a layout matching the iteration order of the iterator.

When `op[i]` is NULL, the requested data type `op_dtypes[i]` may be NULL as well, in which case it is automatically generated from the dtypes of the arrays which are flagged as readable. The rules for generating the dtype are the same is for UFuncs. Of special note is handling of byte order in the selected dtype. If there is exactly one input, the input’s dtype is used as is. Otherwise, if more than one input dtypes are combined together, the output will be in native byte order.

After being allocated with this flag, the caller may retrieve the new array by calling `NpyIter_GetOperandArray` and getting the i-th object in the returned C array. The caller must call `Py_INCREF` on it to claim a reference to the array.

**NPY_ITER_NO_SUBTYPE**

For use with `NPY_ITER_ALLOCATE`, this flag disables allocating an array subtype for the output, forcing it to be a straight ndarray.

TODO: Maybe it would be better to introduce a function `NpyIter_GetWrappedOutput` and remove this flag?

**NPY_ITER_NO_BROADCAST**

Ensures that the input or output matches the iteration dimensions exactly.

**NPY_ITER ARRAYS MASK**

New in version 1.7.

Indicates that this operand is the mask to use for selecting elements when writing to operands which have the `NPY_ITER_WRITEMASKED` flag applied to them. Only one operand may have `NPY_ITER_ARRAYS MASK` flag applied to it.
The data type of an operand with this flag should be either `NPY_BOOL`, `NPY_MASK`, or a struct dtype whose fields are all valid mask dtypes. In the latter case, it must match up with a struct operand being WRITEMASKED, as it is specifying a mask for each field of that array.

This flag only affects writing from the buffer back to the array. This means that if the operand is also `NPY_ITER_READWRITE` or `NPY_ITER_WRITEONLY`, code doing iteration can write to this operand to control which elements will be untouched and which ones will be modified. This is useful when the mask should be a combination of input masks, for example. Mask values can be created with the `NpyMask_Create` function.

**NPY_ITER_WRITEMASKED**

New in version 1.7.

Indicates that only elements which the operand with the ARRAYMASK flag indicates are intended to be modified by the iteration. In general, the iterator does not enforce this, it is up to the code doing the iteration to follow that promise. Code can use the `NpyMask_IsExposed` inline function to test whether the mask at a particular element allows writing.

When this flag is used, and this operand is buffered, this changes how data is copied from the buffer into the array. A masked copying routine is used, which only copies the elements in the buffer for which `NpyMask_IsExposed` returns true from the corresponding element in the ARRAYMASK operand.

```c
NpyIter* NpyIter_AdvancedNew(npy_intp  nop, PyArrayObject** op, npy_uint32 flags, NPY_ORDER order, NPY_CASTING casting, npy_uint32* op_flags, PyArray_Descr** op_dtypes, int oa_ndim, int** op_axes, npy_intp* itershape, npy_intp buffersize);
```

Extends `NpyIter_MultiNew` with several advanced options providing more control over broadcasting and buffering.

If -1/NULL values are passed to `oa_ndim, op_axes, itershape, and buffersize, it is equivalent to `NpyIter_MultiNew`.

The parameter `oa_ndim`, when not zero or -1, specifies the number of dimensions that will be iterated with customized broadcasting. If it is provided, `op_axes` must and `itershape` can also be provided. The `op_axes` parameter let you control in detail how the axes of the operand arrays get matched together and iterated. In `op_axes`, you must provide an array of `nop` pointers to `oa_ndim`-sized arrays of type `npy_intp`. If an entry in `op_axes` is NULL, normal broadcasting rules will apply. In `op_axes[j][i]` is stored either a valid axis of `op[j]`, or -1 which means `newaxis`. Within each `op_axes[j]` array, axes may not be repeated. The following example is how normal broadcasting applies to a 3-D array, a 2-D array, a 1-D array and a scalar.

**Note:** Before NumPy 1.8 `oa_ndim == 0` was used for signalling that that `op_axes` and `itershape` are unused. This is deprecated and should be replaced with -1. Better backward compatibility may be achieved by using `NpyIter_MultiNew` for this case.

```c
int oa_ndim = 3; /* # iteration axes */
int op0_axes[] = {0, 1, 2}; /* 3-D operand */
int op1_axes[] = {-1, 0, 1}; /* 2-D operand */
int op2_axes[] = {-1, -1, 0}; /* 1-D operand */
int op3_axes[] = {-1, -1, -1} /* 0-D (scalar) operand */
int* op_axes[] = {op0_axes, op1_axes, op2_axes, op3_axes};
```

The `itershape` parameter allows you to force the iterator to have a specific iteration shape. It is an array of length `oa_ndim`. When an entry is negative, its value is determined from the operands. This parameter allows automatically allocated outputs to get additional dimensions which don’t match up with any dimension of an input.

If `buffersize` is zero, a default buffer size is used, otherwise it specifies how big of a buffer to use. Buffers which are powers of 2 such as 4096 or 8192 are recommended.
Returns NULL if there is an error, otherwise returns the allocated iterator.

*NpyIter* `NpyIter_Copy (NpyIter* iter)`

Makes a copy of the given iterator. This function is provided primarily to enable multithreaded iteration of the data.

TODO: Move this to a section about multithreaded iteration.

The recommended approach to multithreaded iteration is to first create an iterator with the flags `NPY_ITER_EXTERNAL_LOOP`, `NPY_ITER_RANGED`, `NPY_ITER_BUFFERED`, `NPY_ITER_DELAY_BUFALLOC`, and possibly `NPY_ITER_GROWINNER`. Create a copy of this iterator for each thread (minus one for the first iterator). Then, take the iteration index range `[0, NpyIter_GetIterSize(iter))` and split it up into tasks, for example using a TBB parallel_for loop. When a thread gets a task to execute, it then uses its copy of the iterator by calling `NpyIter_ResetToIterIndexRange` and iterating over the full range.

When using the iterator in multi-threaded code or in code not holding the Python GIL, care must be taken to only call functions which are safe in that context. `NpyIter_Copy` cannot be safely called without the Python GIL, because it increments Python references. The `Reset*` and some other functions may be safely called by passing in the `errmsg` parameter as non-NULL, so that the functions will pass back errors through it instead of setting a Python exception.

```c
int NpyIter_RemoveAxis(NpyIter* iter, int axis)"
```

Removes an axis from iteration. This requires that `NPY_ITER_MULTI_INDEX` was set for iterator creation, and does not work if buffering is enabled or an index is being tracked. This function also resets the iterator to its initial state.

This is useful for setting up an accumulation loop, for example. The iterator can first be created with all the dimensions, including the accumulation axis, so that the output gets created correctly. Then, the accumulation axis can be removed, and the calculation done in a nested fashion.

**WARNING:** This function may change the internal memory layout of the iterator. Any cached functions or pointers from the iterator must be retrieved again! The iterator range will be reset as well.

Returns `NPY_SUCCEED` or `NPY_FAIL`.

```c
int NpyIter_RemoveMultiIndex (NpyIter* iter)
```

If the iterator is tracking a multi-index, this strips support for them, and does further iterator optimizations that are possible if multi-indices are not needed. This function also resets the iterator to its initial state.

**WARNING:** This function may change the internal memory layout of the iterator. Any cached functions or pointers from the iterator must be retrieved again!

After calling this function, :cfunc:`NpyIter_HasMultiIndex`(iter) will return false.

Returns `NPY_SUCCEED` or `NPY_FAIL`.

```c
int NpyIter_EnableExternalLoop (NpyIter* iter)
```

If `NpyIter_RemoveMultiIndex` was called, you may want to enable the flag `NPY_ITER_EXTERNAL_LOOP`. This flag is not permitted together with `NPY_ITER_MULTI_INDEX`, so this function is provided to enable the feature after `NpyIter_RemoveMultiIndex` is called. This function also resets the iterator to its initial state.

**WARNING:** This function changes the internal logic of the iterator. Any cached functions or pointers from the iterator must be retrieved again!

Returns `NPY_SUCCEED` or `NPY_FAIL`.

```c
int NpyIter_Deallocate (NpyIter* iter)
```

Deallocates the iterator object. This additionally frees any copies made, triggering UPDATEIFCOPY behavior where necessary.
Returns NPY_SUCCEED or NPY_FAIL.

int NpyIter_Reset (NpyIter* iter, char** errmsg)
Resets the iterator back to its initial state, at the beginning of the iteration range.

Returns NPY_SUCCEED or NPY_FAIL. If errmsg is non-NULL, no Python exception is set when NPY_FAIL is returned. Instead, *errmsg is set to an error message. When errmsg is non-NULL, the function may be safely called without holding the Python GIL.

int NpyIter_ResetToIterIndexRange (NpyIter* iter, npy_intp istart, npy_intp iend, char** errmsg)
Resets the iterator and restricts it to the iterindex range [istart, iend). See NpyIter_Copy for an explanation of how to use this for multi-threaded iteration. This requires that the flag NPY_ITER_RANGED was passed to the iterator constructor.

If you want to reset both the iterindex range and the base pointers at the same time, you can do the following to avoid extra buffer copying (be sure to add the return code error checks when you copy this code).

/* Set to a trivial empty range */
NpyIter_ResetToIterIndexRange(iter, 0, 0);
/* Set the base pointers */
NpyIter_ResetBasePointers(iter, baseptrs);
/* Set to the desired range */
NpyIter_ResetToIterIndexRange(iter, istart, iend);

Returns NPY_SUCCEED or NPY_FAIL. If errmsg is non-NULL, no Python exception is set when NPY_FAIL is returned. Instead, *errmsg is set to an error message. When errmsg is non-NULL, the function may be safely called without holding the Python GIL.

int NpyIter_ResetBasePointers (NpyIter *iter, char** baseptrs, char** errmsg)
Resets the iterator back to its initial state, but using the values in baseptrs for the data instead of the pointers from the arrays being iterated. This functions is intended to be used, together with the op_axes parameter, by nested iteration code with two or more iterators.

Returns NPY_SUCCEED or NPY_FAIL. If errmsg is non-NULL, no Python exception is set when NPY_FAIL is returned. Instead, *errmsg is set to an error message. When errmsg is non-NULL, the function may be safely called without holding the Python GIL.

TODO: Move the following into a special section on nested iterators.

Creating iterators for nested iteration requires some care. All the iterator operands must match exactly, or the calls to NpyIter_ResetBasePointers will be invalid. This means that automatic copies and output allocation should not be used haphazardly. It is possible to still use the automatic data conversion and casting features of the iterator by creating one of the iterators with all the conversion parameters enabled, then grabbing the allocated operands with the NpyIter_GetOperandArray function and passing them into the constructors for the rest of the iterators.

WARNING: When creating iterators for nested iteration, the code must not use a dimension more than once in the different iterators. If this is done, nested iteration will produce out-of-bounds pointers during iteration.

WARNING: When creating iterators for nested iteration, buffering can only be applied to the innermost iterator. If a buffered iterator is used as the source for baseptrs, it will point into a small buffer instead of the array and the inner iteration will be invalid.

The pattern for using nested iterators is as follows.

NpyIter *iter1, *iter1;
NpyIter_IterNextFunc *iternext1, *iternext2;
char **dataptrsl;

/*
 * With the exact same operands, no copies allowed, and
* no axis in op_axes used both in iter1 and iter2.
* Buffering may be enabled for iter2, but not for iter1.
*/

iter1 = ...; iter2 = ...;

iternext1 = NpyIter_GetIterNext(iter1);
iternext2 = NpyIter_GetIterNext(iter2);
dataptrs1 = NpyIterGetDataPtrArray(iter1);

do {
    NpyIter_ResetBasePointers(iter2, dataptrs1);
    do
    { /* Use the iter2 values */
    } while (iternext2(iter2));
} while (iternext1(iter1));

int NpyIter_GotoMultiIndex (NpyIter* iter, npy_intp* multi_index)
Adjusts the iterator to point to the ndim indices pointed to by multi_index. Returns an error if a multi-index is not being tracked, the indices are out of bounds, or inner loop iteration is disabled.

Returns NPY_SUCCEED or NPY_FAIL.

int NpyIter_GotoIndex (NpyIter* iter, npy_intp index)
Adjusts the iterator to point to the index specified. If the iterator was constructed with the flag NPY_ITER_C_INDEX, index is the C-order index, and if the iterator was constructed with the flag NPY_ITER_F_INDEX, index is the Fortran-order index. Returns an error if there is no index being tracked, the index is out of bounds, or inner loop iteration is disabled.

Returns NPY_SUCCEED or NPY_FAIL.

npy_intp NpyIter_GetIterSize (NpyIter* iter)
Returns the number of elements being iterated. This is the product of all the dimensions in the shape. When a multi index is being tracked (and NpyIter_RemoveAxis may be called) the size may be -1 to indicate an iterator is too large. Such an iterator is invalid, but may become valid after NpyIter_RemoveAxis is called. It is not necessary to check for this case.

npy_intp NpyIter_GetIterIndex (NpyIter* iter)
Gets the iterindex of the iterator, which is an index matching the iteration order of the iterator.

void NpyIter_GetIterIndexRange (NpyIter* iter, npy_intp* istart, npy_intp* iend)
Gets the iterindex sub-range that is being iterated. If NPY_ITER_RANGED was not specified, this always returns the range [0, NpyIter_IterSize(iter)].

int NpyIter_GotoIterIndex (NpyIter* iter, npy_intp iterindex)
Adjusts the iterator to point to the iterindex specified. The IterIndex is an index matching the iteration order of the iterator. Returns an error if the iterindex is out of bounds, buffering is enabled, or inner loop iteration is disabled.

Returns NPY_SUCCEED or NPY_FAIL.

npy_bool NpyIter_HasDelayedBufAlloc (NpyIter* iter)
Returns 1 if the flag NPY_ITER_DELAY_BUFALLOC was passed to the iterator constructor, and no call to one of the Reset functions has been done yet, 0 otherwise.

npy_bool NpyIter_HasExternalLoop (NpyIter* iter)
Returns 1 if the caller needs to handle the inner-most 1-dimensional loop, or 0 if the iterator handles all looping. This is controlled by the constructor flag NPY_ITER_EXTERNAL_LOOP or NpyIter_EnableExternalLoop.
npy_bool NpyIter_HasMultiIndex (NpyIter* iter)
    Returns 1 if the iterator was created with the NPY_ITER_MULTI_INDEX flag, 0 otherwise.

npy_bool NpyIter_HasIndex (NpyIter* iter)
    Returns 1 if the iterator was created with the NPY_ITER_C_INDEX or NPY_ITER_F_INDEX flag, 0 otherwise.

npy_bool NpyIter_RequiresBuffering (NpyIter* iter)
    Returns 1 if the iterator requires buffering, which occurs when an operand needs conversion or alignment and
    so cannot be used directly.

npy_bool NpyIter_IsBuffered (NpyIter* iter)
    Returns 1 if the iterator was created with the NPY_ITER_BUFFERED flag, 0 otherwise.

npy_bool NpyIter_IsGrowInner (NpyIter* iter)
    Returns 1 if the iterator was created with the NPY_ITER_GROWINNER flag, 0 otherwise.

npy_intp NpyIter_GetBufferSize (NpyIter* iter)
    If the iterator is buffered, returns the size of the buffer being used, otherwise returns 0.

int NpyIter_GetNDim (NpyIter* iter)
    Returns the number of dimensions being iterated. If a multi-index was not requested in the iterator constructor,
    this value may be smaller than the number of dimensions in the original objects.

int NpyIter_GetNOp (NpyIter* iter)
    Returns the number of operands in the iterator.

    When NPY_ITER_USE_MASKNA is used on an operand, a new operand is added to the end of the operand list
    in the iterator to track that operand’s NA mask. Thus, this equals the number of construction operands plus the
    number of operands for which the flag NPY_ITER_USE_MASKNA was specified.

int NpyIter_GetFirstMaskNAOp (NpyIter* iter)
    New in version 1.7.
    Returns the index of the first NA mask operand in the array. This value is equal to the number of operands
    passed into the constructor.

npy_intp* NpyIter_GetAxisStrideArray (NpyIter* iter, int axis)
    Gets the array of strides for the specified axis. Requires that the iterator be tracking a multi-index, and that
    buffering not be enabled.

    This may be used when you want to match up operand axes in some fashion, then remove them with
    NpyIter_RemoveAxis to handle their processing manually. By calling this function before removing the
    axes, you can get the strides for the manual processing.

    Returns NULL on error.

int NpyIter_GetShape (NpyIter* iter, npy_intp* outshape)
    Returns the broadcast shape of the iterator in outshape. This can only be called on an iterator which is
    tracking a multi-index.

    Returns NPY_SUCCEED or NPY_FAIL.

PyArray_Descr** NpyIter_GetDescrArray (NpyIter* iter)
    This gives back a pointer to the npy data type Descrs for the objects being iterated. The result points into
    iter, so the caller does not gain any references to the Descrs.

    This pointer may be cached before the iteration loop, calling iternext will not change it.

PyObject** NpyIter_GetOperandArray (NpyIter* iter)
    This gives back a pointer to the npy operand PyObjects that are being iterated. The result points into iter, so
    the caller does not gain any references to the PyObjects.
npy_int8* `NpyIter_GetMaskNAIndexArray (NpyIter* iter)`

New in version 1.7.

This gives back a pointer to the nop indices which map construction operands with NPY_ITER_USE_MASKNA flagged to their corresponding NA mask operands and vice versa. For operands which were not flagged with NPY_ITER_USE_MASKNA, this array contains negative values.

PyObject* `NpyIter_GetIterView (NpyIter* iter, npy_intp i)`

This gives back a reference to a new ndarray view, which is a view into the i-th object in the array :cfunc:`NpyIter_GetOperandArray`(), whose dimensions and strides match the internal optimized iteration pattern. A C-order iteration of this view is equivalent to the iterator’s iteration order.

For example, if an iterator was created with a single array as its input, and it was possible to rearrange all its axes and then collapse it into a single strided iteration, this would return a view that is a one-dimensional array.

void `NpyIter_GetReadFlags (NpyIter* iter, char* outreadflags)`

Fills nop flags. Sets outreadflags[i] to 1 if op[i] can be read from, and to 0 if not.

void `NpyIter_GetWriteFlags (NpyIter* iter, char* outwriteflags)`

Fills nop flags. Sets outwriteflags[i] to 1 if op[i] can be written to, and to 0 if not.

int `NpyIter_CreateCompatibleStrides (NpyIter* iter, npy_intp itemsize, npy_intp* outstrides)`

Builds a set of strides which are the same as the strides of an output array created using the NPY_ITER_ALLOCATE flag, where NULL was passed for op_axes. This is for data packed contiguously, but not necessarily in C or Fortran order. This should be used together with NpyIter_GetShape and NpyIter_GetNDim with the flag NPY_ITER_MULTI_INDEX passed into the constructor.

A use case for this function is to match the shape and layout of the iterator and tack on one or more dimensions. For example, in order to generate a vector per input value for a numerical gradient, you pass in ndim*itemsize for itemsize, then add another dimension to the end with size ndim and stride itemsize. To do the Hessian matrix, you do the same thing but add two dimensions, or take advantage of the symmetry and pack it into 1 dimension with a particular encoding.

This function may only be called if the iterator is tracking a multi-index and if NPY_ITER_DONT_NEGATE_STRIDES was used to prevent an axis from being iterated in reverse order.

If an array is created with this method, simply adding ‘itemsize’ for each iteration will traverse the new array matching the iterator.

Returns NPY_SUCCEED or NPY_FAIL.

npy_bool `NpyIter_IsFirstVisit (NpyIter* iter, int iop)`

New in version 1.7.

Checks to see whether this is the first time the elements of the specified reduction operand which the iterator points at are being seen for the first time. The function returns a reasonable answer for reduction operands and when buffering is disabled. The answer may be incorrect for buffered non-reduction operands.

This function is intended to be used in EXTERNAL_LOOP mode only, and will produce some wrong answers when that mode is not enabled.

If this function returns true, the caller should also check the inner loop stride of the operand, because if that stride is 0, then only the first element of the innermost external loop is being visited for the first time.

**WARNING:** For performance reasons, ‘iop’ is not bounds-checked, it is not confirmed that ‘iop’ is actually a reduction operand, and it is not confirmed that EXTERNAL_LOOP mode is enabled. These checks are the responsibility of the caller, and should be done outside of any inner loops.
5.5.7 Functions For Iteration

NpyIter_IterNextFunc* NpyIter_GetIterNext (NpyIter* iter, char** errmsg)

Returns a function pointer for iteration. A specialized version of the function pointer may be calculated by this function instead of being stored in the iterator structure. Thus, to get good performance, it is required that the function pointer be saved in a variable rather than retrieved for each loop iteration.

Returns NULL if there is an error. If errmsg is non-NULL, no Python exception is set when NPY_FAIL is returned. Instead, *errmsg is set to an error message. When errmsg is non-NULL, the function may be safely called without holding the Python GIL.

The typical looping construct is as follows.

NpyIter_IterNextFunc *iternext = NpyIter_GetIterNext(iter, NULL);
char** dataptr = NpyIter_GetDataPtrArray(iter);

do {
    /* use the addresses dataptr[0], ... dataptr[nop-1] */
} while(iternext(iter));

When NPY_ITER_EXTERNAL_LOOP is specified, the typical inner loop construct is as follows.

NpyIter_IterNextFunc *iternext = NpyIter_GetIterNext(iter, NULL);
char** dataptr = NpyIter_GetDataPtrArray(iter);
npy_intp* stride = NpyIter_GetInnerStrideArray(iter);
npy_intp* size_ptr = NpyIter_GetInnerLoopSizePtr(iter), size;
npy_intp iop, nop = NpyIter_GetNOp(iter);

do {
    size = *size_ptr;
    while (size--) {
        /* use the addresses dataptr[0], ... dataptr[nop-1] */
        for (iop = 0; iop < nop; ++iop) {
            dataptr[iop] += stride[iop];
        }
    }
} while (iternext());

Observe that we are using the dataptr array inside the iterator, not copying the values to a local temporary. This is possible because when iternext() is called, these pointers will be overwritten with fresh values, not incrementally updated.

If a compile-time fixed buffer is being used (both flags NPY_ITER_BUFFERED and NPY_ITER_EXTERNAL_LOOP), the inner size may be used as a signal as well. The size is guaranteed to become zero when iternext() returns false, enabling the following loop construct. Note that if you use this construct, you should not pass NPY_ITER_GROWINNER as a flag, because it will cause larger sizes under some circumstances.

/* The constructor should have buffersize passed as this value */
#define FIXED_BUFFER_SIZE 1024

NpyIter_IterNextFunc *iternext = NpyIter_GetIterNext(iter, NULL);
char** dataptr = NpyIter_GetDataPtrArray(iter);
npy_intp* stride = NpyIter_GetInnerStrideArray(iter);
npy_intp* size_ptr = NpyIter_GetInnerLoopSizePtr(iter), size;
npy_intp i, iop, nop = NpyIter_GetNOp(iter);

/* One loop with a fixed inner size */
size = *size_ptr;
while (size == FIXED_BUFFER_SIZE) {
  /*
  * This loop could be manually unrolled by a factor
  * which divides into FIXED_BUFFER_SIZE
  */
  for (i = 0; i < FIXED_BUFFER_SIZE; ++i) {
    /* use the addresses dataptr[0], ... dataptr[nop-1] */
    for (iop = 0; iop < nop; ++iop) {
      dataptr[iop] += stride[iop];
    }
  }
  iternext();
  size = *size_ptr;
}

/*@ Finish-up loop with variable inner size */
if (size > 0) do {
  size = *size_ptr;
  while (size--) {
    /* use the addresses dataptr[0], ... dataptr[nop-1] */
    for (iop = 0; iop < nop; ++iop) {
      dataptr[iop] += stride[iop];
    }
  }
} while (iternext());

NpyIter_GetMultiIndexFunc *NpyIter_GetGetMultiIndex (NpyIter* iter, char** errmsg)
Returns a function pointer for getting the current multi-index of the iterator. Returns NULL if the iterator is not tracking a multi-index. It is recommended that this function pointer be cached in a local variable before the iteration loop.

Returns NULL if there is an error. If errmsg is non-NULL, no Python exception is set when NPY_FAIL is returned. Instead, *errmsg is set to an error message. When errmsg is non-NULL, the function may be safely called without holding the Python GIL.

char** NpyIter_GetDataPtrArray (NpyIter* iter)
This gives back a pointer to the nop data pointers. If NPY_ITER_EXTERNAL_LOOP was not specified, each data pointer points to the current data item of the iterator. If no inner iteration was specified, it points to the first data item of the inner loop.

This pointer may be cached before the iteration loop, calling iternext will not change it. This function may be safely called without holding the Python GIL.

char** NpyIter_GetInitialDataPtrArray (NpyIter* iter)
Gets the array of data pointers directly into the arrays (never into the buffers), corresponding to iteration index 0.

These pointers are different from the pointers accepted by NpyIter_ResetBasePointers, because the direction along some axes may have been reversed.

This function may be safely called without holding the Python GIL.

npy_intp* NpyIter_GetIndexPtr (NpyIter* iter)
This gives back a pointer to the index being tracked, or NULL if no index is being tracked. It is only useable if one of the flags NPY_ITER_C_INDEX or NPY_ITER_F_INDEX were specified during construction.

When the flag NPY_ITER_EXTERNAL_LOOP is used, the code needs to know the parameters for doing the inner loop. These functions provide that information.
npy_intp* **NpyIter_GetInnerStrideArray** (NpyIter* *iter*)
Returns a pointer to an array of the *n* strides, one for each iterated object, to be used by the inner loop.

This pointer may be cached before the iteration loop, calling *iternext* will not change it. This function may be safely called without holding the Python GIL.

npy_intp* **NpyIter_GetInnerLoopSizePtr** (NpyIter* *iter*)
Returns a pointer to the number of iterations the inner loop should execute.

This address may be cached before the iteration loop, calling *iternext* will not change it. The value itself may change during iteration, in particular if buffering is enabled. This function may be safely called without holding the Python GIL.

void **NpyIter_GetInnerFixedStrideArray** (NpyIter* *iter*, npy_intp* *out_strides*)
Gets an array of strides which are fixed, or will not change during the entire iteration. For strides that may change, the value NPY_MAX_INTP is placed in the stride.

Once the iterator is prepared for iteration (after a reset if NPY_DELAY_BUFALLOC was used), call this to get the strides which may be used to select a fast inner loop function. For example, if the stride is 0, that means the inner loop can always load its value into a variable once, then use the variable throughout the loop, or if the stride equals the itemsize, a contiguous version for that operand may be used.

This function may be safely called without holding the Python GIL.

### 5.6 UFunc API

#### 5.6.1 Constants

**UFUNC_ERR_{HANDLER}**

{HANDLER} can be **IGNORE**, **WARN**, **RAISE**, or **CALL**

**UFUNC_{THING}_{ERR}**

{THING} can be **MASK**, **SHIFT**, or **FPE**, and {ERR} can be **DIVIDEBYZERO**, **OVERFLOW**, **UNDERFLOW**, and **INVALID**.

**PyUFunc_{VALUE}**

{VALUE} can be **One** (1), **Zero** (0), or **None** (-1)

#### 5.6.2 Macros

**NPY_LOOP_BEGIN_THREADS**

Used in universal function code to only release the Python GIL if loop->obj is not true (i.e. this is not an OBJECT array loop). Requires use of **NPY_BEGIN_THREADS_DEF** in variable declaration area.

**NPY_LOOP_END_THREADS**

Used in universal function code to re-acquire the Python GIL if it was released (because loop->obj was not true).

**UFUNC_CHECK_ERROR** (loop)

A macro used internally to check for errors and goto fail if found. This macro requires a fail label in the current code block. The loop variable must have at least members (obj, errormask, and errorobj). If loop->obj is nonzero, then PyErr_Occurred () is called (meaning the GIL must be held). If loop->obj is zero, then if loop->errormask is nonzero, PyUFunc_checkfperr is called with arguments loop->errormask and loop->errorobj. If the result of this check of the IEEE floating point registers is true then the code redirects to the fail label which must be defined.
**UFUNC_CHECK_STATUS** (ret)

Deprecated: use npy_clear_floatstatus from npy_math.h instead.

A macro that expands to platform-dependent code. The `ret` variable can can be any integer. The `UFUNC_FPE_{ERR}` bits are set in `ret` according to the status of the corresponding error flags of the floating point processor.

### 5.6.3 Functions

**PyObject** PyUFunc_FromFuncAndData(PyUFuncGenericFunction* func,
void** data, char* types, int ntypes, int nin, int nout, int identity,
char* name, char* doc, int check_return)

Create a new broadcasting universal function from required variables. Each ufunc builds around the notion of an element-by-element operation. Each ufunc object contains pointers to 1-d loops implementing the basic functionality for each supported type.

**Note:** The `func`, `data`, `types`, `name`, and `doc` arguments are not copied by `PyUFunc_FromFuncAndData`. The caller must ensure that the memory used by these arrays is not freed as long as the ufunc object is alive.

#### Parameters

- **func** – Must to an array of length `ntypes` containing `PyUFuncGenericFunction` items. These items are pointers to functions that actually implement the underlying (element-by-element) function \( N \) times.
- **data** – Should be NULL or a pointer to an array of size `ntypes`. This array may contain arbitrary extra-data to be passed to the corresponding 1-d loop function in the `func` array.
- **types** – Must be of length \((nin + nout) \times ntypes\), and it contains the data-types (built-in only) that the corresponding function in the `func` array can deal with.
- **ntypes** – How many different data-type “signatures” the ufunc has implemented.
- **nin** – The number of inputs to this operation.
- **nout** – The number of outputs
- **name** – The name for the ufunc. Specifying a name of ‘add’ or ‘multiply’ enables a special behavior for integer-typed reductions when no dtype is given. If the input type is an integer (or boolean) data type smaller than the size of the `int`_ data type, it will be internally upcast to the `int`_ (or `uint`) data type.
- **doc** – Allows passing in a documentation string to be stored with the ufunc. The documentation string should not contain the name of the function or the calling signature as that will be dynamically determined from the object and available when accessing the `__doc__` attribute of the ufunc.
- **check_return** – Unused and present for backwards compatibility of the C-API. A corresponding `check_return` integer does exist in the ufunc structure and it does get set with this value when the ufunc object is created.

int PyUFunc_RegisterLoopForType(PyUFuncObject* ufunc,
int usertype, PyUFuncGenericFunction function, int* arg_types, void* data)

This function allows the user to register a 1-d loop with an already-created ufunc to be used whenever the
ufunc is called with any of its input arguments as the user-defined data-type. This is needed in order to make
ufuncs work with built-in data-types. The data-type must have been previously registered with the numpy
system. The loop is passed in as function. This loop can take arbitrary data which should be passed in as data.
The data-types the loop requires are passed in as arg_types which must be a pointer to memory at least as large
as ufunc->nargs.

```c
int PyUFunc_RegisterLoopForDescr(PyUFuncObject* ufunc,
PyArray_Descr* userdtype, PyUFuncGenericFunction function,
PyArray_Descr** arg_dtypes, void* data)
```

This function behaves like PyUFunc_RegisterLoopForType above, except that it allows the user to register a
1-d loop using PyArray_Descr objects instead of dtype type num values. This allows a 1-d loop to be registered
for structured array data-dtypes and custom data-types instead of scalar data-types.

```c
int PyUFunc_ReplaceLoopBySignature(PyUFuncObject* ufunc,
PyUFuncGenericFunction newfunc, int* signature,
PyUFuncGenericFunction* oldfunc)
```

Replace a 1-d loop matching the given signature in the already-created ufunc with the new 1-d loop newfunc.
Return the old 1-d loop function in oldfunc. Return 0 on success and -1 on failure. This function works only
with built-in types (use PyUFunc_RegisterLoopForType for user-defined types). A signature is an array
of data-type numbers indicating the inputs followed by the outputs assumed by the 1-d loop.

```c
int PyUFunc_GenericFunction(PyUFuncObject* self,
PyObject* args, PyObject* kwds, PyArrayObject** mps)
```

A generic ufunc call. The ufunc is passed in as self, the arguments to the ufunc as args and kwds. The mps
argument is an array of PyArrayObject pointers whose values are discarded and which receive the converted
input arguments as well as the ufunc outputs when success is returned. The user is responsible for managing
this array and receives a new reference for each array in mps. The total number of arrays in mps is given by self
->nin + self->nout.

Returns 0 on success, -1 on error.

```c
int PyUFunc_checkfperr (int errmask, PyObject* errobj)
```

A simple interface to the IEEE error-flag checking support. The errmask argument is a mask of
UFUNC_MASK_{ERR} bitmasks indicating which errors to check for (and how to check for them). The errobj must be a Python tuple with two elements: a string containing the name which will be used in any
communication of error and either a callable Python object (call-back function) or Py_None. The callable
object will only be used if UFUNC_ERR_CALL is set as the desired error checking method. This routine
manages the GIL and is safe to call even after releasing the GIL. If an error in the IEEE-compatible hardware
is determined a -1 is returned, otherwise a 0 is returned.

```c
void PyUFunc_clearfperr ()
```

Clear the IEEE error flags.

```c
void PyUFunc_GetPyValues(char* name, int* bufsize,
int* errmask, PyObject** errobj)
```

Get the Python values used for ufunc processing from the thread-local storage area unless the defaults have
been set in which case the name lookup is bypassed. The name is placed as a string in the first element of
*errobj. The second element is the looked-up function to call on error callback. The value of the looked-up
buffer-size to use is passed into bufsize, and the value of the error mask is placed into errmask.
5.6.4 Generic functions

At the core of every ufunc is a collection of type-specific functions that defines the basic functionality for each of the supported types. These functions must evaluate the underlying function $N \geq 1$ times. Extra-data may be passed in that may be used during the calculation. This feature allows some general functions to be used as these basic looping functions. The general function has all the code needed to point variables to the right place and set up a function call. The general function assumes that the actual function to call is passed in as the extra data and calls it with the correct values. All of these functions are suitable for placing directly in the array of functions stored in the functions member of the PyUFuncObject structure.

```c
void PyUFunc_f_f_As_d_d(char** args, npy_intp* dimensions,
    npy_intp* steps, void* func)

void PyUFunc_d_d(char** args, npy_intp* dimensions,
    npy_intp* steps, void* func)

void PyUFunc_f_f(char** args, npy_intp* dimensions,
    npy_intp* steps, void* func)

void PyUFunc_g_g(char** args, npy_intp* dimensions,
    npy_intp* steps, void* func)

void PyUFunc_F_F_As_D_D(char** args, npy_intp* dimensions,
    npy_intp* steps, void* func)

void PyUFunc_F_F(char** args, npy_intp* dimensions,
    npy_intp* steps, void* func)

void PyUFunc_D_D(char** args, npy_intp* dimensions,
    npy_intp* steps, void* func)

void PyUFunc_G_G(char** args, npy_intp* dimensions,
    npy_intp* steps, void* func)

void PyUFunc_e_e(char** args, npy_intp* dimensions,
    npy_intp* steps, void* func)

void PyUFunc_e_e_As_f_f(char** args, npy_intp* dimensions,
    npy_intp* steps, void* func)
```

5.6. UFunc API
void PyUFunc_e_e_As_d_d(char** args, npy_intp* dimensions,
npy_intp* steps, void* func)

Type specific, core 1-d functions for ufuncs where each calculation is obtained by calling a function taking
one input argument and returning one output. This function is passed in func. The letters correspond to
dtypechar's of the supported data types ( e - half, f - float, d - double, g - long double, F - cfloat, D - cdouble, G - clongdouble). The argument func must support the same signature. The _As_X_X variants assume ndarray's
of one data type but cast the values to use an underlying function that takes a different data type. Thus,
PyUFunc_f_f_As_d_d uses ndarrays of data type NPY_FLOAT but calls out to a C-function that takes
double and returns double.

void PyUFunc_ff_f_As_dd_d(char** args, npy_intp* dimensions,
npy_intp* steps, void* func)

void PyUFunc_ff_f(char** args, npy_intp* dimensions,
npy_intp* steps, void* func)

void PyUFunc_dd_d(char** args, npy_intp* dimensions,
npy_intp* steps, void* func)

void PyUFunc_gg_g(char** args, npy_intp* dimensions,
npy_intp* steps, void* func)

void PyUFunc_FF_F_As_DD_D(char** args, npy_intp* dimensions,
npy_intp* steps, void* func)

void PyUFunc_DD_D(char** args, npy_intp* dimensions,
npy_intp* steps, void* func)

void PyUFunc_FF_F(char** args, npy_intp* dimensions,
npy_intp* steps, void* func)

void PyUFunc_GG_G(char** args, npy_intp* dimensions,
npy_intp* steps, void* func)

void PyUFunc_ee_e(char** args, npy_intp* dimensions,
npy_intp* steps, void* func)

void PyUFunc_ee_e_As_ff_f(char** args, npy_intp* dimensions,
npy_intp* steps, void* func)

void PyUFunc_ee_e_As_dd_d(char** args, npy_intp* dimensions,
  npy_intp* steps, void* func)

Type specific, core 1-d functions for ufuncs where each calculation is obtained by calling a function taking two input arguments and returning one output. The underlying function to call is passed in as func. The letters correspond to dtypechar's of the specific data type supported by the general-purpose function. The argument func must support the corresponding signature. The _As_XX_X variants assume ndarrays of one data type but cast the values at each iteration of the loop to use the underlying function that takes a different data type.

void PyUFunc_O_O(char** args, npy_intp* dimensions,
  npy_intp* steps, void* func)

void PyUFunc ОО_O(char** args, npy_intp* dimensions,
  npy_intp* steps, void* func)

One-input, one-output, and two-input, one-output core 1-d functions for the NPY_OBJECT data type. These functions handle reference count issues and return early on error. The actual function to call is func and it must accept calls with the signature (PyObject*) (PyObject*) for PyUFunc_O_O or (PyObject*) (PyObject*, PyObject*) for PyUFunc ОО_O.

void PyUFunc_O_O_method(char** args, npy_intp* dimensions,
  npy_intp* steps, void* func)

This general purpose 1-d core function assumes that func is a string representing a method of the input object. For each iteration of the loop, the Python object is extracted from the array and its func method is called returning the result to the output array.

void PyUFunc ОО_O_method(char** args, npy_intp* dimensions,
  npy_intp* steps, void* func)

This general purpose 1-d core function assumes that func is a string representing a method of the input object that takes one argument. The first argument in args is the method whose function is called, the second argument in args is the argument passed to the function. The output of the function is stored in the third entry of args.

void PyUFunc_On_Om(char** args, npy_intp* dimensions,
  npy_intp* steps, void* func)

This is the 1-d core function used by the dynamic ufuncs created by umath.frompyfunc(function, nin, nout). In this case func is a pointer to a PyUFunc_PyFuncData structure which has definition

PyUFunc_PyFuncData

typedef struct {
    int nin;
    int nout;
    PyObject *callable;
} PyUFunc_PyFuncData;

At each iteration of the loop, the nin input objects are extracted from their object arrays and placed into an argument tuple, the Python callable is called with the input arguments, and the nout outputs are placed into their object arrays.
5.6.5 Importing the API

PY_UFUNC_UNIQUE_SYMBOL

NO_IMPORT_UFUNC

void import_ufunc (void)

These are the constants and functions for accessing the ufunc C-API from extension modules in precisely the same way as the array C-API can be accessed. The import_ufunc () function must always be called (in the initialization subroutine of the extension module). If your extension module is in one file then that is all that is required. The other two constants are useful if your extension module makes use of multiple files. In that case, define PY_UFUNC_UNIQUE_SYMBOL to something unique to your code and then in source files that do not contain the module initialization function but still need access to the UFUNC API, define PY_UFUNC_UNIQUE_SYMBOL to the same name used previously and also define NO_IMPORT_UFUNC.

The C-API is actually an array of function pointers. This array is created (and pointed to by a global variable) by import_ufunc. The global variable is either statically defined or allowed to be seen by other files depending on the state of PY_UFUNC_UNIQUE_SYMBOL and NO_IMPORT_UFUNC.

5.7 Generalized Universal Function API

There is a general need for looping over not only functions on scalars but also over functions on vectors (or arrays). This concept is realized in Numpy by generalizing the universal functions (ufuncs). In regular ufuncs, the elementary function is limited to element-by-element operations, whereas the generalized version (gufuncs) supports “sub-array” by “sub-array” operations. The Perl vector library PDL provides a similar functionality and its terms are re-used in the following.

Each generalized ufunc has information associated with it that states what the “core” dimensionality of the inputs is, as well as the corresponding dimensionality of the outputs (the element-wise ufuncs have zero core dimensions). The list of the core dimensions for all arguments is called the “signature” of a ufunc. For example, the ufunc numpy.add has signature (),()->() defining two scalar inputs and one scalar output.

Another example is the function inner1d(a,b) with a signature of (i),(i)->(). This applies the inner product along the last axis of each input, but keeps the remaining indices intact. For example, where a is of shape (3,5,N) and b is of shape (5,N), this will return an output of shape (3,5). The underlying elementary function is called 3 * 5 times. In the signature, we specify one core dimension (i) for each input and zero core dimensions () for the output, since it takes two 1-d arrays and returns a scalar. By using the same name i, we specify that the two corresponding dimensions should be of the same size (or one of them is of size 1 and will be broadcasted).

The dimensions beyond the core dimensions are called “loop” dimensions. In the above example, this corresponds to (3,5).

The usual numpy “broadcasting” rules apply, where the signature determines how the dimensions of each input/output object are split into core and loop dimensions:

1. While an input array has a smaller dimensionality than the corresponding number of core dimensions, 1’s are prepended to its shape.
2. The core dimensions are removed from all inputs and the remaining dimensions are broadcasted; defining the loop dimensions.
3. The output is given by the loop dimensions plus the output core dimensions.
5.7.1 Definitions

Elementary Function
Each ufunc consists of an elementary function that performs the most basic operation on the smallest portion of array arguments (e.g. adding two numbers is the most basic operation in adding two arrays). The ufunc applies the elementary function multiple times on different parts of the arrays. The input/output of elementary functions can be vectors; e.g., the elementary function of inner1d takes two vectors as input.

Signature
A signature is a string describing the input/output dimensions of the elementary function of a ufunc. See section below for more details.

Core Dimension
The dimensionality of each input/output of an elementary function is defined by its core dimensions (zero core dimensions correspond to a scalar input/output). The core dimensions are mapped to the last dimensions of the input/output arrays.

Dimension Name
A dimension name represents a core dimension in the signature. Different dimensions may share a name, indicating that they are of the same size (or are broadcastable).

Dimension Index
A dimension index is an integer representing a dimension name. It enumerates the dimension names according to the order of the first occurrence of each name in the signature.

5.7.2 Details of Signature

The signature defines “core” dimensionality of input and output variables, and thereby also defines the contraction of the dimensions. The signature is represented by a string of the following format:

- Core dimensions of each input or output array are represented by a list of dimension names in parentheses, \((i_1, \ldots, i_N)\); a scalar input/output is denoted by \((\)\). Instead of \(i_1, i_2, \) etc, one can use any valid Python variable name.
- Dimension lists for different arguments are separated by \(\)\,.\) Input/output arguments are separated by \(\rightarrow\).
- If one uses the same dimension name in multiple locations, this enforces the same size (or broadcastable size) of the corresponding dimensions.

The formal syntax of signatures is as follows:

\[
\begin{align*}
\text{<Signature>} & ::= \text{<Input arguments>} \rightarrow \text{<Output arguments>} \\
\text{<Input arguments>} & ::= \text{<Argument list>} \\
\text{<Output arguments>} & ::= \text{<Argument list>} \\
\text{<Argument list>} & ::= \text{nil} | \text{<Argument>} | \text{<Argument>} \rightarrow \text{<Argument list>} \\
\text{<Argument>} & ::= "(" \text{<Core dimension list>} ")" \\
\text{<Core dimension list>} & ::= \text{nil} | \text{<Dimension name>} | \text{<Dimension name>} \rightarrow \text{<Core dimension list>} \\
\text{<Dimension name>} & ::= \text{valid Python variable name}
\end{align*}
\]

Notes:
1. All quotes are for clarity.
2. Core dimensions that share the same name must be broadcastable, as the two \(i\) in our example above. Each dimension name typically corresponding to one level of looping in the elementary function’s implementation.
3. White spaces are ignored.
Here are some examples of signatures:

<table>
<thead>
<tr>
<th>Function</th>
<th>Signature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>add</td>
<td>() -&gt; ()</td>
<td></td>
</tr>
<tr>
<td>inner1d</td>
<td>(i), (i) -&gt; ()</td>
<td></td>
</tr>
<tr>
<td>sum1d</td>
<td>(i) -&gt; ()</td>
<td></td>
</tr>
<tr>
<td>dot2d</td>
<td>(m,n), (n,p) -&gt; (m,)</td>
<td>matrix multiplication</td>
</tr>
<tr>
<td>outer_inner</td>
<td>(i,t), (j,t) -&gt; (i,)</td>
<td>inner over the last dimension, outer over the second to last, and loop/broadcast over the rest.</td>
</tr>
</tbody>
</table>

### 5.7.3 C-API for implementing Elementary Functions

The current interface remains unchanged, and `PyUFunc_FromFuncAndData` can still be used to implement (specialized) ufuncs, consisting of scalar elementary functions.

One can use `PyUFunc_FromFuncAndDataAndSignature` to declare a more general ufunc. The argument list is the same as `PyUFunc_FromFuncAndData`, with an additional argument specifying the signature as a C string.

Furthermore, the callback function is of the same type as before, `void (*foo)(char **args, intp *dimensions, intp *steps, void *func)`. When invoked, `args` is a list of length `nargs` containing the data of all input/output arguments. For a scalar elementary function, `steps` is also of length `nargs`, denoting the strides used for the arguments. `dimensions` is a pointer to a single integer defining the size of the axis to be looped over.

For a non-trivial signature, `dimensions` will also contain the sizes of the core dimensions as well, starting at the second entry. Only one size is provided for each unique dimension name and the sizes are given according to the first occurrence of a dimension name in the signature.

The first `nargs` elements of `steps` remain the same as for scalar ufuncs. The following elements contain the strides of all core dimensions for all arguments in order.

For example, consider a ufunc with signature `(i, j), (i) -> ()`. In this case, `args` will contain three pointers to the data of the input/output arrays `a`, `b`, `c`. Furthermore, `dimensions` will be `[N, I, J]` to define the size of `N` of the loop and the sizes `I` and `J` for the core dimensions `i` and `j`. Finally, `steps` will be `[a_N, b_N, c_N, a_i, a_j, b_i]`, containing all necessary strides.

### 5.8 Numpy core libraries

New in version 1.3.0.

Starting from numpy 1.3.0, we are working on separating the pure C, “computational” code from the python dependent code. The goal is twofolds: making the code cleaner, and enabling code reuse by other extensions outside numpy (scipy, etc...).

#### 5.8.1 Numpy core math library

The numpy core math library (`npymath`) is a first step in this direction. This library contains most math-related C99 functionality, which can be used on platforms where C99 is not well supported. The core math functions have the same API as the C99 ones, except for the `npy_` * prefix.

The available functions are defined in `<numpy/npy_math.h>` - please refer to this header when in doubt.
Floating point classification

**NPY_NAN**
This macro is defined to a NaN (Not a Number), and is guaranteed to have the signbit unset (`positive’ NaN). The corresponding single and extension precision macro are available with the suffix F and L.

**NPY_INFINITY**
This macro is defined to a positive inf. The corresponding single and extension precision macro are available with the suffix F and L.

**NPY_PZERO**
This macro is defined to positive zero. The corresponding single and extension precision macro are available with the suffix F and L.

**NPY_NZERO**
This macro is defined to negative zero (that is with the sign bit set). The corresponding single and extension precision macro are available with the suffix F and L.

```c
int npy_isnan(x)
This is a macro, and is equivalent to C99 isnan: works for single, double and extended precision, and return a non 0 value is x is a NaN.
```

```c
int npy_isfinite(x)
This is a macro, and is equivalent to C99 isfinite: works for single, double and extended precision, and return a non 0 value is x is neither a NaN nor an infinity.
```

```c
int npy_isinf(x)
This is a macro, and is equivalent to C99 isinf: works for single, double and extended precision, and return a non 0 value is x is infinite (positive and negative).
```

```c
int npy_signbit(x)
This is a macro, and is equivalent to C99 signbit: works for single, double and extended precision, and return a non 0 value is x has the signbit set (that is the number is negative).
```

```c
double npy_copysign(double x, double y)
This is a function equivalent to C99 copysign: return x with the same sign as y. Works for any value, including inf and nan. Single and extended precisions are available with suffix f and l.
```

New in version 1.4.0.

Useful math constants

The following math constants are available in npy_math.h. Single and extended precision are also available by adding the F and L suffixes respectively.

**NPY_E**
Base of natural logarithm (e)

**NPY_LOG2E**
Logarithm to base 2 of the Euler constant (\( \frac{\ln(e)}{\ln(2)} \))

**NPY_LOG10E**
Logarithm to base 10 of the Euler constant (\( \frac{\ln(e)}{\ln(10)} \))

**NPY_LOGE2**
Natural logarithm of 2 (\( \ln(2) \))

**NPY_LOGE10**
Natural logarithm of 10 (\( \ln(10) \))
NumPy Reference, Release 1.9.2

**NPY_PI**
- Pi ($\pi$)

**NPY_PI_2**
- Pi divided by 2 ($\frac{\pi}{2}$)

**NPY_PI_4**
- Pi divided by 4 ($\frac{\pi}{4}$)

**NPY_1_PI**
- Reciprocal of pi ($\frac{1}{\pi}$)

**NPY_2_PI**
- Two times the reciprocal of pi ($\frac{2}{\pi}$)

**NPY_EULER**

The Euler constant

$$\lim_{n \to \infty} \left( \sum_{k=1}^{n} \frac{1}{k} - \ln n \right)$$

---

**Low-level floating point manipulation**

Those can be useful for precise floating point comparison.

double **npy_nextafter** (double x, double y)
- This is a function equivalent to C99 nextafter: return next representable floating point value from x in the direction of y. Single and extended precisions are available with suffix f and l.
  - New in version 1.4.0.

double **npy_spacing** (double x)
- This is a function equivalent to Fortran intrinsic. Return distance between x and next representable floating point value from x, e.g. spacing(1) == eps. spacing of nan and +/- inf return nan. Single and extended precisions are available with suffix f and l.
  - New in version 1.4.0.

void **npy_set_floatstatus_divbyzero** ()
- Set the divide by zero floating point exception
  - New in version 1.6.0.

void **npy_set_floatstatus_overflow** ()
- Set the overflow floating point exception
  - New in version 1.6.0.

void **npy_set_floatstatus_underflow** ()
- Set the underflow floating point exception
  - New in version 1.6.0.

void **npy_set_floatstatus_invalid** ()
- Set the invalid floating point exception
  - New in version 1.6.0.

int **npy_get_floatstatus** ()
- Get floating point status. Returns a bitmask with following possible flags:
  - NPY_FPE_DIVIDEBYZERO
  - NPY_FPE_OVERFLOW
Numpy Reference, Release 1.9.2

- NPY_FPE_UNDERFLOW
- NPY_FPE_INVALID

New in version 1.9.0.

int npy_clear_floatstatus()
Clears the floating point status. Returns the previous status mask.

New in version 1.9.0.

Complex functions

New in version 1.4.0.

C99-like complex functions have been added. Those can be used if you wish to implement portable C extensions. Since we still support platforms without C99 complex type, you need to restrict to C90-compatible syntax, e.g.:

/* a = 1 + 2i */
np y_complex a = npy_cpack(1, 2);
npy_complex b;

b = npy_log(a);

Linking against the core math library in an extension

New in version 1.4.0.

To use the core math library in your own extension, you need to add the npymath compile and link options to your extension in your setup.py:

```python
>>> from numpy.distutils.misc_util import get_info
>>> info = get_info('npymath')
>>> config.add_extension('foo', sources=['foo.c'], extra_info=info)
```

In other words, the usage of info is exactly the same as when using blas_info and co.

Half-precision functions

New in version 2.0.0.

The header file <numpy/halffloat.h> provides functions to work with IEEE 754-2008 16-bit floating point values. While this format is not typically used for numerical computations, it is useful for storing values which require floating point but do not need much precision. It can also be used as an educational tool to understand the nature of floating point round-off error.

Like for other types, NumPy includes a typedef npy_half for the 16 bit float. Unlike for most of the other types, you cannot use this as a normal type in C, since is is a typedef for npy_uint16. For example, 1.0 looks like 0x3c00 to C, and if you do an equality comparison between the different signed zeros, you will get -0.0 != 0.0 (0x8000 != 0x0000), which is incorrect.

For these reasons, NumPy provides an API to work with npy_half values accessible by including <numpy/halffloat.h> and linking to 'npymath'. For functions that are not provided directly, such as the arithmetic operations, the preferred method is to convert to float or double and back again, as in the following example.
npy_half sum(int n, npy_half *array) {
    float ret = 0;
    while (n--) {
        ret += npy_half_to_float(*array++);
    }
    return npy_float_to_half(ret);
}

External Links:
- 754-2008 IEEE Standard for Floating-Point Arithmetic
- OpenGL Half Float Pixel Support
- The OpenEXR image format.

NPY_HALF_ZERO
This macro is defined to positive zero.

NPY_HALF_PZERO
This macro is defined to positive zero.

NPY_HALF_NZERO
This macro is defined to negative zero.

NPY_HALF_ONE
This macro is defined to 1.0.

NPY_HALF_NEGONE
This macro is defined to -1.0.

NPY_HALF_PINF
This macro is defined to +inf.

NPY_HALF_NINF
This macro is defined to -inf.

NPY_HALF_NAN
This macro is defined to a NaN value, guaranteed to have its sign bit unset.

float npy_half_to_float (npy_half h)
Converts a half-precision float to a single-precision float.

double npy_half_to_double (npy_half h)
Converts a half-precision float to a double-precision float.

npy_half npy_float_to_half (float f)
Converts a single-precision float to a half-precision float. The value is rounded to the nearest representable half, with ties going to the nearest even. If the value is too small or too big, the system’s floating point underflow or overflow bit will be set.

npy_half npy_double_to_half (double d)
Converts a double-precision float to a half-precision float. The value is rounded to the nearest representable half, with ties going to the nearest even. If the value is too small or too big, the system’s floating point underflow or overflow bit will be set.

int npy_half_eq (npy_half h1, npy_half h2)
Compares two half-precision floats (h1 == h2).

int npy_half_ne (npy_half h1, npy_half h2)
Compares two half-precision floats (h1 != h2).
int **npy_half_le** (npy_half h1, npy_half h2)
   Compares two half-precision floats (h1 <= h2).

int **npy_half_lt** (npy_half h1, npy_half h2)
   Compares two half-precision floats (h1 < h2).

int **npy_half_ge** (npy_half h1, npy_half h2)
   Compares two half-precision floats (h1 >= h2).

int **npy_half_gt** (npy_half h1, npy_half h2)
   Compares two half-precision floats (h1 > h2).

int **npy_half_eq_nonan** (npy_half h1, npy_half h2)
   Compares two half-precision floats that are known to not be NaN (h1 == h2). If a value is NaN, the result is undefined.

int **npy_half_lt_nonan** (npy_half h1, npy_half h2)
   Compares two half-precision floats that are known to not be NaN (h1 < h2). If a value is NaN, the result is undefined.

int **npy_half_le_nonan** (npy_half h1, npy_half h2)
   Compares two half-precision floats that are known to not be NaN (h1 <= h2). If a value is NaN, the result is undefined.

int **npy_half_iszero** (npy_half h)
   Tests whether the half-precision float has a value equal to zero. This may be slightly faster than calling npy_half_eq(h, NPY_ZERO).

int **npy_half_isnan** (npy_half h)
   Tests whether the half-precision float is a NaN.

int **npy_half_isinf** (npy_half h)
   Tests whether the half-precision float is plus or minus Inf.

int **npy_half_isfinite** (npy_half h)
   Tests whether the half-precision float is finite (not NaN or Inf).

int **npy_half_signbit** (npy_half h)
   Returns 1 if h is negative, 0 otherwise.

**npy_half** npy_half_copysign (npy_half x, npy_half y)
   Returns the value of x with the sign bit copied from y. Works for any value, including Inf and NaN.

**npy_half** npy_half_spacing (npy_half h)
   This is the same for half-precision float as npy_spacing and npy_spacingf described in the low-level floating point section.

**npy_half** npy_half_nextafter (npy_half x, npy_half y)
   This is the same for half-precision float as npy_nextafter and npy_nextafterf described in the low-level floating point section.

**npy_uint16** npy_floatbits_to_halfbits (npy_uint32 f)
   Low-level function which converts a 32-bit single-precision float, stored as a uint32, into a 16-bit half-precision float.

**npy_uint16** npy_doublebits_to_halfbits (npy_uint64 d)
   Low-level function which converts a 64-bit double-precision float, stored as a uint64, into a 16-bit half-precision float.

**npy_uint32** npy_halfbits_to_floatbits (npy_uint16 h)
   Low-level function which converts a 16-bit half-precision float into a 32-bit single-precision float, stored as a uint32.
npy_uint64 **npy_halfbits_to_doublebits**(npy_uint16 h)

Low-level function which converts a 16-bit half-precision float into a 64-bit double-precision float, stored as a uint64.

## 5.9 C API Deprecations

### 5.9.1 Background

The API exposed by NumPy for third-party extensions has grown over years of releases, and has allowed programmers to directly access NumPy functionality from C. This API can be best described as “organic”. It has emerged from multiple competing desires and from multiple points of view over the years, strongly influenced by the desire to make it easy for users to move to NumPy from Numeric and Numarray. The core API originated with Numeric in 1995 and there are patterns such as the heavy use of macros written to mimic Python’s C-API as well as account for compiler technology of the late 90’s. There is also only a small group of volunteers who have had very little time to spend on improving this API.

There is an ongoing effort to improve the API. It is important in this effort to ensure that code that compiles for NumPy 1.X continues to compile for NumPy 1.X. At the same time, certain API’s will be marked as deprecated so that future-looking code can avoid these API’s and follow better practices.

Another important role played by deprecation markings in the C API is to move towards hiding internal details of the NumPy implementation. For those needing direct, easy, access to the data of ndarrays, this will not remove this ability. Rather, there are many potential performance optimizations which require changing the implementation details, and NumPy developers have been unable to try them because of the high value of preserving ABI compatibility. By deprecating this direct access, we will in the future be able to improve NumPy’s performance in ways we cannot presently.

### 5.9.2 Deprecation Mechanism NPY_NO_DEPRECATED_API

In C, there is no equivalent to the deprecation warnings that Python supports. One way to do deprecations is to flag them in the documentation and release notes, then remove or change the deprecated features in a future major version (NumPy 2.0 and beyond). Minor versions of NumPy should not have major C-API changes, however, that prevent code that worked on a previous minor release. For example, we will do our best to ensure that code that compiled and worked on NumPy 1.4 should continue to work on NumPy 1.7 (but perhaps with compiler warnings).

To use the NPY_NO_DEPRECATED_API mechanism, you need to #define it to the target API version of NumPy before #including any NumPy headers. If you want to confirm that your code is clean against 1.7, use:

```
#define NPY_NO_DEPRECATED_API NPY_1_7_API_VERSION
```

On compilers which support a #warning mechanism, NumPy issues a compiler warning if you do not define the symbol NPY_NO_DEPRECATED_API. This way, the fact that there are deprecations will be flagged for third-party developers who may not have read the release notes closely.
6.1 Numpy C Code Explanations

Fanaticism consists of redoubling your efforts when you have forgotten your aim. — George Santayana

An authority is a person who can tell you more about something than you really care to know. — Unknown

This Chapter attempts to explain the logic behind some of the new pieces of code. The purpose behind these explanations is to enable somebody to be able to understand the ideas behind the implementation somewhat more easily than just staring at the code. Perhaps in this way, the algorithms can be improved on, borrowed from, and/or optimized.

6.1.1 Memory model

One fundamental aspect of the ndarray is that an array is seen as a “chunk” of memory starting at some location. The interpretation of this memory depends on the stride information. For each dimension in an \( N \)-dimensional array, an integer (stride) dictates how many bytes must be skipped to get to the next element in that dimension. Unless you have a single-segment array, this stride information must be consulted when traversing through an array. It is not difficult to write code that accepts strides, you just have to use (char *) pointers because strides are in units of bytes. Keep in mind also that strides do not have to be unit-multiples of the element size. Also, remember that if the number of dimensions of the array is 0 (sometimes called a rank-0 array), then the strides and dimensions variables are NULL.

Besides the structural information contained in the strides and dimensions members of the PyArrayObject, the flags contain important information about how the data may be accessed. In particular, the NPY_ARRAY_ALIGNED flag is set when the memory is on a suitable boundary according to the data-type array. Even if you have a contiguous chunk of memory, you cannot just assume it is safe to dereference a data-type-specific pointer to an element. Only if the NPY_ARRAY_ALIGNED flag is set is this a safe operation (on some platforms it will work but on others, like Solaris, it will cause a bus error). The NPY_ARRAY_WRITEABLE should also be ensured if you plan on writing to the memory area of the array. It is also possible to obtain a pointer to an unwritable memory area. Sometimes, writing to the memory area when the NPY_ARRAY_WRITEABLE flag is not set will just be rude. Other times it can cause program crashes (e.g. a data-area that is a read-only memory-mapped file).

6.1.2 Data-type encapsulation

The data-type is an important abstraction of the ndarray. Operations will look to the data-type to provide the key functionality that is needed to operate on the array. This functionality is provided in the list of function pointers pointed to by the ‘f’ member of the PyArray_Descr structure. In this way, the number of data-types can be extended simply by providing a PyArray_Descr structure with suitable function pointers in the ‘f’ member. For built-in types there are some optimizations that by-pass this mechanism, but the point of the data-type abstraction is to allow new data-types to be added.
One of the built-in data-types, the void data-type allows for arbitrary records containing 1 or more fields as elements of the array. A field is simply another data-type object along with an offset into the current record. In order to support arbitrarily nested fields, several recursive implementations of data-type access are implemented for the void type. A common idiom is to cycle through the elements of the dictionary and perform a specific operation based on the data-type object stored at the given offset. These offsets can be arbitrary numbers. Therefore, the possibility of encountering mis-aligned data must be recognized and taken into account if necessary.

### 6.1.3 N-D Iterators

A very common operation in much of NumPy code is the need to iterate over all the elements of a general, strided, N-dimensional array. This operation of a general-purpose N-dimensional loop is abstracted in the notion of an iterator object. To write an N-dimensional loop, you only have to create an iterator object from an ndarray, work with the dataptr member of the iterator object structure and call the macro `PyArray_ITER_NEXT` (it) on the iterator object to move to the next element. The “next” element is always in C-contiguous order. The macro works by first special casing the C-contiguous, 1-D, and 2-D cases which work very simply.

For the general case, the iteration works by keeping track of a list of coordinate counters in the iterator object. At each iteration, the last coordinate counter is increased (starting from 0). If this counter is smaller then one less than the size of the array in that dimension (a pre-computed and stored value), then the counter is increased and the dataptr member is increased by the strides in that dimension and the macro ends. If the end of a dimension is reached, the counter for the last dimension is reset to zero and the dataptr is moved back to the beginning of that dimension by subtracting the strides value times one less than the number of elements in that dimension (this is also pre-computed and stored in the backstrides member of the iterator object). In this case, the macro does not end, but a local dimension counter is decremented so that the next-to-last dimension replaces the role that the last dimension played and the previously-described tests are executed again on the next-to-last dimension. In this way, the dataptr is adjusted appropriately for arbitrary striding.

The coordinates member of the `PyArrayIterObject` structure maintains the current N-d counter unless the underlying array is C-contiguous in which case the coordinate counting is by-passed. The index member of the `PyArrayIterObject` keeps track of the current flat index of the iterator. It is updated by the `PyArray_ITER_NEXT` macro.

### 6.1.4 Broadcasting

In Numeric, broadcasting was implemented in several lines of code buried deep in ufuncobject.c. In NumPy, the notion of broadcasting has been abstracted so that it can be performed in multiple places. Broadcasting is handled by the function `PyArray_Broadcast`. This function requires a `PyArrayMultiIterObject` (or something that is a binary equivalent) to be passed in. The `PyArrayMultiIterObject` keeps track of the broadcasted number of dimensions and size in each dimension along with the total size of the broadcasted result. It also keeps track of the number of arrays being broadcast and a pointer to an iterator for each of the arrays being broadcasted.

The `PyArray_Broadcast` function takes the iterators that have already been defined and uses them to determine the broadcast shape in each dimension (to create the iterators at the same time that broadcasting occurs then use the `PyMultiIter_New` function). Then, the iterators are adjusted so that each iterator thinks it is iterating over an array with the broadcasted size. This is done by adjusting the iterators number of dimensions, and the shape in each dimension. This works because the iterator strides are also adjusted. Broadcasting only adjusts (or adds) length-1 dimensions. For these dimensions, the strides variable is simply set to 0 so that the data-pointer for the iterator over that array doesn’t move as the broadcasting operation operates over the extended dimension.

Broadcasting was always implemented in Numeric using 0-valued strides for the extended dimensions. It is done in exactly the same way in NumPy. The big difference is that now the array of strides is kept track of in a `PyArrayIterObject`, the iterators involved in a broadcasted result are kept track of in a `PyArrayMultiIterObject`, and the `PyArray_BroadCast` call implements the broad-casting rules.
6.1.5 Array Scalars

The array scalars offer a hierarchy of Python types that allow a one-to-one correspondence between the data-type stored in an array and the Python-type that is returned when an element is extracted from the array. An exception to this rule was made with object arrays. Object arrays are heterogeneous collections of arbitrary Python objects. When you select an item from an object array, you get back the original Python object (and not an object array scalar which does exist but is rarely used for practical purposes).

The array scalars also offer the same methods and attributes as arrays with the intent that the same code can be used to support arbitrary dimensions (including 0-dimensions). The array scalars are read-only (immutable) with the exception of the void scalar which can also be written to so that record-array field setting works more naturally (a[0]['f1'] = value).

6.1.6 Advanced (“Fancy”) Indexing

The implementation of advanced indexing represents some of the most difficult code to write and explain. In fact, there are two implementations of advanced indexing. The first works only with 1-D arrays and is implemented to handle expressions involving a.flat[obj]. The second is general-purpose that works for arrays of “arbitrary dimension” (up to a fixed maximum). The one-dimensional indexing approaches were implemented in a rather straightforward fashion, and so it is the general-purpose indexing code that will be the focus of this section.

There is a multi-layer approach to indexing because the indexing code can at times return an array scalar and at other times return an array. The functions with “_nice” appended to their name do this special handling while the function without the _nice appendage always return an array (perhaps a 0-dimensional array). Some special-case optimizations (the index being an integer scalar, and the index being a tuple with as many dimensions as the array) are handled in array_subscript_nice function which is what Python calls when presented with the code “a[obj]:” These optimizations allow fast single-integer indexing, and also ensure that a 0-dimensional array is not created only to be discarded as the array scalar is returned instead. This provides significant speed-up for code that is selecting many scalars out of an array (such as in a loop). However, it is still not faster than simply using a list to store standard Python scalars, because that is optimized by the Python interpreter itself.

After these optimizations, the array_subscript function itself is called. This function first checks for field selection which occurs when a string is passed as the indexing object. Then, 0-D arrays are given special-case consideration. Finally, the code determines whether or not advanced, or fancy, indexing needs to be performed. If fancy indexing is not needed, then standard view-based indexing is performed using code borrowed from Numeric which parses the indexing object and returns the offset into the data-buffer and the dimensions necessary to create a new view of the array. The strides are also changed by multiplying each stride by the step-size requested along the corresponding dimension.

Fancy-indexing check

The fancy_indexing_check routine determines whether or not to use standard view-based indexing or new copy-based indexing. If the indexing object is a tuple, then view-based indexing is assumed by default. Only if the tuple contains an array object or a sequence object is fancy-indexing assumed. If the indexing object is an array, then fancy indexing is automatically assumed. If the indexing object is any other kind of sequence, then fancy-indexing is assumed by default. This is over-ridden to simple indexing if the sequence contains any slice, newaxis, or Ellipsis objects, and no arrays or additional sequences are also contained in the sequence. The purpose of this is to allow the construction of “slicing” sequences which is a common technique for building up code that works in arbitrary numbers of dimensions.

Fancy-indexing implementation

The concept of indexing was also abstracted using the idea of an iterator. If fancy indexing is performed, then a PyArrayMapIterObject is created. This internal object is not exposed to Python. It is created in order to handle
the fancy-indexing at a high-level. Both get and set fancy-indexing operations are implemented using this object. Fancy indexing is abstracted into three separate operations: (1) creating the `PyArrayMapIterObject` from the indexing object, (2) binding the `PyArrayMapIterObject` to the array being indexed, and (3) getting (or setting) the items determined by the indexing object. There is an optimization implemented so that the `PyArrayIterObject` (which has its own less complicated fancy-indexing) is used for indexing when possible.

**Creating the mapping object**

The first step is to convert the indexing objects into a standard form where iterators are created for all of the index array inputs and all Boolean arrays are converted to equivalent integer index arrays (as if nonzero(arr) had been called). Finally, all integer arrays are replaced with the integer 0 in the indexing object and all of the index-array iterators are “broadcast” to the same shape.

**Binding the mapping object**

When the mapping object is created it does not know which array it will be used with so once the index iterators are constructed during mapping-object creation, the next step is to associate these iterators with a particular ndarray. This process interprets any ellipsis and slice objects so that the index arrays are associated with the appropriate axis (the axis indicated by the iteraxis entry corresponding to the iterator for the integer index array). This information is then used to check the indices to be sure they are within range of the shape of the array being indexed. The presence of ellipsis and/or slice objects implies a sub-space iteration that is accomplished by extracting a sub-space view of the array (using the index object resulting from replacing all the integer index arrays with 0) and storing the information about where this sub-space starts in the mapping object. This is used later during mapping-object iteration to select the correct elements from the underlying array.

**Getting (or Setting)**

After the mapping object is successfully bound to a particular array, the mapping object contains the shape of the resulting item as well as iterator objects that will walk through the currently-bound array and either get or set its elements as needed. The walk is implemented using the `PyArray_MapIterNext` function. This function sets the coordinates of an iterator object into the current array to be the next coordinate location indicated by all of the indexing-object iterators while adjusting, if necessary, for the presence of a sub-space. The result of this function is that the dataptr member of the mapping object structure is pointed to the next position in the array that needs to be copied out or set to some value.

When advanced indexing is used to extract an array, an iterator for the new array is constructed and advanced in phase with the mapping object iterator. When advanced indexing is used to place values in an array, a special “broadcasted” iterator is constructed from the object being placed into the array so that it will only work if the values used for setting have a shape that is “broadcastable” to the shape implied by the indexing object.

### 6.1.7 Universal Functions

Universal functions are callable objects that take \( N \) inputs and produce \( M \) outputs by wrapping basic 1-D loops that work element-by-element into full easy-to-use functions that seamlessly implement broadcasting, type-checking and buffered coercion, and output-argument handling. New universal functions are normally created in C, although there is a mechanism for creating ufuncs from Python functions (`frompyfunc`). The user must supply a 1-D loop that implements the basic function taking the input scalar values and placing the resulting scalars into the appropriate output slots as explained in implementation.

**Setup**

Every ufunc calculation involves some overhead related to setting up the calculation. The practical significance of this overhead is that even though the actual calculation of the ufunc is very fast, you will be able to write array and type-specific code that will work faster for small arrays than the ufunc. In particular, using ufuncs to perform many calculations on 0-D arrays will be slower than other Python-based solutions (the silently-imported scalarmath
module exists precisely to give array scalars the look-and-feel of ufunc-based calculations with significantly reduced overhead).

When a ufunc is called, many things must be done. The information collected from these setup operations is stored in a loop-object. This loop object is a C-structure (that could become a Python object but is not initialized as such because it is only used internally). This loop object has the layout needed to be used with PyArray_Broadcast so that the broadcasting can be handled in the same way as it is handled in other sections of code.

The first thing done is to look-up in the thread-specific global dictionary the current values for the buffer-size, the error mask, and the associated error object. The state of the error mask controls what happens when an error-condition is found. It should be noted that checking of the hardware error flags is only performed after each 1-D loop is executed. This means that if the input and output arrays are contiguous and of the correct type so that a single 1-D loop is performed, then the flags may not be checked until all elements of the array have been calculated. Looking up these values in a thread-specific dictionary takes time which is easily ignored for all but very small arrays.

After checking, the thread-specific global variables, the inputs are evaluated to determine how the ufunc should proceed and the input and output arrays are constructed if necessary. Any inputs which are not arrays are converted to arrays (using context if necessary). Which of the inputs are scalars (and therefore converted to 0-D arrays) is noted.

Next, an appropriate 1-D loop is selected from the 1-D loops available to the ufunc based on the input array types. This 1-D loop is selected by trying to match the signature of the data-types of the inputs against the available signatures. The signatures corresponding to built-in types are stored in the types member of the ufunc structure. The signatures corresponding to user-defined types are stored in a linked-list of function-information with the head element stored as a `Object` in the userloops dictionary keyed by the data-type number (the first user-defined type in the argument list is used as the key). The signatures are searched until a signature is found to which the input arrays can all be cast safely (ignoring any scalar arguments which are not allowed to determine the type of the result). The implication of this search procedure is that “lesser types” should be placed below “larger types” when the signatures are stored. If no 1-D loop is found, then an error is reported. Otherwise, the argument_list is updated with the stored signature — in case casting is necessary and to fix the output types assumed by the 1-D loop.

If the ufunc has 2 inputs and 1 output and the second input is an Object array then a special-case check is performed so that NotImplemented is returned if the second input is not an ndarray, has the __array_priority__ attribute, and has an __r{op}__ special method. In this way, Python is signaled to give the other object a chance to complete the operation instead of using generic object-array calculations. This allows (for example) sparse matrices to override the multiplication operator 1-D loop.

For input arrays that are smaller than the specified buffer size, copies are made of all non-contiguous, mis-aligned, or out-of-byteorder arrays to ensure that for small arrays, a single-loop is used. Then, array iterators are created for all the input arrays and the resulting collection of iterators is broadcast to a single shape.

The output arguments (if any) are then processed and any missing return arrays are constructed. If any provided output array doesn’t have the correct type (or is mis-aligned) and is smaller than the buffer size, then a new output array is constructed with the special UPDATEIFCOPY flag set so that when it is DEREF’d on completion of the function, it’s contents will be copied back into the output array. Iterators for the output arguments are then processed.

Finally, the decision is made about how to execute the looping mechanism to ensure that all elements of the input arrays are combined to produce the output arrays of the correct type. The options for loop execution are one-loop (for contiguous, aligned, and correct data-type), strided-loop (for non-contiguous but still aligned and correct data-type), and a buffered loop (for mis-aligned or incorrect data-type situations). Depending on which execution method is called for, the loop is then setup and computed.

**Function call**

This section describes how the basic universal function computation loop is setup and executed for each of the three different kinds of execution possibilities. If `NPY_ALLOW_THREADS` is defined during compilation, then the Python Global Interpreter Lock (GIL) is released prior to calling all of these loops (as long as they don’t involve object arrays).
It is re-acquired if necessary to handle error conditions. The hardware error flags are checked only after the 1-D loop is calculated.

**One Loop**

This is the simplest case of all. The ufunc is executed by calling the underlying 1-D loop exactly once. This is possible only when we have aligned data of the correct type (including byte-order) for both input and output and all arrays have uniform strides (either contiguous, 0-D, or 1-D). In this case, the 1-D computational loop is called once to compute the calculation for the entire array. Note that the hardware error flags are only checked after the entire calculation is complete.

**Strided Loop**

When the input and output arrays are aligned and of the correct type, but the striding is not uniform (non-contiguous and 2-D or larger), then a second looping structure is employed for the calculation. This approach converts all of the iterators for the input and output arguments to iterate over all but the largest dimension. The inner loop is then handled by the underlying 1-D computational loop. The outer loop is a standard iterator loop on the converted iterators. The hardware error flags are checked after each 1-D loop is completed.

**Buffered Loop**

This is the code that handles the situation whenever the input and/or output arrays are either misaligned or of the wrong data-type (including being byte-swapped) from what the underlying 1-D loop expects. The arrays are also assumed to be non-contiguous. The code works very much like the strided loop except for the inner 1-D loop is modified so that pre-processing is performed on the inputs and post-processing is performed on the outputs in bufsize chunks (where bufsize is a user-settable parameter). The underlying 1-D computational loop is called on data that is copied over (if it needs to be). The setup code and the loop code is considerably more complicated in this case because it has to handle:

- memory allocation of the temporary buffers
- deciding whether or not to use buffers on the input and output data (mis-aligned and/or wrong data-type)
- copying and possibly casting data for any inputs or outputs for which buffers are necessary.
- special-casing Object arrays so that reference counts are properly handled when copies and/or casts are necessary.
- breaking up the inner 1-D loop into bufsize chunks (with a possible remainder).

Again, the hardware error flags are checked at the end of each 1-D loop.

**Final output manipulation**

Ufuncs allow other array-like classes to be passed seamlessly through the interface in that inputs of a particular class will induce the outputs to be of that same class. The mechanism by which this works is the following. If any of the inputs are not ndarrays and define the `__array_wrap__` method, then the class with the largest `__array_priority__` attribute determines the type of all the outputs (with the exception of any output arrays passed in). The `__array_wrap__` method of the input array will be called with the ndarray being returned from the ufunc as its input. There are two calling styles of the `__array_wrap__` function supported. The first takes the ndarray as the first argument and a tuple of “context” as the second argument. The context is (ufunc, arguments, output argument number). This is the first call tried. If a TypeError occurs, then the function is called with just the ndarray as the first argument.

**Methods**

There are three methods of ufuncs that require calculation similar to the general-purpose ufuncs. These are reduce, accumulate, and reduceat. Each of these methods requires a setup command followed by a loop. There are four loop
styles possible for the methods corresponding to no-elements, one-element, strided-loop, and buffered-loop. These are the same basic loop styles as implemented for the general purpose function call except for the no-element and one-element cases which are special-cases occurring when the input array objects have 0 and 1 elements respectively.

Setup

The setup function for all three methods is construct_reduce. This function creates a reducing loop object and fills it with parameters needed to complete the loop. All of the methods only work on ufuncs that take 2-inputs and return 1 output. Therefore, the underlying 1-D loop is selected assuming a signature of \([\text{otype}, \text{otype}, \text{otype}]\) where otype is the requested reduction data-type. The buffer size and error handling is then retrieved from (per-thread) global storage. For small arrays that are mis-aligned or have incorrect data-type, a copy is made so that the un-buffered section of code is used. Then, the looping strategy is selected. If there is 1 element or 0 elements in the array, then a simple looping method is selected. If the array is not mis-aligned and has the correct data-type, then strided looping is selected. Otherwise, buffered looping must be performed. Looping parameters are then established, and the return array is constructed. The output array is of a different shape depending on whether the method is reduce, accumulate, or reduceat. If an output array is already provided, then it’s shape is checked. If the output array is not C-contiguous, aligned, and of the correct data type, then a temporary copy is made with the UPDATEIFCOPY flag set. In this way, the methods will be able to work with a well-behaved output array but the result will be copied back into the true output array when the method computation is complete. Finally, iterators are set up to loop over the correct axis (depending on the value of axis provided to the method) and the setup routine returns to the actual computation routine.

Reduce

All of the ufunc methods use the same underlying 1-D computational loops with input and output arguments adjusted so that the appropriate reduction takes place. For example, the key to the functioning of reduce is that the 1-D loop is called with the output and the second input pointing to the same position in memory and both having a step-size of 0. The first input is pointing to the input array with a step-size given by the appropriate stride for the selected axis. In this way, the operation performed is

\[
o = \begin{array}{l}i[0] \\
i[k] \text{<op>} o[k - 1] \quad k = 1 \ldots N
\end{array}
\]

where \(N + 1\) is the number of elements in the input, \(i\), \(o\) is the output, and \(i[k]\) is the \(k^{th}\) element of \(i\) along the selected axis. This basic operations is repeated for arrays with greater than 1 dimension so that the reduction takes place for every 1-D sub-array along the selected axis. An iterator with the selected dimension removed handles this looping.

For buffered loops, care must be taken to copy and cast data before the loop function is called because the underlying loop expects aligned data of the correct data-type (including byte-order). The buffered loop must handle this copying and casting prior to calling the loop function on chunks no greater than the user-specified bufsize.

Accumulate

The accumulate function is very similar to the reduce function in that the output and the second input both point to the output. The difference is that the second input points to memory one stride behind the current output pointer. Thus, the operation performed is

\[
o[0] = \begin{array}{l}i[0] \\
i[k] \text{<op>} o[k - 1] \quad k = 1 \ldots N
\end{array}
\]

The output has the same shape as the input and each 1-D loop operates over \(N\) elements when the shape in the selected axis is \(N + 1\). Again, buffered loops take care to copy and cast the data before calling the underlying 1-D computational loop.

Reduceat

The reduceat function is a generalization of both the reduce and accumulate functions. It implements a reduce over ranges of the input array specified by indices. The extra indices argument is checked to be sure that every input

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is not too large for the input array along the selected dimension before the loop calculations take place. The loop implementation is handled using code that is very similar to the reduce code repeated as many times as there are elements in the indices input. In particular: the first input pointer passed to the underlying 1-D computational loop points to the input array at the correct location indicated by the index array. In addition, the output pointer and the second input pointer passed to the underlying 1-D loop point to the same position in memory. The size of the 1-D computational loop is fixed to be the difference between the current index and the next index (when the current index is the last index, then the next index is assumed to be the length of the array along the selected dimension). In this way, the 1-D loop will implement a reduce over the specified indices.

Mis-aligned or a loop data-type that does not match the input and/or output data-type is handled using buffered code where-in data is copied to a temporary buffer and cast to the correct data-type if necessary prior to calling the underlying 1-D function. The temporary buffers are created in (element) sizes no bigger than the user settable buffer-size value. Thus, the loop must be flexible enough to call the underlying 1-D computational loop enough times to complete the total calculation in chunks no bigger than the buffer-size.

6.2 Internal organization of numpy arrays

It helps to understand a bit about how numpy arrays are handled under the covers to help understand numpy better. This section will not go into great detail. Those wishing to understand the full details are referred to Travis Oliphant’s book “Guide to Numpy”.

Numpy arrays consist of two major components, the raw array data (from now on, referred to as the data buffer), and the information about the raw array data. The data buffer is typically what people think of as arrays in C or Fortran, a contiguous (and fixed) block of memory containing fixed sized data items. Numpy also contains a significant set of data that describes how to interpret the data in the data buffer. This extra information contains (among other things):

1. The basic data element’s size in bytes
2. The start of the data within the data buffer (an offset relative to the beginning of the data buffer).
3. The number of dimensions and the size of each dimension
4. The separation between elements for each dimension (the ‘stride’). This does not have to be a multiple of the element size
5. The byte order of the data (which may not be the native byte order)
6. Whether the buffer is read-only
7. Information (via the dtype object) about the interpretation of the basic data element. The basic data element may be as simple as a int or a float, or it may be a compound object (e.g., struct-like), a fixed character field, or Python object pointers.
8. Whether the array is to interpreted as C-order or Fortran-order.

This arrangement allow for very flexible use of arrays. One thing that it allows is simple changes of the metadata to change the interpretation of the array buffer. Changing the byteorder of the array is a simple change involving no rearrangement of the data. The shape of the array can be changed very easily without changing anything in the data buffer or any data copying at all.

Among other things that are made possible is one can create a new array metadata object that uses the same data buffer to create a new view of that data buffer that has a different interpretation of the buffer (e.g., different shape, offset, byte order, strides, etc) but shares the same data bytes. Many operations in numpy do just this such as slices. Other operations, such as transpose, don’t move data elements around in the array, but rather change the information about the shape and strides so that the indexing of the array changes, but the data in the doesn’t move.

Typically these new versions of the array metadata but the same data buffer are new ‘views’ into the data buffer. There is a different ndarray object, but it uses the same data buffer. This is why it is necessary to force copies through use of the .copy() method if one really wants to make a new and independent copy of the data buffer.
New views into arrays mean the the object reference counts for the data buffer increase. Simply doing away with the original array object will not remove the data buffer if other views of it still exist.

### 6.3 Multidimensional Array Indexing Order Issues

What is the right way to index multi-dimensional arrays? Before you jump to conclusions about the one and true way to index multi-dimensional arrays, it pays to understand why this is a confusing issue. This section will try to explain in detail how numpy indexing works and why we adopt the convention we do for images, and when it may be appropriate to adopt other conventions.

The first thing to understand is that there are two conflicting conventions for indexing 2-dimensional arrays. Matrix notation uses the first index to indicate which row is being selected and the second index to indicate which column is selected. This is opposite the geometrically oriented-convention for images where people generally think the first index represents x position (i.e., column) and the second represents y position (i.e., row). This alone is the source of much confusion; matrix-oriented users and image-oriented users expect two different things with regard to indexing.

The second issue to understand is how indices correspond to the order the array is stored in memory. In Fortran the first index is the most rapidly varying index when moving through the elements of a two dimensional array as it is stored in memory. If you adopt the matrix convention for indexing, then this means the matrix is stored one column at a time (since the first index moves to the next row as it changes). Thus Fortran is considered a Column-major language. C has just the opposite convention. In C, the last index changes most rapidly as one moves through the array as stored in memory. Thus C is a Row-major language. The matrix is stored by rows. Note that in both cases it presumes that the matrix convention for indexing is being used, i.e., for both Fortran and C, the first index is the row. Note this convention implies that the indexing convention is invariant and that the data order changes to keep that so.

But that’s not the only way to look at it. Suppose one has large two-dimensional arrays (images or matrices) stored in data files. Suppose the data are stored by rows rather than by columns. If we are to preserve our index convention (whether matrix or image) that means that depending on the language we use, we may be forced to reorder the data if it is read into memory to preserve our indexing convention. For example if we read row-ordered data into memory without reordering, it will match the matrix indexing convention for C, but not for Fortran. Conversely, it will match the image indexing convention for Fortran, but not for C. For C, if one is using data stored in row order, and one wants to preserve the image index convention, the data must be reordered when reading into memory.

In the end, which you do for Fortran or C depends on which is more important, not reordering data or preserving the indexing convention. For large images, reordering data is potentially expensive, and often the indexing convention is inverted to avoid that.

The situation with numpy makes this issue yet more complicated. The internal machinery of numpy arrays is flexible enough to accept any ordering of indices. One can simply reorder indices by manipulating the internal stride information for arrays without reordering the data at all. Numpy will know how to map the new index order to the data without moving the data.

So if this is true, why not choose the index order that matches what you most expect? In particular, why not define row-ordered images to use the image convention? (This is sometimes referred to as the Fortran convention vs the C convention, thus the ‘C’ and ‘FORTRAN’ order options for array ordering in numpy.) The drawback of doing this is potential performance penalties. It’s common to access the data sequentially, either implicitly in array operations or explicitly by looping over rows of an image. When that is done, then the data will be accessed in non-optimal order. As the first index is incremented, what is actually happening is that elements spaced far apart in memory are being sequentially accessed, with usually poor memory access speeds. For example, for a two dimensional image ‘im’ defined so that im[0, 10] represents the value at x=0, y=10. To be consistent with usual Python behavior then im[0] would represent a column at x=0. Yet that data would be spread over the whole array since the data are stored in row order. Despite the flexibility of numpy’s indexing, it can’t really paper over the fact basic operations are rendered inefficient because of data order or that getting contiguous subarrays is still awkward (e.g., im[:,0] for the first row, vs im[0]), thus one can’t use an idiom such as for row in im; for col in im does work, but doesn’t yield contiguous column data.
As it turns out, numpy is smart enough when dealing with ufuncs to determine which index is the most rapidly varying one in memory and uses that for the innermost loop. Thus for ufuncs there is no large intrinsic advantage to either approach in most cases. On the other hand, use of .flat with a FORTRAN ordered array will lead to non-optimal memory access as adjacent elements in the flattened array (iterator, actually) are not contiguous in memory.

Indeed, the fact is that Python indexing on lists and other sequences naturally leads to an outside-to inside ordering (the first index gets the largest grouping, the next the next largest, and the last gets the smallest element). Since image data are normally stored by rows, this corresponds to position within rows being the last item indexed.

If you do want to use Fortran ordering realize that there are two approaches to consider: 1) accept that the first index is just not the most rapidly changing in memory and have all your I/O routines reorder your data when going from memory to disk or visa versa, or use numpy’s mechanism for mapping the first index to the most rapidly varying data. We recommend the former if possible. The disadvantage of the latter is that many of numpy’s functions will yield arrays without Fortran ordering unless you are careful to use the ‘order’ keyword. Doing this would be highly inconvenient.

Otherwise we recommend simply learning to reverse the usual order of indices when accessing elements of an array. Granted, it goes against the grain, but it is more in line with Python semantics and the natural order of the data.
7.1 Numpy.i: a SWIG Interface File for NumPy

7.1.1 Introduction

The Simple Wrapper and Interface Generator (or SWIG) is a powerful tool for generating wrapper code for interfacing to a wide variety of scripting languages. SWIG can parse header files, and using only the code prototypes, create an interface to the target language. But SWIG is not omnipotent. For example, it cannot know from the prototype:

```c
double rms(double* seq, int n);
```

what exactly `seq` is. Is it a single value to be altered in-place? Is it an array, and if so what is its length? Is it input-only? Output-only? Input-output? SWIG cannot determine these details, and does not attempt to do so.

If we designed `rms`, we probably made it a routine that takes an input-only array of length `n` of `double` values called `seq` and returns the root mean square. The default behavior of SWIG, however, will be to create a wrapper function that compiles, but is nearly impossible to use from the scripting language in the way the C routine was intended.

For Python, the preferred way of handling contiguous (or technically, *strided*) blocks of homogeneous data is with NumPy, which provides full object-oriented access to multidimensional arrays of data. Therefore, the most logical Python interface for the `rms` function would be (including doc string):

```python
def rms(seq):
    """
    rms: return the root mean square of a sequence
    rms(numpy.ndarray) -> double
    rms(list) -> double
    rms(tuple) -> double
    """
```

where `seq` would be a NumPy array of `double` values, and its length `n` would be extracted from `seq` internally before being passed to the C routine. Even better, since NumPy supports construction of arrays from arbitrary Python sequences, `seq` itself could be a nearly arbitrary sequence (so long as each element can be converted to a `double`) and the wrapper code would internally convert it to a NumPy array before extracting its data and length.

SWIG allows these types of conversions to be defined via a mechanism called *typemaps*. This document provides information on how to use `numpy.i`, a SWIG interface file that defines a series of typemaps intended to make the type of array-related conversions described above relatively simple to implement. For example, suppose that the `rms` function prototype defined above was in a header file named `rms.h`. To obtain the Python interface discussed above, your SWIG interface file would need the following:

```swig
%! #define SWIG_FILE_WITH_INIT
#include "rms.h"
%}
```
NumPy Reference, Release 1.9.2

%include "numpy.i"
%init %{
import_array();
%}
%apply (double* IN_ARRAY1, int DIM1) {(double* seq, int n)};
%include "rms.h"

Typemaps are keyed off a list of one or more function arguments, either by type or by type and name. We will
refer to such lists as signatures. One of the many typemaps defined by numpy.i is used above and has the signature
(double* IN_ARRAY1, int DIM1). The argument names are intended to suggest that the double* argument
is an input array of one dimension and that the int represents the size of that dimension. This is precisely the pattern
in the rms prototype.
Most likely, no actual prototypes to be wrapped will have the argument names IN_ARRAY1 and DIM1. We use
the SWIG %apply directive to apply the typemap for one-dimensional input arrays of type double to the actual
prototype used by rms. Using numpy.i effectively, therefore, requires knowing what typemaps are available and
what they do.
A SWIG interface file that includes the SWIG directives given above will produce wrapper code that looks something
like:
1 PyObject *_wrap_rms(PyObject *args) {
2
PyObject *resultobj = 0;
3
double *arg1 = (double *) 0 ;
4
int arg2 ;
5
double result;
6
PyArrayObject *array1 = NULL ;
7
int is_new_object1 = 0 ;
8
PyObject * obj0 = 0 ;
9
10
if (!PyArg_ParseTuple(args,(char *)"O:rms",&obj0)) SWIG_fail;
11
{
12
array1 = obj_to_array_contiguous_allow_conversion(
13
obj0, NPY_DOUBLE, &is_new_object1);
14
npy_intp size[1] = {
15
-1
16
};
17
if (!array1 || !require_dimensions(array1, 1) ||
18
!require_size(array1, size, 1)) SWIG_fail;
19
arg1 = (double*) array1->data;
20
arg2 = (int) array1->dimensions[0];
21
}
22
result = (double)rms(arg1,arg2);
23
resultobj = SWIG_From_double((double)(result));
24
{
25
if (is_new_object1 && array1) Py_DECREF(array1);
26
}
27
return resultobj;
28 fail:
29
{
30
if (is_new_object1 && array1) Py_DECREF(array1);
31
}
32
return NULL;
33 }

The typemaps from numpy.i are responsible for the following lines of code: 12–20, 25 and 30. Line 10 parses

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the input to the \texttt{rms} function. From the format string "O:rms", we can see that the argument list is expected to be a single Python object (specified by the \texttt{O} before the colon) and whose pointer is stored in \texttt{obj0}. A number of functions, supplied by \texttt{numpy.i}, are called to make and check the (possible) conversion from a generic Python object to a NumPy array. These functions are explained in the section \texttt{Helper Functions}, but hopefully their names are self-explanatory. At line 12 we use \texttt{obj0} to construct a NumPy array. At line 17, we check the validity of the result: that it is non-null and that it has a single dimension of arbitrary length. Once these states are verified, we extract the data buffer and length in lines 19 and 20 so that we can call the underlying C function at line 22. Line 25 performs memory management for the case where we have created a new array that is no longer needed.

This code has a significant amount of error handling. Note the \texttt{SWIG\_fail} is a macro for \texttt{goto fail}, referring to the label at line 28. If the user provides the wrong number of arguments, this will be caught at line 10. If construction of the NumPy array fails or produces an array with the wrong number of dimensions, these errors are caught at line 17. And finally, if an error is detected, memory is still managed correctly at line 30.

Note that if the C function signature was in a different order:

\begin{verbatim}
double rms(int n, double* seq);
\end{verbatim}

that \texttt{SWIG} would not match the typemap signature given above with the argument list for \texttt{rms}. Fortunately, \texttt{numpy.i} has a set of typemaps with the data pointer given last:

\begin{verbatim}
%apply (int DIM1, double* IN\_ARRAY1) {(int n, double* seq)};
\end{verbatim}

This simply has the effect of switching the definitions of \texttt{arg1} and \texttt{arg2} in lines 3 and 4 of the generated code above, and their assignments in lines 19 and 20.

\subsection*{7.1.2 Using \texttt{numpy.i}}

The \texttt{numpy.i} file is currently located in the tools/swig sub-directory under the \texttt{numpy} installation directory. Typically, you will want to copy it to the directory where you are developing your wrappers.

A simple module that only uses a single \texttt{SWIG} interface file should include the following:

\begin{verbatim}
{%
#define SWIG\_FILE\_WITH\_INIT
%
#include "numpy.i"
%init %{ import\_array(); }
%

Within a compiled Python module, \texttt{import\_array()} should only get called once. This could be in a C/C++ file that you have written and is linked to the module. If this is the case, then none of your interface files should \#define \texttt{SWIG\_FILE\_WITH\_INIT} or call \texttt{import\_array()}. Or, this initialization call could be in a wrapper file generated by \texttt{SWIG} from an interface file that has the \%init block as above. If this is the case, and you have more than one \texttt{SWIG} interface file, then only one interface file should \#define \texttt{SWIG\_FILE\_WITH\_INIT} and call \texttt{import\_array()}.  

\subsection*{7.1.3 Available Typemaps}

The typemap directives provided by \texttt{numpy.i} for arrays of different data types, say \texttt{double} and \texttt{int}, and dimensions of different types, say \texttt{int} or \texttt{long}, are identical to one another except for the C and NumPy type specifications. The typemaps are therefore implemented (typically behind the scenes) via a macro:

\begin{verbatim}
%numpy\_typemaps(DATA\_TYPE, DATA\_TYPECODE, DIM\_TYPE)
\end{verbatim}
that can be invoked for appropriate (DATA_TYPE, DATA_TYPECODE, DIM_TYPE) triplets. For example:

```c
%numpy_typemaps(double, NPY_DOUBLE, int)
%numpy_typemaps(int, NPY_INT , int)
```

The `numpy.i` interface file uses the `%numpy_typemaps` macro to implement typemaps for the following C data types and `int` dimension types:

- `signed char`
- `unsigned char`
- `short`
- `unsigned short`
- `int`
- `unsigned int`
- `long`
- `unsigned long`
- `long long`
- `unsigned long long`
- `float`
- `double`

In the following descriptions, we reference a generic `DATA_TYPE`, which could be any of the C data types listed above, and `DIM_TYPE` which should be one of the many types of integers.

The typemap signatures are largely differentiated on the name given to the buffer pointer. Names with `FARRAY` are for Fortran-ordered arrays, and names with `ARRAY` are for C-ordered (or 1D arrays).

### Input Arrays

Input arrays are defined as arrays of data that are passed into a routine but are not altered in-place or returned to the user. The Python input array is therefore allowed to be almost any Python sequence (such as a list) that can be converted to the requested type of array. The input array signatures are

1D:

- `( DATA_TYPE IN_ARRAY1[ANY] )`
- `( DATA_TYPE* IN_ARRAY1, int DIM1 )`
- `( int DIM1, DATA_TYPE* IN_ARRAY1 )`

2D:

- `( DATA_TYPE IN_ARRAY2[ANY][ANY] )`
- `( DATA_TYPE* IN_ARRAY2, int DIM1, int DIM2 )`
- `( int DIM1, int DIM2, DATA_TYPE* IN_ARRAY2 )`
- `( DATA_TYPE* IN_FARRAY2, int DIM1, int DIM2 )`
- `( int DIM1, int DIM2, DATA_TYPE* IN_FARRAY2 )`

3D:

- `( DATA_TYPE IN_ARRAY3[ANY][ANY][ANY] )`
In-Place Arrays

In-place arrays are defined as arrays that are modified in-place. The input values may or may not be used, but the values at the time the function returns are significant. The provided Python argument must therefore be a NumPy array of the required type. The in-place signatures are

1D:

- ( DATA_TYPE INPLACE_ARRAY[ANY] )
- ( DATA_TYPE* INPLACE_ARRAY1, int DIM1 )
- ( int DIM1, DATA_TYPE* INPLACE_ARRAY1 )

2D:

- ( DATA_TYPE INPLACE_ARRAY2[ANY][ANY] )
- ( DATA_TYPE* INPLACE_FILL_ARRAY2, int DIM1, int DIM2 )
- ( int DIM1, int DIM2, DATA_TYPE* INPLACE_FILL_ARRAY2 )
- ( DATA_TYPE* INPLACE_FARRAY2, int DIM1, int DIM2 )
- ( int DIM1, int DIM2, DATA_TYPE* INPLACE_FARRAY2 )

3D:

- ( DATA_TYPE INPLACE_ARRAY3[ANY][ANY][ANY] )
- ( DATA_TYPE* INPLACE_ARRAY3, int DIM1, int DIM2, int DIM3 )
- ( int DIM1, int DIM2, int DIM3, DATA_TYPE* INPLACE_ARRAY3 )
- ( DATA_TYPE* INPLACE_FARRAY3, int DIM1, int DIM2, int DIM3 )
- ( int DIM1, int DIM2, int DIM3, DATA_TYPE* INPLACE_FARRAY3 )

4D:

- (DATA_TYPE IN_PLACE_ARRAY4[ANY][ANY][ANY][ANY])
- (DATA_TYPE* IN_PLACE_ARRAY4, DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4)
- (DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4, DATA_TYPE* IN_PLACE_ARRAY4)
- (DATA_TYPE* IN_PLACE_FARRAY4, DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4)
- (DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4, DATA_TYPE* IN_PLACE_FARRAY4)

The first signature listed, (DATA_TYPE IN_PLACE_ARRAY[ANY]) is for one-dimensional arrays with hard-coded dimensions. Likewise, (DATA_TYPE IN_PLACE_ARRAY2[ANY][ANY]) is for two-dimensional arrays with hard-coded dimensions, and similarly for three-dimensional.
NumPy Reference, Release 1.9.2

- (DATA_TYPE INPLACE_ARRAY4[ANY][ANY][ANY][ANY])
- (DATA_TYPE* INPLACE_ARRAY4, DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4)
- (DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, , DIM_TYPE DIM4, DATA_TYPE* INPLACE_ARRAY4)
- (DATA_TYPE* INPLACE_FARRAY4, DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4)
- (DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4, DATA_TYPE* INPLACE_FARRAY4)

These typemaps now check to make sure that the INPLACE_ARRAY arguments use native byte ordering. If not, an exception is raised.

**Argout Arrays**

Argout arrays are arrays that appear in the input arguments in C, but are in fact output arrays. This pattern occurs often when there is more than one output variable and the single return argument is therefore not sufficient. In Python, the conventional way to return multiple arguments is to pack them into a sequence (tuple, list, etc.) and return the sequence. This is what the argout typemaps do. If a wrapped function that uses these argout typemaps has more than one return argument, they are packed into a tuple or list, depending on the version of Python. The Python user does not pass these arrays in, they simply get returned. For the case where a dimension is specified, the python user must provide that dimension as an argument. The argout signatures are

1D:
- ( DATA_TYPE ARGOUT_ARRAY1[ANY] )
- ( DATA_TYPE* ARGOUT_ARRAY1, int DIM1 )
- ( int DIM1, DATA_TYPE* ARGOUT_ARRAY1 )

2D:
- ( DATA_TYPE ARGOUT_ARRAY2[ANY][ANY] )

3D:
- ( DATA_TYPE ARGOUT_ARRAY3[ANY][ANY][ANY] )

4D:
- ( DATA_TYPE ARGOUT_ARRAY4[ANY][ANY][ANY][ANY] )

These are typically used in situations where in C/C++, you would allocate a(n) array(s) on the heap, and call the function to fill the array(s) values. In Python, the arrays are allocated for you and returned as new array objects.

Note that we support DATA_TYPE* argout typemaps in 1D, but not 2D or 3D. This is because of a quirk with the SWIG typemap syntax and cannot be avoided. Note that for these types of 1D typemaps, the Python function will take a single argument representing DIM1.

**Argout View Arrays**

Argoutview arrays are for when your C code provides you with a view of its internal data and does not require any memory to be allocated by the user. This can be dangerous. There is almost no way to guarantee that the internal data from the C code will remain in existence for the entire lifetime of the NumPy array that encapsulates it. If the user destroys the object that provides the view of the data before destroying the NumPy array, then using that array may
result in bad memory references or segmentation faults. Nevertheless, there are situations, working with large data
datasets, where you simply have no other choice.

The C code to be wrapped for argoutview arrays are characterized by pointers: pointers to the dimensions and double
pointers to the data, so that these values can be passed back to the user. The argoutview typemap signatures are
therefore

1D:
- (DATA_TYPE** ARGOUTVIEW_ARRAY1, DIM_TYPE* DIM1)
- (DIM_TYPE* DIM1, DATA_TYPE** ARGOUTVIEW_ARRAY1)

2D:
- (DATA_TYPE** ARGOUTVIEW_ARRAY2, DIM_TYPE* DIM1, DIM_TYPE* DIM2)
- (DIM_TYPE* DIM1, DIM_TYPE* DIM2, DATA_TYPE** ARGOUTVIEW_ARRAY2)
- (DATA_TYPE** ARGOUTVIEW_FARRAY2, DIM_TYPE* DIM1, DIM_TYPE* DIM2)
- (DIM_TYPE* DIM1, DIM_TYPE* DIM2, DATA_TYPE** ARGOUTVIEW_FARRAY2)

3D:
- (DATA_TYPE** ARGOUTVIEW_ARRAY3, DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3)
- (DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DATA_TYPE**
  ARGOUTVIEW_ARRAY3)
- (DATA_TYPE** ARGOUTVIEW_FARRAY3, DIM_TYPE* DIM1, DIM_TYPE* DIM2,
  DIM_TYPE* DIM3)
- (DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DATA_TYPE**
  ARGOUTVIEW_FARRAY3)

4D:
- (DATA_TYPE** ARGOUTVIEW_ARRAY4, DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3,
  DIM_TYPE* DIM4)
- (DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DIM_TYPE* DIM4,
  DATA_TYPE** ARGOUTVIEW_ARRAY4)
- (DATA_TYPE** ARGOUTVIEW_FARRAY4, DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE*
  DIM3, DIM_TYPE* DIM4)
- (DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DIM_TYPE* DIM4,
  DATA_TYPE** ARGOUTVIEW_FARRAY4)

Note that arrays with hard-coded dimensions are not supported. These cannot follow the double pointer signatures of
these typemaps.

Memory Managed Argout View Arrays

A recent addition to numpy.i are typemaps that permit argout arrays with views into memory that is managed. See
the discussion here.

1D:
- (DATA_TYPE** ARGOUTVIEWM_ARRAY1, DIM_TYPE* DIM1)
- (DIM_TYPE* DIM1, DATA_TYPE** ARGOUTVIEWM_ARRAY1)
Output Arrays

The `numpy.i` interface file does not support typemaps for output arrays, for several reasons. First, C/C++ return arguments are limited to a single value. This prevents obtaining dimension information in a general way. Second, arrays with hard-coded lengths are not permitted as return arguments. In other words:

```c
double[3] newVector(double x, double y, double z);
```

is not legal C/C++ syntax. Therefore, we cannot provide typemaps of the form:

```c
%typemap(out) (TYPE[ANY]);
```

If you run into a situation where a function or method is returning a pointer to an array, your best bet is to write your own version of the function to be wrapped, either with `%extend` for the case of class methods or `%ignore` and `%rename` for the case of functions.

Other Common Types: bool

Note that C++ type `bool` is not supported in the list in the `Available Typemaps` section. NumPy bools are a single byte, while the C++ `bool` is four bytes (at least on my system). Therefore:

```c
%numpy_typemaps(bool, NPY_BOOL, int)
```
will result in typemaps that will produce code that reference improper data lengths. You can implement the following macro expansion:

```plaintext
%numpy_typemaps(bool, NPY_UINT, int)
```

to fix the data length problem, and Input Arrays will work fine, but In-Place Arrays might fail type-checking.

### Other Common Types: complex

Typemap conversions for complex floating-point types is also not supported automatically. This is because Python and NumPy are written in C, which does not have native complex types. Both Python and NumPy implement their own (essentially equivalent) `struct` definitions for complex variables:

```c
/* Python */
typedef struct {double real; double imag;} Py_complex;

/* NumPy */
typedef struct {float real, imag;} npy_cfloat;
typedef struct {double real, imag;} npy_cdouble;
```

We could have implemented:

```plaintext
%numpy_typemaps(Py_complex , NPY_CDOUBLE, int)
%numpy_typemaps(npy_cfloat , NPY_CFLOAT , int)
%numpy_typemaps(npy_cdouble, NPY_CDOUBLE, int)
```

which would have provided automatic type conversions for arrays of type `Py_complex`, `npy_cfloat` and `npy_cdouble`. However, it seemed unlikely that there would be any independent (non-Python, non-NumPy) application code that people would be using SWIG to generate a Python interface to, that also used these definitions for complex types. More likely, these application codes will define their own complex types, or in the case of C++, use `std::complex`. Assuming these data structures are compatible with Python and NumPy complex types, `%numpy_typemap` expansions as above (with the user’s complex type substituted for the first argument) should work.

### 7.1.4 NumPy Array Scalars and SWIG

SWIG has sophisticated type checking for numerical types. For example, if your C/C++ routine expects an integer as input, the code generated by SWIG will check for both Python integers and Python long integers, and raise an overflow error if the provided Python integer is too big to cast down to a C integer. With the introduction of NumPy scalar arrays into your Python code, you might conceivably extract an integer from a NumPy array and attempt to pass this to a SWIG-wrapped C/C++ function that expects an `int`, but the SWIG type checking will not recognize the NumPy array scalar as an integer. (Often, this does in fact work – it depends on whether NumPy recognizes the integer type you are using as inheriting from the Python integer type on the platform you are using. Sometimes, this means that code that works on a 32-bit machine will fail on a 64-bit machine.)

If you get a Python error that looks like the following:

```plaintext
TypeError: in method ‘MyClass_MyMethod’, argument 2 of type ‘int’
```

and the argument you are passing is an integer extracted from a NumPy array, then you have stumbled upon this problem. The solution is to modify the SWIG type conversion system to accept NumPy array scalars in addition to the standard integer types. Fortunately, this capability has been provided for you. Simply copy the file:

```plaintext
pyfragments.swg
```

to the working build directory for your project, and this problem will be fixed. It is suggested that you do this anyway, as it only increases the capabilities of your Python interface.
Why is There a Second File?

The SWIG type checking and conversion system is a complicated combination of C macros, SWIG macros, SWIG typemaps and SWIG fragments. Fragments are a way to conditionally insert code into your wrapper file if it is needed, and not insert it if not needed. If multiple typemaps require the same fragment, the fragment only gets inserted into your wrapper code once.

There is a fragment for converting a Python integer to a C long. There is a different fragment that converts a Python integer to a C int, that calls the routine defined in the long fragment. We can make the changes we want here by changing the definition for the long fragment. SWIG determines the active definition for a fragment using a “first come, first served” system. That is, we need to define the fragment for long conversions prior to SWIG doing it internally. SWIG allows us to do this by putting our fragment definitions in the file pyfragments.swg. If we were to put the new fragment definitions in numpy.i, they would be ignored.

7.1.5 Helper Functions

The numpy.i file contains several macros and routines that it uses internally to build its typemaps. However, these functions may be useful elsewhere in your interface file. These macros and routines are implemented as fragments, which are described briefly in the previous section. If you try to use one or more of the following macros or functions, but your compiler complains that it does not recognize the symbol, then you need to force these fragments to appear in your code using:

`%fragment("NumPy_Fragments");`

in your SWIG interface file.

Macros

- `is_array(a)`
  Evaluates as true if `a` is non-NULL and can be cast to a PyArrayObject*.

- `array_type(a)`
  Evaluates to the integer data type code of `a`, assuming `a` can be cast to a PyArrayObject*.

- `array_numdims(a)`
  Evaluates to the integer number of dimensions of `a`, assuming `a` can be cast to a PyArrayObject*.

- `array_dimensions(a)`
  Evaluates to an array of type `npy_intp` and length `array_numdims(a)`, giving the lengths of all of the dimensions of `a`, assuming `a` can be cast to a PyArrayObject*.

- `array_size(a,i)`
  Evaluates to the `i`-th dimension size of `a`, assuming `a` can be cast to a PyArrayObject*.

- `array_strides(a)`
  Evaluates to an array of type `npy_intp` and length `array_numdims(a)`, giving the strides of all of the dimensions of `a`, assuming `a` can be cast to a PyArrayObject*. A stride is the distance in bytes between an element and its immediate neighbor along the same axis.

- `array_stride(a,i)`
  Evaluates to the `i`-th stride of `a`, assuming `a` can be cast to a PyArrayObject*.

- `array_data(a)`
  Evaluates to a pointer of type void* that points to the data buffer of `a`, assuming `a` can be cast to a PyArrayObject*. 
array_descr(a)
Returns a borrowed reference to the dtype property (PyArray_Descr*) of a, assuming a can be cast to a PyArrayObject*.

array_flags(a)
Returns an integer representing the flags of a, assuming a can be cast to a PyArrayObject*.

array_enableflags(a,f)
Sets the flag represented by f of a, assuming a can be cast to a PyArrayObject*.

array_is_contiguous(a)
Evaluates as true if a is a contiguous array. Equivalent to (PyArray_ISCONTIGUOUS(a)).

array_is_native(a)
Evaluates as true if the data buffer of a uses native byte order. Equivalent to (PyArray_ISNOTSWAPPED(a)).

array_is_fortran(a)
Evaluates as true if a is FORTRAN ordered.

Routines

pytype_string()
Return type: const char*
Arguments:
• PyObject* py_obj, a general Python object.
Return a string describing the type of py_obj.

typecode_string()
Return type: const char*
Arguments:
• int typecode, a NumPy integer typecode.
Return a string describing the type corresponding to the NumPy typecode.

type_match()
Return type: int
Arguments:
• int actual_type, the NumPy typecode of a NumPy array.
• int desired_type, the desired NumPy typecode.
Make sure that actual_type is compatible with desired_type. For example, this allows character and byte types, or int and long types, to match. This is now equivalent to PyArray_EquivTypenums().

obj_to_array_no_conversion()
Return type: PyArrayObject*
Arguments:
• PyObject* input, a general Python object.
• int typecode, the desired NumPy typecode.
Cast *input* to a *PyArrayObject* if legal, and ensure that it is of type *typecode*. If *input* cannot be cast, or the *typecode* is wrong, set a Python error and return *NULL*.

**obj_to_array_allow_conversion()**

Return type: PyArrayObject*

Arguments:
- PyObject* *input*, a general Python object.
- int *typecode*, the desired NumPy typecode of the resulting array.
- int* *is_new_object*, returns a value of 0 if no conversion performed, else 1.

Convert *input* to a NumPy array with the given *typecode*. On success, return a valid PyArrayObject* with the correct type. On failure, the Python error string will be set and the routine returns *NULL*.

**make_contiguous()**

Return type: PyArrayObject*

Arguments:
- PyArrayObject* *ary*, a NumPy array.
- int* *is_new_object*, returns a value of 0 if no conversion performed, else 1.
- int *min_dims*, minimum allowable dimensions.
- int *max_dims*, maximum allowable dimensions.

Check to see if *ary* is contiguous. If so, return the input pointer and flag it as not a new object. If it is not contiguous, create a new PyArrayObject* using the original data, flag it as a new object and return the pointer.

**make_fortran()**

Return type: PyArrayObject*

Arguments
- PyArrayObject* *ary*, a NumPy array.
- int* *is_new_object*, returns a value of 0 if no conversion performed, else 1.

Check to see if *ary* is Fortran contiguous. If so, return the input pointer and flag it as not a new object. If it is not Fortran contiguous, create a new PyArrayObject* using the original data, flag it as a new object and return the pointer.

**obj_to_array_contiguous_allow_conversion()**

Return type: PyArrayObject*

Arguments:
- PyObject* *input*, a general Python object.
- int *typecode*, the desired NumPy typecode of the resulting array.
- int* *is_new_object*, returns a value of 0 if no conversion performed, else 1.

Convert *input* to a contiguous PyArrayObject* of the specified type. If the input object is not a contiguous PyArrayObject*, a new one will be created and the new object flag will be set.

**obj_to_array_fortran_allow_conversion()**
Return type: PyArrayObject*

Arguments:
  • PyObject* input, a general Python object.
  • int typecode, the desired NumPy typecode of the resulting array.
  • int* is_new_object, returns a value of 0 if no conversion performed, else 1.

Convert input to a Fortran contiguous PyArrayObject* of the specified type. If the input object is not a Fortran contiguous PyArrayObject*, a new one will be created and the new object flag will be set.

require_contiguous()

Return type: int

Arguments:
  • PyArrayObject* ary, a NumPy array.

Test whether ary is contiguous. If so, return 1. Otherwise, set a Python error and return 0.

require_native()

Return type: int

Arguments:
  • PyArrayObject* ary, a NumPy array.

Require that ary is not byte-swapped. If the array is not byte-swapped, return 1. Otherwise, set a Python error and return 0.

require_dimensions()

Return type: int

Arguments:
  • PyArrayObject* ary, a NumPy array.
  • int exact_dimensions, the desired number of dimensions.

Require ary to have a specified number of dimensions. If the array has the specified number of dimensions, return 1. Otherwise, set a Python error and return 0.

require_dimensions_n()

Return type: int

Arguments:
  • PyArrayObject* ary, a NumPy array.
  • int* exact_dimensions, an array of integers representing acceptable numbers of dimensions.
  • int n, the length of exact_dimensions.

Require ary to have one of a list of specified number of dimensions. If the array has one of the specified number of dimensions, return 1. Otherwise, set the Python error string and return 0.

require_size()
Return type: int
Arguments:

• PyArrayObject* ary, a NumPy array.

• npy_int* size, an array representing the desired lengths of each dimension.

• int n, the length of size.

Require ary to have a specified shape. If the array has the specified shape, return 1. Otherwise, set the Python error string and return 0.

7.1.6 Beyond the Provided Typemaps

There are many C or C++ array/NumPy array situations not covered by a simple `%include "numpy.i"` and subsequent `%apply` directives.

A Common Example

Consider a reasonable prototype for a dot product function:

double dot(int len, double* vec1, double* vec2);

The Python interface that we want is:

```python
def dot(vec1, vec2):
    ""
    dot(PyObject,PyObject) -> double
    ""
```

The problem here is that there is one dimension argument and two array arguments, and our typemaps are set up for dimensions that apply to a single array (in fact, SWIG does not provide a mechanism for associating `len` with `vec2` that takes two Python input arguments). The recommended solution is the following:

```swig
%apply (int DIM1, double* IN_ARRAY1) {(int len1, double* vec1),
    (int len2, double* vec2)}

%rename (dot) my_dot;
%exception my_dot {
    $action
        if (PyErr_Occurred()) SWIG_fail;
    }
%inline %{
    double my_dot(int len1, double* vec1, int len2, double* vec2) {
        if (len1 != len2) {
            PyErr_Format(PyExc_ValueError,
                "Arrays of lengths (%d,%d) given",
                len1, len2);
```
return 0.0;
}
return dot(len1, vec1, vec2);
%

If the header file that contains the prototype for double dot() also contains other prototypes that you want to wrap, so that you need to %include this header file, then you will also need a %ignore dot; directive, placed after the %rename and before the %include directives. Or, if the function in question is a class method, you will want to use %extend rather than %inline in addition to %ignore.

A note on error handling: Note that my_dot returns a double but that it can also raise a Python error. The resulting wrapper function will return a Python float representation of 0.0 when the vector lengths do not match. Since this is not NULL, the Python interpreter will not know to check for an error. For this reason, we add the %exception directive above for my_dot to get the behavior we want (note that $action is a macro that gets expanded to a valid call to my_dot). In general, you will probably want to write a SWIG macro to perform this task.

Other Situations

There are other wrapping situations in which numpy.i may be helpful when you encounter them.

- In some situations, it is possible that you could use the %numpy_typemaps macro to implement typemaps for your own types. See the Other Common Types: bool or Other Common Types: complex sections for examples. Another situation is if your dimensions are of a type other than int (say long for example):

  %numpy_typemaps(double, NPY_DOUBLE, long)

- You can use the code in numpy.i to write your own typemaps. For example, if you had a five-dimensional array as a function argument, you could cut-and-paste the appropriate four-dimensional typemaps into your interface file. The modifications for the fourth dimension would be trivial.

- Sometimes, the best approach is to use the %extend directive to define new methods for your classes (or overload existing ones) that take a PyObject* (that either is or can be converted to a PyArrayObject*) instead of a pointer to a buffer. In this case, the helper routines in numpy.i can be very useful.

- Writing typemaps can be a bit nonintuitive. If you have specific questions about writing SWIG typemaps for NumPy, the developers of numpy.i do monitor the Numpy-discussion and Swig-user mail lists.

A Final Note

When you use the %apply directive, as is usually necessary to use numpy.i, it will remain in effect until you tell SWIG that it shouldn’t be. If the arguments to the functions or methods that you are wrapping have common names, such as length or vector, these typemaps may get applied in situations you do not expect or want. Therefore, it is always a good idea to add a %clear directive after you are done with a specific typemap:

%apply (double* IN_ARRAY1, int DIM1) [(double* vector, int length)]
%include "my_header.h"
%clear (double* vector, int length);

In general, you should target these typemap signatures specifically where you want them, and then clear them after you are done.

7.1.7 Summary

Out of the box, numpy.i provides typemaps that support conversion between NumPy arrays and C arrays:
• That can be one of 12 different scalar types: signed char, unsigned char, short, unsigned short, int, unsigned int, long, unsigned long, long long, unsigned long long, float and double.

• That support 74 different argument signatures for each data type, including:
  – One-dimensional, two-dimensional, three-dimensional and four-dimensional arrays.
  – Input-only, in-place, argout, argoutview, and memory managed argoutview behavior.
  – Hard-coded dimensions, data-buffer-then-dimensions specification, and dimensions-then-data-buffer specification.
  – Both C-ordering (“last dimension fastest”) or Fortran-ordering (“first dimension fastest”) support for 2D, 3D and 4D arrays.

The numpy.i interface file also provides additional tools for wrapper developers, including:

• A SWIG macro (%numpy_typemaps) with three arguments for implementing the 74 argument signatures for the user’s choice of (1) C data type, (2) NumPy data type (assuming they match), and (3) dimension type.

• Fourteen C macros and fifteen C functions that can be used to write specialized typemaps, extensions, or inlined functions that handle cases not covered by the provided typemaps. Note that the macros and functions are coded specifically to work with the NumPy C/API regardless of NumPy version number, both before and after the deprecation of some aspects of the API after version 1.6.

### 7.2 Testing the numpy.i Typemaps

#### 7.2.1 Introduction

Writing tests for the numpy.i SWIG interface file is a combinatorial headache. At present, 12 different data types are supported, each with 74 different argument signatures, for a total of 888 typemaps supported “out of the box”. Each of these typemaps, in turn, might require several unit tests in order to verify expected behavior for both proper and improper inputs. Currently, this results in 1,427 individual unit tests that are performed when make test is run in the numpy/docs/swig subdirectory.

To facilitate this many similar unit tests, some high-level programming techniques are employed, including C and SWIG macros, as well as Python inheritance. The purpose of this document is to describe the testing infrastructure employed to verify that the numpy.i typemaps are working as expected.

#### 7.2.2 Testing Organization

There are three independent testing frameworks supported, for one-, two-, and three-dimensional arrays respectively. For one-dimensional arrays, there are two C++ files, a header and a source, named:

Vector.h  
Vector.cxx

that contain prototypes and code for a variety of functions that have one-dimensional arrays as function arguments. The file:

Vector.i

is a SWIG interface file that defines a python module Vector that wraps the functions in Vector.h while utilizing the typemaps in numpy.i to correctly handle the C arrays.

The Makefile calls swig to generate Vector.py and Vector_wrap.cxx, and also executes the setup.py script that compiles Vector_wrap.cxx and links together the extension module _Vector.so or
Vector.dylib, depending on the platform. This extension module and the proxy file Vector.py are both placed in a subdirectory under the build directory.

The actual testing takes place with a Python script named:

testVector.py

that uses the standard Python library module unittest, which performs several tests of each function defined in Vector.h for each data type supported.

Two-dimensional arrays are tested in exactly the same manner. The above description applies, but with Matrix substituted for Vector. For three-dimensional tests, substitute Tensor for Vector. For four-dimensional tests, substitute SuperTensor for Vector. For the descriptions that follow, we will reference the Vector tests, but the same information applies to Matrix, Tensor and SuperTensor tests.

The command make test will ensure that all of the test software is built and then run all three test scripts.

### 7.2.3 Testing Header Files

Vector.h is a C++ header file that defines a C macro called TEST_FUNC_PROTOS that takes two arguments: TYPE, which is a data type name such as unsigned int; and SNAME, which is a short name for the same data type with no spaces, e.g. uint. This macro defines several function prototypes that have the prefix SNAME and have at least one argument that is an array of type TYPE. Those functions that have return arguments return a TYPE value.

TEST_FUNC_PROTOS is then implemented for all of the data types supported by numpy.i:

- signed char
- unsigned char
- short
- unsigned short
- int
- unsigned int
- long
- unsigned long
- long long
- unsigned long long
- float
- double

### 7.2.4 Testing Source Files

Vector.cxx is a C++ source file that implements compilable code for each of the function prototypes specified in Vector.h. It defines a C macro TEST_FUNCS that has the same arguments and works in the same way as TEST_FUNC_PROTOS does in Vector.h. TEST_FUNCS is implemented for each of the 12 data types as above.
7.2.5 Testing SWIG Interface Files

Vector.i is a SWIG interface file that defines python module Vector. It follows the conventions for using numpy.i as described in this chapter. It defines a SWIG macro %apply_numpy_typemaps that has a single argument TYPE. It uses the SWIG directive %apply to apply the provided typemaps to the argument signatures found in Vector.h. This macro is then implemented for all of the data types supported by numpy.i. It then does a %include "Vector.h" to wrap all of the function prototypes in Vector.h using the typemaps in numpy.i.

7.2.6 Testing Python Scripts

After make is used to build the testing extension modules, testVector.py can be run to execute the tests. As with other scripts that use unittest to facilitate unit testing, testVector.py defines a class that inherits from unittest.TestCase:

class VectorTestCase(unittest.TestCase):

However, this class is not run directly. Rather, it serves as a base class to several other python classes, each one specific to a particular data type. The VectorTestCase class stores two strings for typing information:

    self.typeStr
    A string that matches one of the SNAME prefixes used in Vector.h and Vector.cxx. For example, "double".

    self.typeCode
    A short (typically single-character) string that represents a data type in numpy and corresponds to self.typeStr. For example, if self.typeStr is "double", then self.typeCode should be "d".

Each test defined by the VectorTestCase class extracts the python function it is trying to test by accessing the Vector module’s dictionary:

    length = Vector.__dict__[self.typeStr + "Length"]

In the case of double precision tests, this will return the python function Vector.doubleLength.

We then define a new test case class for each supported data type with a short definition such as:

    class doubleTestCase(VectorTestCase):
        def __init__(self, methodName="runTest"):
            VectorTestCase.__init__(self, methodName)
            self.typeStr = "double"
            self.typeCode = "d"

Each of these 12 classes is collected into a unittest.TestSuite, which is then executed. Errors and failures are summed together and returned as the exit argument. Any non-zero result indicates that at least one test did not pass.
Large parts of this manual originate from Travis E. Oliphant’s book Guide to Numpy (which generously entered Public Domain in August 2008). The reference documentation for many of the functions are written by numerous contributors and developers of Numpy, both prior to and during the Numpy Documentation Marathon.

Please help to improve NumPy’s documentation! Instructions on how to join the ongoing documentation marathon can be found on the scipy.org website.


[R218] Francis Hunt and Paul Johnson, On the Pareto Distribution of Sourceforge projects.


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