Numpy
Python for Ecologists

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Overview of files

- Install Numpy
- Array
- Indexing
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- Reference

Install Numpy

- Windows
  - 1. for 32 bit machine, download from: http://sourceforge.net/projects/numpy/files/NumPy/1.6.2/
  - 2. for 64 bit system, download from: http://www.lfd.uci.edu/~gohlke/pythonlibs/
  - **Portable Python** http://www.portablepython.com/wiki/PortablePython2.7.3.1

Create an array

```
# create an array from a list
>>>a=np.array([10, 20, 30, 40])
>>>a
>>>> [10 20 30 40]
>>> a.shape
>>>(4,)
```

np.array (cont'd)

```
>>> b = np. array([[1, 2, 3, 4],[4, 5, 6, 7], [7, 8, 9, 10]])
>>> b
>>> [[ 1  2  3  4]
       [ 4  5  6  7]
       [ 7  8  9 10]]
>>> b.shape
>>>(2,2)
>>> b.reshape(4,3)
>>> [[ 1  2  3]
      [ 4  4  5]
      [ 6  7  7]
      [ 8  9 10]]
```

np.array (cont'd)

```
>>> b.shape = 6,-1
```

Python will automatically calculate the length of second axis 12/6=2

```
>>>b
>>> [[ 1  2]
       [ 3  4]
       [ 4  5]
       [ 6  7]
       [ 7  8]
       [ 9 10]]
```

np.array (cont'd)

```
>>>b = np.array([[1, 2, 3, 4],[4, 5, 6, 7], [7, 8, 9,
   10]],dtype=float)
>>>b.dtype
>>> float64
>>>b
>>> [[  1.   2.   3.   4.]
     [  4.   5.   6.   7.]
     [  7.   8.   9.  10.]]
```

np.arange

np.array approach is not efficient, let's try np.arange

np.arange(*start*, *stop*, *step*, *dtype=None*)

>>>np.arange(0,4,1)

>>>[0 1 2 3] (does not include '4')

>>> np.arange(4)

>>>[0 1 2 3]

np.linespace

np.linspace(start, stop, num, endpoint=True, retstep=False)

>>>a = np.linspace(2.0, 3.0, num=5, endpoint= True, retstep=True)

>>>(array([2. , 2.25, 2.5 , 2.75, 3.]), 0.25)

>>>b = np.linspace(2.0, 3.0, num=5, endpoint= False, retstep=True)

>>>(array([2. , 2.2, 2.4, 2.6, 2.8]), 0.2)

Structured (record) Arrays

- allows access to its data using named fields.

```
>>>persontype = np.dtype({'names':['name', 'age',
   'weight'],'formats':['S32','i', 'f']})

>>>a = np.array([(“Name A",32,75.5),(“Name B",24,65.5)],
        dtype=persontype)

>>>a
>>>[('Name A', 32, 75.5) ('Name B', 24, 65.5)]
```

```
>>a[0]
>>>(‘Name A', 32, 75.5)

>>>a['name']
>>>['Name A' 'Name B']

>>>a[‘age’][0]
>>>32

>> a[‘name’][1]=‘tao’              #modify
>>>a
>>> [('Name A', 32, 75.5) ('tao', 24, 65.5)]
```

Some propertites

```
>>>a = np.array([[1, 2, 3, 4],[4, 5, 6, 7], [7, 8, 9, 10]],dtype=float)
>>>[[ 0 10 20]
      [30 40 50]]

>>>a.shape          #shape
>>>(2, 3)

>>>a.ndim           #number of dimensions
>>>2

>>>a.dtype          #data type
>>> int32

>>>a.size           #number of elements
>>>6

>>> k= a.flat       #return a flat iterator over an array
>>>for i in k:
 >>>   print i
```

fromfunction

- Construct an array by executing a function over each coordinate

```
>>>def func(i):
>>>    return i%4+1
>>> np.fromfunction(func, (5,))
>>> [ 1.  2.  3.  4.  1.]
```

Indexing

```
>>> a = np.arange(10)
```

Integer index

```
>>> a[5]
>>5
```

A range (starts at the 3th and ends before 5th)

```
>>> a[3:5]
>>>[3, 4]
```

The first five elements

>>> a[:5]

>>>[0, 1, 2, 3, 4]

Counting backwards

>>> a[:-1]

array([0, 1, 2, 3, 4, 5, 6, 7, 8])

Reverse the array

>>> a[::-1]

>>>[9, 8, 7, 6, 5, 4, 3, 2, 1, 0]

>>> a[::-1][::2] #every other one

>>>[9, 7, 5, 3, 1]

Two dimensions

>>b = np.array([[1, 2, 3, 4],[4, 5, 6, 7], [7, 8, 9, 10]])

>>c= b[:,::-1]

b= [[1 2 3 4]
 [4 5 6 7]
 [7 8 9 10]]

c= [[4 3 2 1]
 [7 6 5 4]
 [10 9 8 7]]

Modify content

```
>>> a[2:4] = 100,101
>>> a
>>> [ 0, 1, 100, 101, 4, 5, 6, 7, 8, 9]
```

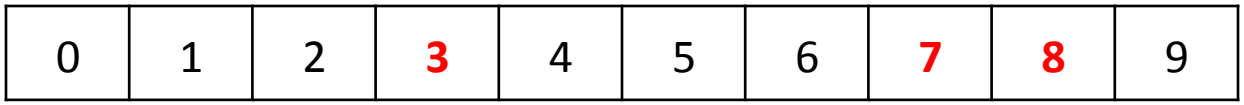
0	1	**100**	**101**	4	5	6	7	8	9

a[i:j:k] *i* is the starting index, *j* is the stopping index, and *k* is the step.

```
>>> a[1:-1:2]
>>>[ 1, 101, 5, 7]
```

0	**1**	100	**101**	4	**5**	6	**7**	8	9

```
>>>x = np.arange(10)
>>> [0 1 2 3 4 5 6 7 8 9]
>>>x[[3, 3, -3, 8]]   #list
>> [3 3 7 8]
```




```
>> x[np.array([3,3,-3,8])] #array
>> [3 3 7 8]

>> x[np.array([True, False, True, False, False])]
>> [0 2]        #the missing ones considered as ‘False’
```

Multidimensions

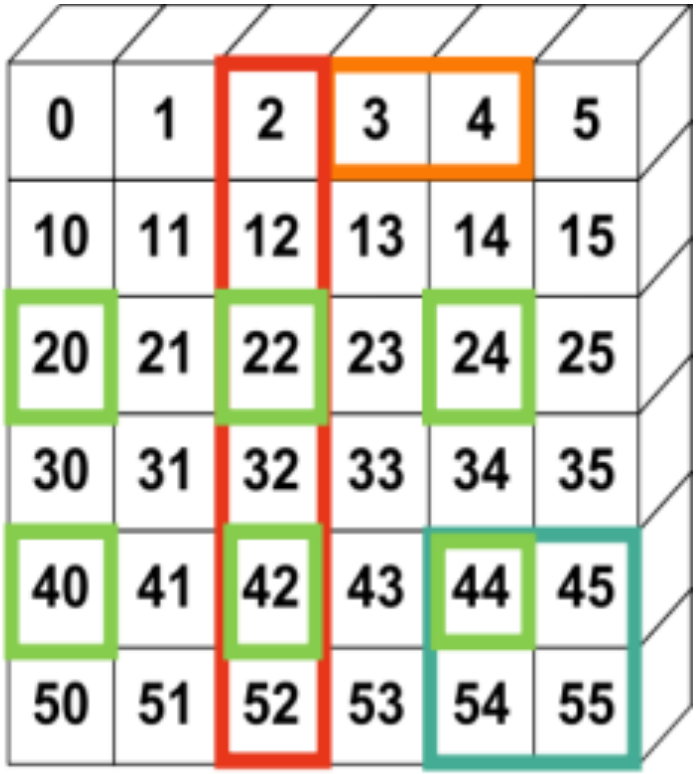
a = np.arange(0, 60, 10).reshape(-1, 1)+np.arange(0, 6)

0	**1**	**2**	**3**	**4**	**5**
10	**11**	**12**	**13**	**14**	**15**
20	**21**	**22**	**23**	**24**	**25**
30	**31**	**32**	**33**	**34**	**35**
40	**41**	**42**	**43**	**44**	**45**
50	**51**	**52**	**53**	**54**	**55**

```
>>>a[:,2]
>>> [ 2 12 22 32 42 52]

>>>a[0,3:5]
>>>[3,4]

>>>a[4:,4:]  #select a 'block'
>>> [[44 45]
      [54 55]]
```



>>>a[2::2,::2] #start from 3rd row, $step_{row}$=2, start from 1st col, $step_{col}$=2

```
>>>[[20 22 24]
      [40 42 44]]

>>>x[2::2,::-1]?
>>> [[25 24 23 22 21 20]
      [45 44 43 42 41 40]]
```

np.indices

- Return an array representing the indices of a grid

  x = np.arange(20).reshape(5, 4)

  x=[[0 1 2 3]
  [4 5 6 7]
  [8 9 10 11]
  [12 13 14 15]
  [16 17 18 19]]

  row, col = np.indices((2, 3))

  x[row, col]=[[0 1 2]
  [4 5 6]]

- Extract the required elements directly with ``x[:2, :3]``.

Broadcasting

- Deal with inputs that do not have exactly the same shape.

- Rule 1: if arrays do not have the same number of dimensions, then a "1" will be repeatedly added to the shapes of the smaller arrays

- Rule 2: arrays with a size of 1 along a particular dimension act as if they had the size of the array with the largest shape along that dimension.

```
>>> a = np.arange(0, 60, 10).reshape(-1, 1)    # a.shape=(6,1)
>>> b = np.arange(0, 5)                                  #b.shape=(5,)
>>> c = a+b
```

How does array c looks like?

```
>>> a
>>>[[ 0]
      [10]
      [20]
      [30]
      [40]
      [50]]
```

Rule 1

```
>>> a = a.repeat(5, axis=1)
          >>>a
>>> [[ 0  0  0  0  0]
       [10 10 10 10 10]
       [20 20 20 20 20]
       [30 30 30 30 30]
       [40 40 40 40 40]
                                                    [50 50 50
   50 50]]
```

```
>>>b = np.arange(0, 5)
>>>b
>>> [0, 1, 2, 3, 4]
>>>b.shape
>>>(5,)
```

Rule 1

```
>>> b.shape=1,5
>>> b
>>>[[0, 1, 2, 3, 4]]
```

Rule 2

```
>>> b = b.repeat(6,axis=0)
>>> b
>>> [[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],
       [0, 1, 2, 3, 4]]
```

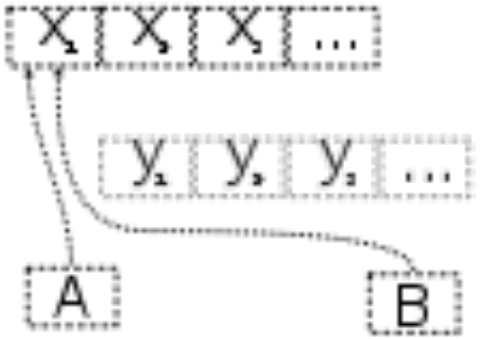
```
>>> c = a + b
>>> c
>>> [[ 0  1  2  3  4]
       [10 11 12 13 14]
       [20 21 22 23 24]
       [30 31 32 33 34]
       [40 41 42 43 44]
       [50 51 52 53 54]]
```

Deep copy shallow copy

- A shallow copies collection structure, not the elements. With a shallow copy, two collections now share the individual elements.

Shallow copy

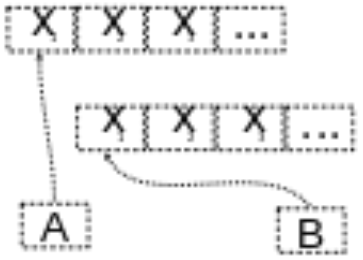
```
>>>a = np.arange(0, 60, 10)
>>>b=a
>>>a
>>>[ 0 10 20 30 40 50]
>>>b
>>>[ 0 10 20 30 40 50]
>>>b[0]=100
>>>b
>>>[100  10  20  30  40  50]
>>>a
>>>[100  10  20  30  40  50]
```



- Deep copies duplicate everything. A deep copy of a collection is two collections with all of the elements in the original collection duplicated.

Deep copy

```
>>>a = np.arange(0, 60, 10)
>>> b= copy.deepcopy(a)
>>>a
>>>b[0]=100
>>>b
>>>[100  10  20  30  40  50]
>>>a
>>>[0  10  20  30  40  50]
```



np.array VS np.mat

```
>>> a=np.mat('4 3; 2 1')
>>>a
>>> [[4 3]
      [2 1]]
>>> b=np.mat('1 2; 3 4')
>>>b
>>> [[1 2]
      [3 4]]
>>>c=a*b
>>>c
>>> [[13 20]
      [ 5  8]]
```

```
>>> a= np.array([[4, 3], [2, 1]])
>>>a
>>> [[4 3]
      [2 1]]
>>> b= np.array([[1, 2], [3, 4]])
>>>b
>>> [[1 2]
      [3 4]]
>>>c=a*b
>>>c
>>> [[4 6]
      [6 4]]
>>>d=np.dot(a,b)
>>> [[13 20]
      [ 5  8]]
```

```
>>>A = matrix( [[1,2,3],[11,12,13],[21,22,23]]) # Creates a matrix.
>>> [[ 1  2  3]
       [11 12 13]
       [21 22 23]]

>>>print A.T              # Transpose of A
>>> [[ 1 11 21]
       [ 2 12 22]
        [ 3 13 23]]

>>>print A.I              # Inverse of A.
>>> [[  3.00239975e+14  -6.00479950e+14   3.00239975e+14]
       [ -6.00479950e+14   1.20095990e+15  -6.00479950e+14]
       [  3.00239975e+14  -6.00479950e+14   3.00239975e+14]]
```

Solve a linear system

$$[a]_{3\times3}[x]_{3\times1} = [b]_{3\times1}$$

```
>>> a= np.random.rand(3,3)
>>> [[ 0.26835516  0.1812329   0.07554446]
       [ 0.2915491   0.27213494  0.05657924]
       [ 0.89496488  0.35577792  0.88181086]]
>>> b= np.random.rand(3).reshape(3,-1)
>>> [[ 0.80181235]
 [ 0.13312618]
 [ 0.5599297 ]]
>>>x=np.linalg.solve(a,b)
>>> [[ 0.83270995]
       [ 0.43698752]
       [-0.144376  ]]
```

More numpy matrix functions

- **NumPy for MATLAB Users**

http://www.scipy.org/NumPy_for_Matlab_Users

- **NumPy for R (and S-Plus) users**

http://mathesaurus.sourceforge.net/r-numpy.html

Reference

- Official document
  NumPy User Guide (not the reference guide)
  http://docs.scipy.org/doc/numpy/numpy-user.pdf
- Guide to NumPy by Travis E. Oliphant
  http://www.tramy.us/numpybook.pdf
- http://stackoverflow.com/