

Numpy Stack

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- Numeric (1995)
- Numarray (for large arrays)
- scipy.core (briefly, around 2005)
- numpy (2005)

Currently

- numpy 1.6
- **de facto** standard
- very stable

`numpy.array` or `numpy.ndarray`.

Multi-dimensional array of numbers.

numpy example

```
import numpy as np
A = np.array([
    [0, 1, 2],
    [2, 3, 4],
    [4, 5, 6],
    [6, 7, 8]])
print A[0,0]
print A[0,1]
print A[1,0]
```

Some Array Properties

```
import numpy as np
A = np.array([
    [0,1,2],
    [2,3,4],
    [4,5,6],
    [6,7,8]])
print A.shape
print A.size
```

Some Array Functions

```
...  
print A.max()  
print A.min()
```

- `max()`: maximum
- `min()`: minimum
- `ptp()`: spread (max - min)
- `sum()`: sum
- `std()`: standard deviation
- ...

Other Functions

- `np.exp`
- `np.sin`
- ...

All of these work **element-wise!**

Arithmetic Operations

```
import numpy as np
A = np.array([0,1,2,3])
B = np.array([1,1,2,2])

print A + B
print A * B
print A / B
```

Mixing arrays of different dimensions

```
import numpy as np
A = np.array([
    [0,0,1],
    [1,1,2],
    [1,2,2],
    [3,2,2]
])
B = np.array([2,1,2])

print A + B
print A * B
```

Special case: scalar.

```
import numpy as np
A = np.arange(100)
print A + 2
A += 2
```

`numpy.ndarray` is a homogeneous array of numbers.

Types

- Boolean
- integers
- floating point numbers
- ...

Object Construction

```
import numpy as np
A = np.array([0,1,1],float)
A = np.array([0,1,1],bool)
```

Reduction

```
A = np.array([
    [0, 0, 1],
    [1, 2, 3],
    [2, 4, 2],
    [1, 0, 1]])
print A.max(0)
print A.max(1)
print A.max()
```

prints

```
[2,4,3]
[1,3,4,1]
4
```

The same is true for many other functions.

```
import numpy as np
A = np.array([
    [0, 1, 2],
    [2, 3, 4],
    [4, 5, 6],
    [6, 7, 8]])
print A[0]
print A[0].shape
print A[1]
print A[:, 2]
```

Two minute break

- Talk to your neighbours
- Play around in Python
- Ask questions

Slices Share Memory!

```
import numpy as np
A = np.array([
    [0, 1, 2],
    [2, 3, 4],
    [4, 5, 6],
    [6, 7, 8]])
B = A[0]
B[0] = -1
print A[0,0]
```

Pass is By Reference

```
def double(A):  
    A *= 2
```

```
A = np.arange(20)  
double(A)
```

Pass is By Reference

```
def double(A):  
    A *= 2
```

```
A = np.arange(20)  
double(A)
```

```
A = np.arange(20)  
B = A.copy()
```

Logical Arrays

```
A = np.array([-1, 0, 1, 2, -2, 3, 4, -2])  
print (A > 0)
```

Logical Arrays II

```
A = np.array([-1, 0, 1, 2, -2, 3, 4, -2])  
print ( (A > 0) & (A < 3) ).mean()
```

What does this do?

Logical Indexing

```
A[A < 0] = 0
```

or

```
A *= (A > 0)
```

```
print 'Mean of positives ', A[A > 0].mean()
```

Some Helper Functions

Constructing Arrays

```
A = np.zeros((10,10), int)
B = np.ones(10)
C = np.arange(100).reshape((10,10))
...
```

Multiple Dimensions

```
img = np.zeros((1024,1024,3))
```


<http://docs.scipy.org/doc/>

Matplotlib is a **plotting library** for Python.

```
import pylab
import numpy as np
X = np.linspace(-4,+4,1000)
pylab.plot(X,np.exp(-X**2))
pylab.xlabel(r '$x$ ')
pylab.ylabel(r '$\exp(-x^{\{2\}})$ ')
pylab.savefig('gaussian.pdf')
```

<http://matplotlib.sf.net/>

Matplotlib Example

