COMPSCI 590N
Lecture 6: NumPy 2

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Outline

1 Shape Manipulation and Broadcasting

2 Miscellaneous NumPy

Shape Manipulation

NumPy provides various functions for changing the shape/size of an array. The most basic is `reshape` which returns an array with a new shape.

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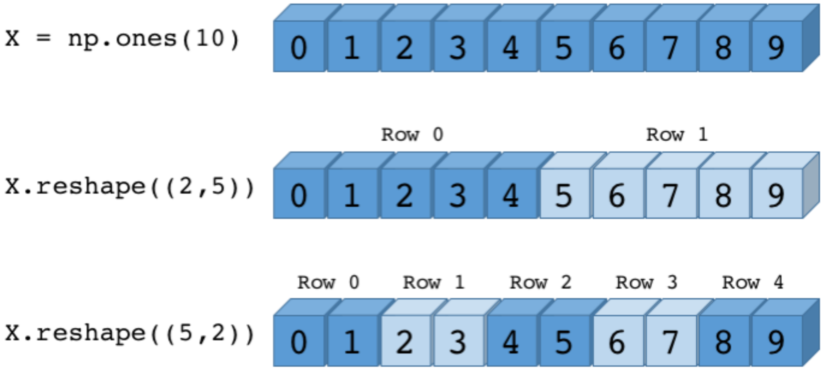
```
>>> A = np.arange(9)
>>> A
array([0, 1, 2, 3, 4, 5, 6, 7, 8])
>>> A.reshape((3,3))
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])

>>> A.shape = (3,3)
>>> A
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])
```

Shape Manipulation



```
X = np.ones(10)
X.reshape((2,5))
X.reshape((5,2))
```

Shape Manipulation

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```
>>> A = np.arange(6)
>>> A.
>>> A.reshape((2,-1))
array([[0, 1, 2],
       [3, 4, 5]])
>>> A.reshape((-1,2))
array([[0, 1],
       [2, 3],
       [4, 5]])
```

Shape Manipulation

Other useful functions return specific shapes:

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```
>>> A.ravel()
array([0, 1, 2, 3, 4, 5])

>>> A.transpose() # Also use a.T
array([[0, 3],
       [1, 4],
       [2, 5]])
```

Fancy Indexing

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```
>>> A = np.arange(10)
>>> B = (A%2) == 0
>>> A[B] # Select all even numbers
array([0, 2, 4, 6, 8])

>>> A = np.array([[0,-1],[2,3],[-3,2]])
>>> A
array([[ 0, -1],
       [ 2,  3],
       [-3,  2]])
>>> B = A.sum(1) < 0
>>> A[B,:] # Select all rows whose sum is < 0
array([[ 0, -1],
       [-3,  2]])
```

Fancy Indexing

Arrays can also be indexed using other **integer** arrays.

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```
>>> A = 2*np.arange(10)
>>> B = np.array([1,4,5,7])
>>> A[B]
array([ 2,  8, 10, 14])

>>> A = np.arange(6).reshape((2,3))
>>> A
array([[0, 1, 2],
       [3, 4, 5]])
>>> B = np.array([0,0,1])
>>> C = np.array([1,2,2])
>>> A[B,C] # One array for each dimension
array([1, 2, 5])
```

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```
>>> A = np.arange(6).reshape((2,3))
>>> A
array([[0, 1, 2],
       [3, 4, 5]])
>>> B = np.arange(5)
>>> A * B
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: operands could not be broadcast together
    with shapes (2,3) (5,)
```

Broadcasting

In some special cases, NumPy will replicate one or more of the inputs so that it can perform the desired operation. This is called **broadcasting**.

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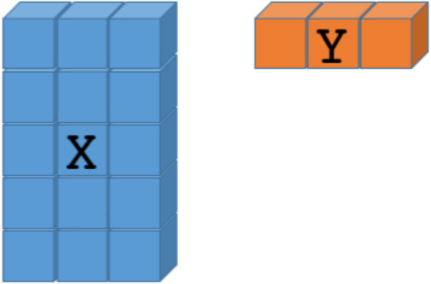
```
>>> A = np.arange(6).reshape((2,3))
>>> A
array([[0, 1, 2],
       [3, 4, 5]])
>>> B = np.arange(3)
>>> A * B # B is copied for each row of A
array([[ 0,  1,  4],
       [ 0,  4, 10]])
```

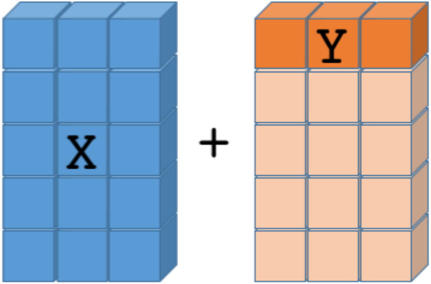
Broadcasting

```
X = np.ones((5,3))
Y = np.ones(3)
```



Broadcasting

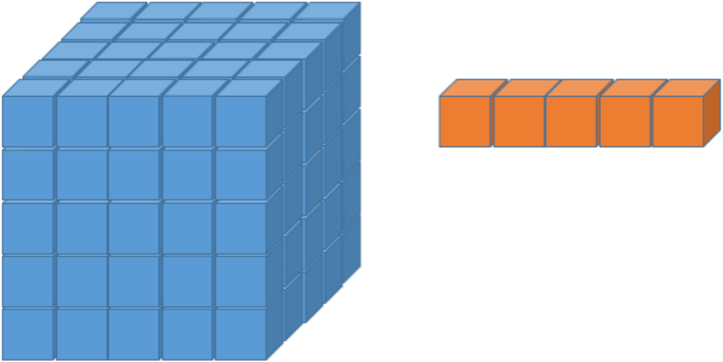
```
X = np.ones((5,3))
Y = np.ones(3)
Z = X + Y
```



Broadcasting

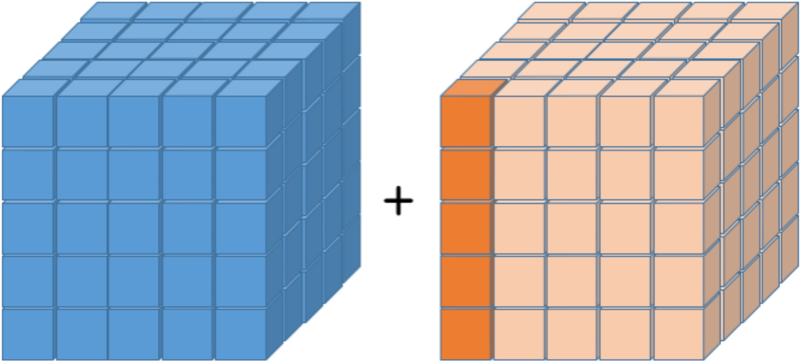
```
X = np.ones((5,5,5))
```

```
Y = np.ones(5)
```



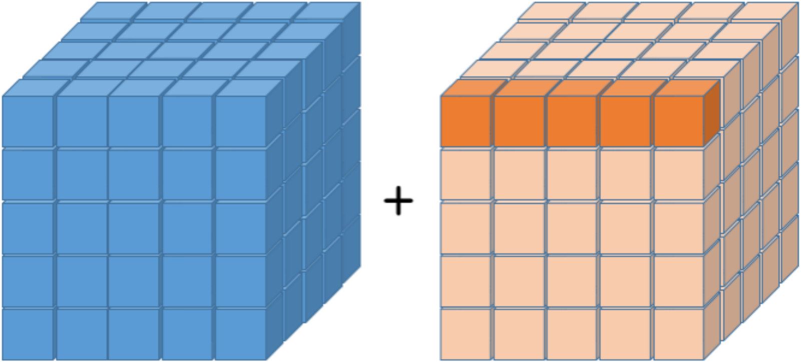
Broadcasting

```
Z = X + Y.reshape((5,1,1))
```



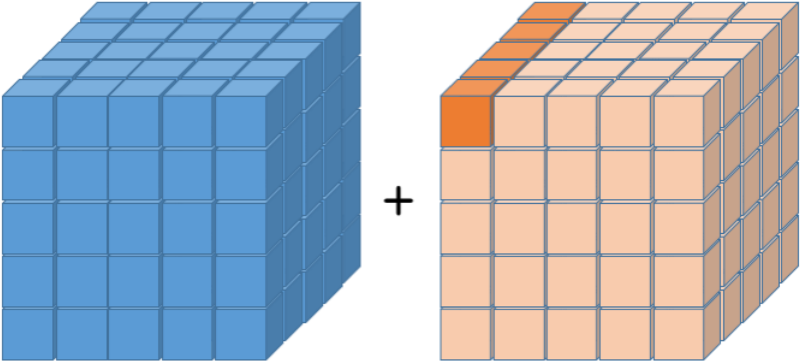
Broadcasting

```
Z = X + Y.reshape((1,5,1))
```



Broadcasting

```
Z = X + Y.reshape((1,1,5))
```



Interactive Demo

Interactive Demo

1. How do you set all of the negative elements in an array to zero?
2. Recall that you can set an entire slice of an array by using indexed assignment. What happens when assign to a slice indexed by an array and there are duplicates in the **index** array?
   - For example:
     `a[np.array([1,1,2])] = np.array([1,2,3])`
3. Use broadcasting to calculate the outer product of two one dimensional arrays (i.e. $A \otimes B = AB^T$).

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Reductions

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```
>>> A = np.arange(6).reshape((3,2))
>>> A.sum()
15
```

Reductions

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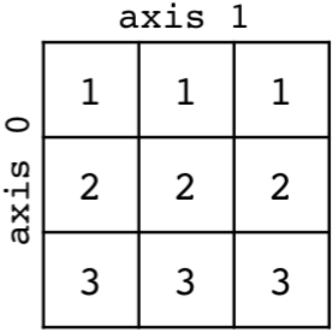

1	1	1
2	2	2
3	3	3

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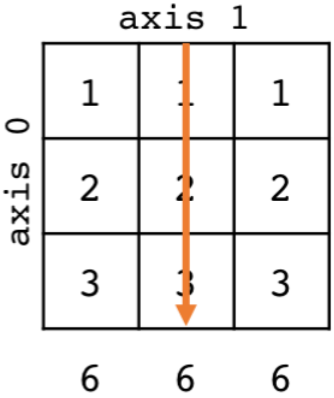
```
X.sum(axis = 0)
```



1	1	1
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6 6 6

Reductions

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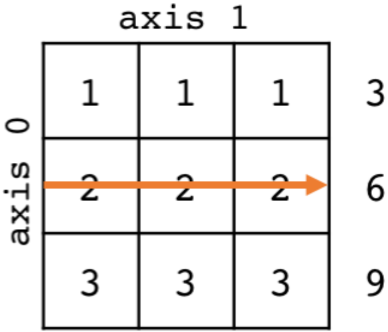
```
X.sum(axis = 1)
```



1	1	1	3
2	2	2	6
3	3	3	9

Reductions

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```
>>> A = np.arange(6).reshape((3,2))
>>> A.prod(axis=0)
array([ 0,  6, 20])
>>> A.max(axis=1) # Also min
array([1, 3, 5])
>>> A.argmax(axis=1) # Also argmin
array([1, 1, 1])
>>> A.mean(axis=1)
array([ 0.5,  2.5,  4.5])
>>> A.std(axis=-1) # -1 corresponds to the last
    dimension
array([ 0.5,  0.5,  0.5])
>>> np.median(A,axis=1) # Not a member function
array([ 0.5,  2.5,  4.5])
```

Stacking

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```
>>> A = np.ones((3,4))
>>> B = np.ones((3,4))
>>> np.vstack((A,B)).shape # first dimension
(6, 4)
>>> np.hstack((A,B)).shape # second dimension
(3, 8)
>>> np.stack((A,B)).shape # new dimension
(2, 3, 4)
>>> np.concatenate((A,B),axis=0).shape # any dimension
(6, 4)
>>> np.concatenate((A,B),axis=1).shape # any dimension
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```

Analogues to each of these functions exist for splitting arrays.

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```
>>> A = np.ones((3,4))
>>> B = A
>>> B is A
True
>>> B = A.copy()  # Create a new copy of 'A' in memory
>>> B is A
False
```

Basic Linear Algebra

NumPy implements many of the standard linear algebra functions:

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- And many more...

File I/O

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```
>>> np.savetxt("my_array.csv",my_array,delimiter=’,’)
>>> my_array = np.loadtxt("my_array.npy",delimiter=’,’)
```

’Object’ Arrays

In general arrays store only a single type, however, you can create mixed type arrays by setting the data type to `object`. In python, everything an `object` so these arrays can store anything.

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```
>>> A = np.array([1,2.0,"string"],dtype=object)
>>> A + A
array([2, 4.0, ’stringstring’], dtype=object)
>>> A / 3
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unsupported operand type(s) for /: ’str’ and
    ’int’
```

Interactive Demo

Interactive Demo

1. What is the difference between the reductions `sum` and `cumsum`?
2. `view()` can be used in a similar way as copy, but has a slightly different effect. Try to figure out what view does.