Overview:

Numpy is a multidimensional array library.
Lists are very slow.

Why is NumPy Faster?

NumPy is very fast. Because NumPy uses fixed type i.e it stores as Int32.
Lists are slow because they keep references. And an integer in list takes a hell lot of memory.
NumPy has no type checking.
NumPy has contiguous memory.
We can multiply arrays in NumPy. a*b

Applications of NumPy:

Replacement of MATLAB for Mathematics.
Backend of Pandas.
Photography.
Machine Learning e.g. Tensors.

NumPy import:

```
import numpy as np
```

Basics

Basic array:

```
a = np.array([1,2,3])
```

[1 2 3]

2-D array:

```
b = np.array([[1,2,3],[4,5,6]])
#Should have equal elements in all rows
```

[[1 2 3]
 [4 5 6]]

Get dimension of NumPy array:

```
b.ndim
```

2

Get shape:

```
b.shape
```

(2, 3)

Get Type:

```
a.dtype
```

dtype('int32')

Specifying type of array while initialization:

```
a = np.array([[1,2,3],[4,5,6]],dtype='int16')
a.dtype
```

dtype('int16')

Size of a single item for int16 array:

```
a.itemsize
```

2

Total number of elements in array:

```
a.size
```

6

Total number of bytes in array:

```
a.nbytes
```

12

Accessing/Changing specific elements, rows, columns,etc

To get a specific element (row, column):

```
a = np.array([[1,2,3,4,5,6,7],[8,9,10,11,12,13,14]])
a[0,0]
```

1

Other stuff::

```
a[0,-1]
```

7

```
a[0,:]
```

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

```
a[:,2]
```

array([3, 10])

```
a[:,2:4]
```

array([[3, 4],
       [10, 11]])

General Syntax - a[start_index:end_index:step_size, start_index:end_index:step_size, …..n dimensions]

Accessing multiple indices (Indices (1,1), (1,2) and (1,3)):

```
file_data[[1,1,1],[1,2,3]]
```

Setting values:

```
a[0,3]=10
```

Setting values for entire row:

```
a = np.array([[1,2,3,4,5,6,7],[8,9,10,11,12,13,14]])
a[1,:]=99
print(a)
```

```
[[ 1  2  3  4  5  6  7]
 [99 99 99 99 99 99 99]]
```

3-D array:

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

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

 [[5 6]
  [7 8]]]
```

Accessing a 3-D element:

```
b[1,1,0]
```

```
7
```

Using a range function:

```
np.arange(start = 0, stop = 5, step = 1)
```

array([0, 1, 2, 3, 4])

linspace (which we give start and end point and intervals in between):

```
np.linspace(start = 0, stop = 100, num = 5)
```

array([0., 25., 50., 75., 100.])

To ravel an array:

```
a = np.array([[1,2,3],[4,5,6]])
np.ravel(a)
```

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

Initializing different types of arrays

To create an array of zeros using dimensions:

```
b = np.zeros((2,3))
print(b)
```

[[0. 0. 0.]
 [0. 0. 0.]]

To create an array of ones using dimensions:

```
b = np.ones((2,3), dtype='int32')
print(b)
```

```
[[1 1 1]
 [1 1 1]]
```

Any other number (we use full):

```
b = np.full((2,2), 99)
```

```
[[99 99]
 [99 99]]
```

If we want it to have the same dimensions as another array:

```
b = np.full_like(a, 4) or b = np.full(a.shape(), 4)
```

Generating a random number array:

```
b = np.random.rand(4,2)
```

```
[[0.85754961 0.91127152]
 [0.45251941 0.12162455]
 [0.50694868 0.05315512]
 [0.70002409 0.30481215]]
```

Generating a random number array using shape of other array:

```
b = np.random.random_sample(a.shape)
```

Generating a random number array using randn(includes negative numbers):

```
array = np.random.randn(4)
```

```
[ 0.50302852 -1.24692807  1.04556022 -0.05267173]
```

Array with random integers:

```
b = np.random.randint(4,7, size=(3,3))
#Array with random numbers from 4 to 7 where 7 is exclusive
```

```
[[5 4 5]
 [6 4 5]
 [5 4 4]]
```

Identity matrix:

```
b = np.identity(3)
```

```
[[1. 0. 0.]
 [0. 1. 0.]
 [0. 0. 1.]]
```

Repeating an array:

```
arr = np.array([[1,2,3]])
b = np.repeat(arr, 3, axis = 0) # Where 3 is no. of times to repeat
print(b)
```

```
[[1 2 3]
 [1 2 3]
 [1 2 3]]
```

Repeating an array horizontally:

```
arr = np.array([[1,2,3]])
b = np.repeat(arr, 3, axis = 1) # Where 3 is no. of times to repeat
print(b)
```

```
[[1 1 1 2 2 2 3 3 3]]
```

To print a design:

```
import numpy as np

n = int(input())
arr = np.full((n,n),99)
for i in range(0,n):
    arr[i:-i,i:-i] = i
print(arr)
```

```
[[99 99 99 99 99 99 99 99 99 99]
 [99  1  1  1  1  1  1  1  1 99]
 [99  1  2  2  2  2  2  2  1 99]
 [99  1  2  3  3  3  3  2  1 99]
 [99  1  2  3  4  4  3  2  1 99]
 [99  1  2  3  4  4  3  2  1 99]
 [99  1  2  3  3  3  3  2  1 99]
 [99  1  2  2  2  2  2  2  1 99]
 [99  1  1  1  1  1  1  1  1 99]
 [99 99 99 99 99 99 99 99 99 99]]
```

Beware of copying an array. It usually copies the link rather than values:

```
a = np.array([1,2,3])
b = a
b[0]=100
print(a)
```

[100 2 3]

To prevent linking of arrays, we use copy():

```
a = np.array([1,2,3])
b = a.copy()
b[0]=100
print(a)
```

[1 2 3]

Mathematics

Basic math on arrays:

```
a = np.array([1,2,3])

print(a + 2)
```

```
print(a - 2)

print(a * 2)

print(a / 2)

print(a ** 2)
```

a + 2
[3 4 5]

a - 2
[-1 0 1]

a * 2
[2 4 6]

a / 2
[0.5 1. 1.5]

a ** 2
[1 4 9]

Sin on the array:

```
a = np.array([1,2,3])
np.sin(a)
```

array([0.84147098, 0.90929743, 0.14112001])

Square root on the array:

```
a = np.array([[1,2,3],[4,5,6]])
np.sqrt(a)
```

```
array([[1.        , 1.41421356, 1.73205081],
       [2.        , 2.23606798, 2.44948974]])
```

Standard deviation on the array:

```
a = np.array([[1,2,3],[4,5,6]])
np.std(a)
```

```
1.707825127659933
```

Exponent e^x:

```
np.exp(a)
```

Logarithm log x:

```
np.log(a)
```

Logarithm $\log_{10}$ x:

```
np.log10(a)
```

Linear Algebra

Matrix multiplication (It should have compatible dimensions):

```
a = np.ones((2,3))
b = np.full((3,2),2)
np.matmul(a,b)
```

```
array([[6., 6.],
       [6., 6.]])
```

Finding the determinant of a matrix:

```
a = np.identity(3)
np.linalg.det(a)
```

```
1.0
```

For more functions on linear algebra.
https://docs.scipy.org/doc/numpy/reference/routines.linalg.html

Statistics

Finding minimum in data:

```
a = np.array([[1,2,3],[4,5,6]])
np.min(a)
```

1

Finding maximum in data:

```
a = np.array([[1,2,3],[4,5,6]])
np.max(a)
```

6

Using axis for min, max:

```
np.min(a, axis=0) #Finds minimum in each column
```

array([1, 2, 3])

```
np.min(a, axis=1) #Finds minimum in each row
```

array([1, 4])

Reorganizing Arrays

Changing dimensions (we can change to any compatible dimension):

```
a = np.array([[1,2,3],[4,5,6]])
a = a.reshape((3,2))
a
```

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

If we use -1 for dimensions in reshape, e.g. (2,-1), (-1,4), except (-1,-1) python will automatically find the right dimension number to replace the -1's place for that dataset.

```
a = np.array([[1,2,3],[4,5,6]])
a = a.reshape((6,1))
a
```

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

Vertical stacking:

```
v1 = np.array([1,2,3,4,5])
v2 = np.array([6,7,8,9,10])

np.vstack([v1,v2])
```

array([[1, 2, 3, 4, 5],
[6, 7, 8, 9, 10]])

Horizontal stacking:

```
h1 = np.ones((2,4),dtype='int32')
```

```
h2 = np.zeros((2,2),dtype='int32')

np.hstack([h1,h2])
```

```
array([[1, 1, 1, 1, 0, 0],
       [1, 1, 1, 1, 0, 0]])
```

Miscellaneous

GitHub link for data:
https://github.com/KeithGalli/NumPy/blob/master/data.txt

Load data from a File:

```
file_data = np.genfromtxt('data.txt',delimiter=',')
```

```
array([[  1.,  13.,  21.,  11., 196.,  75.,   4.,   3.,  34.,   6.,   7.,
          8.,   0.,   1.,   2.,   3.,   4.,   5.],
       [  3.,  42.,  12.,  33., 766.,  75.,   4.,  55.,   6.,   4.,   3.,
          4.,   5.,   6.,   7.,   0.,  11.,  12.],
       [  1.,  22.,  33.,  11., 999.,  11.,   2.,   1.,  78.,   0.,   1.,
          2.,   9.,   8.,   7.,   1.,  76.,  88.]])
```

To change array data type:

```
file_data = file_data.astype('int32')
```

Boolean Masking and Advanced Indexing

File data:

```
array([[  1,  13,  21,  11, 196,  75,   4,   3,  34,   6,   7,   8,   0,
          1,   2,   3,   4,   5],
       [  3,  42,  12,  33, 766,  75,   4,  55,   6,   4,   3,   4,   5,
          6,   7,   0,  11,  12],
       [  1,  22,  33,  11, 999,  11,   2,   1,  78,   0,   1,   2,   9,
          8,   7,   1,  76,  88]])
```

Searching for data which is greater than 50 in the file_data:

```
file_data > 50
```

```
array([[False, False, False, False,  True,  True, False, False, False,
        False, False, False, False, False, False, False, False, False],
       [False, False, False, False,  True,  True, False,  True, False,
        False, False, False, False, False, False, False, False, False],
       [False, False, False, False,  True, False, False, False,  True,
        False, False, False, False, False, False, False,  True,  True]])
```

Indexing the condition:

```
file_data[file_data > 50]
```

```
array([196,  75, 766,  75,  55, 999,  78,  76,  88])
```

We can specify elements of array using list of index:

```
a = np.array([0,10,20,30,40,50,60,70,80])
a[[0,5,8]] # We can specify using index list
```

array([0, 50, 80])

Find if **any** of the values in **ROW** or **COLUMN** has a condition:

```
np.any(file_data > 50, axis=0)
```

array([False, False, False, False, True, True, False, True, True,
       False, False, False, False, False, False, False, True, True])

Find if **all** values in **ROW** or **COLUMN** has a condition:

```
np.all(file_data > 50, axis=0)
```

array([False, False, False, False, True, False, False, False, False,
       False, False, False, False, False, False, False, False, False])

Combining conditions:

```
((file_data > 50) & (file_data <100))
```

array([[False, False, False, False, False, True, False, False, False,
        False, False, False, False, False, False, False, False, False],
       [False, False, False, False, False, True, False, True, False,
        False, False, False, False, False, False, False, False, False],
       [False, False, False, False, False, False, False, False, True,
        False, False, False, False, False, False, False, True, True]])

Not condition:

```
(~(file_data > 50) & (file_data <100))
```

```
array([[ True,  True,  True,  True, False, False,  True,  True,  True,
         True,  True,  True,  True,  True,  True,  True,  True,  True],
       [ True,  True,  True,  True, False, False,  True, False,  True,
         True,  True,  True,  True,  True,  True,  True,  True,  True],
       [ True,  True,  True,  True, False,  True,  True,  True, False,
         True,  True,  True,  True,  True,  True,  True, False, False]])
```

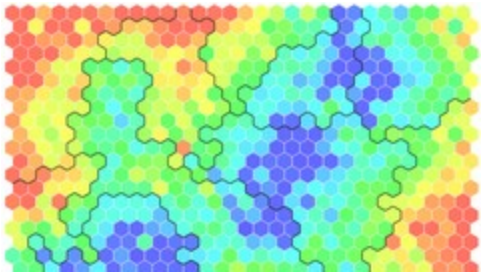
Mesh in numpy:

```
import numpy as np
# from matplotlib import pyplot as plt
# pyplot imported for plotting graphs

x = np.linspace(-4, 4, 9)

# numpy.linspace creates an array of
# 9 linearly placed elements between
# -4 and 4, both inclusive
y = np.linspace(-5, 5, 11)

# The meshgrid function returns
# two 2-dimensional arrays
x_1, y_1 = np.meshgrid(x, y)

print("x_1 = ")
print(x_1)
print("y_1 = ")
print(y_1)
```

```
x_1 =
[[-4. -3. -2. -1.  0.  1.  2.  3.  4.]
 [-4. -3. -2. -1.  0.  1.  2.  3.  4.]
 [-4. -3. -2. -1.  0.  1.  2.  3.  4.]
 [-4. -3. -2. -1.  0.  1.  2.  3.  4.]
 [-4. -3. -2. -1.  0.  1.  2.  3.  4.]
```

```
 [-4. -3. -2. -1.  0.  1.  2.  3.  4.]
 [-4. -3. -2. -1.  0.  1.  2.  3.  4.]
 [-4. -3. -2. -1.  0.  1.  2.  3.  4.]
 [-4. -3. -2. -1.  0.  1.  2.  3.  4.]
 [-4. -3. -2. -1.  0.  1.  2.  3.  4.]
 [-4. -3. -2. -1.  0.  1.  2.  3.  4.]]
y_1 =
[[-5. -5. -5. -5. -5. -5. -5. -5. -5.]
 [-4. -4. -4. -4. -4. -4. -4. -4. -4.]
 [-3. -3. -3. -3. -3. -3. -3. -3. -3.]
 [-2. -2. -2. -2. -2. -2. -2. -2. -2.]
 [-1. -1. -1. -1. -1. -1. -1. -1. -1.]
 [ 0.  0.  0.  0.  0.  0.  0.  0.  0.]
 [ 1.  1.  1.  1.  1.  1.  1.  1.  1.]
 [ 2.  2.  2.  2.  2.  2.  2.  2.  2.]
 [ 3.  3.  3.  3.  3.  3.  3.  3.  3.]
 [ 4.  4.  4.  4.  4.  4.  4.  4.  4.]
 [ 5.  5.  5.  5.  5.  5.  5.  5.  5.]]
```

www.udemy.com/course/deep-learning-prerequisites-the-numpy-stack-in-python



Deep Learning Prerequisites: The Numpy Stack in Python by Lazy Programmer Inc.

Dot Product

Method 1

$$a \cdot b = a^T b = \sum_{d=1}^{D} a_d b_d$$

Method 2

$$a \cdot b = |a||b|cos\theta_{ab}$$

|a| is the magnitude. Meaning it is the square root of the sum of squares of its individual components.

E.g. vector a = 5i + 8j -3k

|a| = sqrt(5*5 + 8*8 + (-3)*(-3))

Dot product with Numpy

```
a = np.array([1,2])
b = np.array([2,1])

np.dot(a,b)
```

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Calculating the magnitude of a vector in Numpy

```
amag = np.linalg.norm(a)
```

Finding the angle between two vectors

```
cosangle = a.dot(b) / (np.linalg.norm(a) * np.linalg.norm(b))
angle = np.arccos(cosangle)
```

Inverse cosine function on a cosine value

```
arccos(angle)
```

Matrix Data Type

```
M = np.matrix([[1,2],[3,4]])
```

But don't use it since official documentation is against using it.

`np.random.randn()`

Return a sample (or samples) from the "standard normal" distribution.

```
G = np.random.randn(10,10)
```

Calculating Mean of an array

```
G.mean()
```

Calculating variance of an array

```
G.var()
```

Calculating inverse of a matrix

```
A = np.array([[1,2],[3,4]])
Ainv = np.linalg.inv(A)
Ainv
```

Calculating determinant of a matrix

```
np.linalg.det(A)
```

Getting the diagonal elements of a matrix

```
np.diag(A)
```

Creating a matrix with a diagonal by a given array of elements

It creates a matrix of zeros but with diagonal elements replaced by the array passed in the arguments.
If we pass a 1-D array, we get a matrix like this.
If we pass a 2-D array, we get its diagonal elements like the previous example.

```
np.diag([1,2])
```

array([[1, 0],
[0, 2]])

To do a matrix multiplication

We do a dot product instead of a *.

```
np.array([[1,2],[3,4]]).dot(np.array([[1,2],[3,4]]))
```

array([[7, 10],
       [15, 22]])

Inner product and outer product

The inner product is the same as the dot product.

The outer product of two vectors produces a rectangular matrix, not a scalar. This is illustrated below.

$$\mathbf{a} = \begin{bmatrix} v \\ w \end{bmatrix} \qquad \mathbf{b} = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \qquad \mathbf{C} = \mathbf{ab'} = \begin{bmatrix} v*x & v*y & v*z \\ w*x & w*y & w*z \end{bmatrix}$$

Notice that the elements of Matrix C consist of the product of elements from Vector A crossed with elements from Vector B. Thus, Matrix C winds up being a matrix of cross products from the two vectors.

Outer product and inner product in Numpy

```
A = np.array([[1],[2]])
B = np.array([[3],[4]])
np.outer(A,B)
```

array([[3, 4],
       [6, 8]])

```
A = np.array([1,2])
B = np.array([3,4])
np.inner(A,B)
```

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Matrix trace (Sum of diagonals of the matrix)

```
np.diag(A).sum()
```

Or

```
 np.trace()
```

Calculating Covariance

```
X = np.random.randn(100,3)
cov = np.cov(X)
```

Calculating Eigenvalues and Eigenvectors

```
eigenvalues, eigenvectors = np.eig(C)

eigenvalues, eigenvectors = np.eigh(C)
```

eigh is for symmetric and Hermitian matrices

Solving a Linear System

Problem: $Ax = b$

Solution: $A^{-1}Ax = x = A^{-1}b$

- Is a system of D equations and D unknowns
- A is DxD, assume it is invertible
- We have all the tools we need to solve this already:
  - Matrix inverse
  - Matrix multiply (dot)

Conventional way to solve linear system

```
A = np.array([[1,2],[3,4]])
b = np.array([1,2])
x = np.linalg.inv(A).dot(b)
x
```

array([0. , 0.5])

Better way in Numpy

```
x = np.linalg.solve(A,b)
```

array([0. , 0.5])

Solving an actual word problem

Example Problem

The admission fee at a small fair is $1.50 for children and $4.00 for adults. On a certain day, 2200 people enter the fair and $5050 is collected. How many children and how many adults attended?

Let:

X1 = number of children, X2 = number of adults

X1 + X2 = 2200

1.5X1 + 4X2 = 5050

$$\begin{pmatrix} 1 & 1 \\ 1.5 & 4 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} 2200 \\ 5050 \end{pmatrix}$$

Program to solve it

```
A = np.array([[1,1],[1.5,4]])
b = np.array([2200,5050])

np.linalg.solve(A,b)
```

array([1500., 700.])

Extras

flatten()

It converts it to a 1D array.

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

[1,2,3,4]

Flatten can take 2 parameters i.e ‘C’(row-major), ‘F’(column-major).

np.mean()

Whenever we compare two Numpy arrays, we get a resultant array of 0’s(true) and 1’s(false). np.mean(A == B) will give the mean of the array of 0’s and 1’s.

np.allclose

Returns True if two arrays are element-wise equal within a tolerance.

```
np.allclose([1e10,1e-7], [1.00001e10,1e-8])
```

False

np.where

Returns the index values where the index is true.

```
a = np.where(p_test != y_test)
```

numpy.expand_dims

Expand the shape of an array.

Insert a new axis that will appear at the axis position in the expanded array shape.

```
numpy.expand_dims(a, axis)
```

```
a = np.expand_dims(X,-1)
```

Here, we are adding an extra dimension.

np.asarray

Converts PIL image to numpy array.

```
from PIL import Image

pic = Image.open('C:/Users/tejas/Desktop/car.jpg')
pic_arr = np.asarray(pic)
type(pic_arr)
```

numpy.ndarray

numpy.power

Increases the power of all values by the specified value.

```
x1 = range(6)
```

[0, 1, 2, 3, 4, 5]

```
np.power(x1, 3)
```

array([0,   1,   8, 27, 64, 125])

numpy.append

It appends to the end of the array.

```
np.append(arr = X, values = np.ones((50,1)).astype(int), axis = 1)
```

Here we are appending ones to the end.

Changing to any data type

numpy.float32()

We pass in a numpy array, it will just convert it to that data type and return.

```
a = np.float32(b)
```

numpy.empty(shape, dtype=float, order='C')

```
np.empty([2, 2])
```

```
array([[ -9.74499359e+001,   6.69583040e-309],
       [  2.13182611e-314,   3.06959433e-309]])
```

numpy.fromstring(string, dtype=float, count=-1, sep='')

A new 1-D array initialized from text data in a string.

```
np.fromstring('1 2', dtype=int, sep=' ')
```

```
array([1, 2])
```

```
np.fromstring('1, 2', dtype=int, sep=',')
```

```
array([1, 2])
```

np.concatenate

```
import numpy as np
a = np.array([1, 2, 3])
b = np.array([5, 6])
c=np.concatenate([a,b,a])
print(c)
```

```
[1 2 3 5 6 1 2 3]
```