

# Introductory Scientific Computing with Python

More on numpy arrays

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# Outline

- 1 Matrices
- 2 Least Squares Fit
- 3 Random numbers
- 4 Summary

# Outline

1 Matrices

2 Least Squares Fit

3 Random numbers

4 Summary

# Matrices: Introduction

All matrix operations are done using **arrays**

# Matrices: Initializing

```
In []: c = array([[11, 12, 13],  
                 [21, 22, 23],  
                 [31, 32, 33]])
```

```
In []: c
```

```
Out []:
```

```
array([[11, 12, 13],  
       [21, 22, 23],  
       [31, 32, 33]])
```

# Initializing some special matrices

```
In []: ones((3,5))
```

```
Out []:
```

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

```
In []: ones_like([1, 2, 3, 4])
```

```
Out []: array([1, 1, 1, 1])
```

```
In []: identity(2)
```

```
Out []:
```

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

Also available **zeros**, **zeros\_like**, **empty**, **empty\_like**

# Accessing elements

```
In []: c
```

```
Out []:
```

```
array([[11, 12, 13],  
       [21, 22, 23],  
       [31, 32, 33]])
```

```
In []: c[1][2]
```

```
Out []: 23
```

```
In []: c[1,2]
```

```
Out []: 23
```

```
In []: c[1]
```

```
Out []: array([21, 22, 23])
```

# Changing elements

```
In []: c[1,1] = -22
```

```
In []: c
```

```
Out []:
```

```
array([[ 11,  12,  13],
       [ 21, -22,  23],
       [ 31,  32,  33]])
```

```
In []: c[1] = 0
```

```
In []: c
```

```
Out []:
```

```
array([[11, 12, 13],
       [ 0,  0,  0],
       [31, 32, 33]])
```

How do you access one **column**?



# Slicing

```
In []: c[:,1]
Out []: array([12,  0, 32])
```

```
In []: c[1,:]
Out []: array([0, 0, 0])
```

```
In []: c[0:2,:]
Out []:
array([[11, 12, 13],
       [ 0,  0,  0]])
```

```
In []: c[1:3,:]
Out []:
array([[ 0,  0,  0],
       [31, 32, 33]])
```

# Slicing ...

```
In []: c[:2, :]
```

```
Out []:
```

```
array([[11, 12, 13],  
       [ 0,  0,  0]])
```

```
In []: c[1:, :]
```

```
Out []:
```

```
array([[ 0,  0,  0],  
       [31, 32, 33]])
```

```
In []: c[1:, :2]
```

```
Out []:
```

```
array([[ 0,  0],  
       [31, 32]])
```

# Striding

```
In []: c[::2, :]
```

```
Out []:
```

```
array([[11, 12, 13],  
       [31, 32, 33]])
```

```
In []: c[:, ::2]
```

```
Out []:
```

```
array([[11, 13],  
       [ 0,  0],  
       [31, 33]])
```

```
In []: c[::2, ::2]
```

```
Out []:
```

```
array([[11, 13],  
       [31, 33]])
```

# Shape of a matrix

```
In []: c
```

```
Out []:
```

```
array([[11, 12, 13],  
       [ 0,  0,  0],  
       [31, 32, 33]])
```

```
In []: c.shape
```

```
Out []: (3, 3)
```

Shape specifies shape or dimensions of a matrix

# Elementary image processing

```
In []: a = imread('bird.png')
```

```
In []: imshow(a)
```

```
Out []: <matplotlib.image.AxesImage object at 0xa0...
```

**imread** returns an array of shape (NX, NY, 4) which represents an image of NX x NY pixels and 4 shades.

**imshow** renders the array as an image.

# Slicing & Striding Exercises

- Crop the image to get the top-left quarter
- Crop the image to get only the bird
- Resize image to half by dropping alternate pixels

# Solutions

```
In []: imshow(a[:256, :256])
```

```
Out []: <matplotlib.image.AxesImage object at 0xb6
```

```
In []: imshow(a[100:300, 300:550])
```

```
Out []: <matplotlib.image.AxesImage object at 0xb7
```

```
In []: imshow(a[:, :2], :2])
```

```
Out []: <matplotlib.image.AxesImage object at 0xb7
```

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# Transpose of a Matrix

```
In []: a = array([[ 1,  1,  2, -1],
...:             [ 2,  5, -1, -9],
...:             [ 2,  1, -1,  3],
...:             [ 1, -3,  2,  7]])
```

```
In []: a.T
```

```
Out []:
```

```
array([[ 1,  2,  2,  1],
       [ 1,  5,  1, -3],
       [ 2, -1, -1,  2],
       [-1, -9,  3,  7]])
```



# Matrix Addition

```
In []: b = array([[3, 2, -1, 5],  
                 [2, -2, 4, 9],  
                 [-1, 0.5, -1, -7],  
                 [9, -5, 7, 3]])
```

```
In []: a + b
```

```
Out []:
```

```
array([[ 4. ,  3. ,  1. ,  4. ],  
       [ 4. ,  3. ,  3. ,  0. ],  
       [ 1. ,  1.5, -2. , -4. ],  
       [10. , -8. ,  9. , 10. ]])
```

# Elementwise Multiplication

```
In []: a*b
```

```
Out []:
```

```
array([[ 3. ,  2. , -2. , -5. ],  
       [ 4. , -10. , -4. , -81. ],  
       [-2. ,  0.5,  1. , -21. ],  
       [ 9. , 15. , 14. , 21. ]])
```

# Matrix Multiplication

```
In []: dot(a, b)
```

```
Out []:
```

```
array([[ -6. ,   6. ,  -6. ,  -3. ],  
       [-64. ,  38.5, -44. ,  35. ],  
       [ 36. , -13.5,  24. ,  35. ],  
       [ 58. , -26. ,  34. , -15. ]])
```

# Inverse of a Matrix

```
In []: inv(a)
```

```
Out []:
```

```
array([[ -0.5 ,  0.55, -0.15,  0.7 ],  
       [ 0.75, -0.5 ,  0.5 , -0.75],  
       [ 0.5 , -0.15, -0.05, -0.1 ],  
       [ 0.25, -0.25,  0.25, -0.25]])
```

```
Try this: I = dot(a, inv(a))
```

# Determinant and sum of all elements

```
In []: det(a)
```

```
Out []: 80.0
```

```
In []: sum(a)
```

```
Out []: 12
```

# Eigenvalues and Eigen Vectors

```
In []: e = array([[3,2,4],[2,0,2],[4,2,3]])
```

```
In []: eig(e)
```

```
Out []:
```

```
(array([-1.,  8., -1.]),  
 array([[ -0.74535599,  0.66666667, -0.1931126 ],  
        [ 0.2981424 ,  0.33333333, -0.78664085],  
        [ 0.59628479,  0.66666667,  0.58643303]]))
```

```
In []: eigvals(e)
```

```
Out []: array([-1.,  8., -1.])
```

# Computing Norms

```
In []: norm(e)
```

```
Out []: 8.1240384046359608
```

# Singular Value Decomposition

```
In []: svd(e)
```

```
Out []:
```

```
(array(
[[ -6.66666667e-01,  -1.23702565e-16,   7.4535599
 [ -3.33333333e-01,  -8.94427191e-01,  -2.9814239
 [ -6.66666667e-01,   4.47213595e-01,  -5.9628479
array([ 8.,  1.,  1.]),
array([[ -0.66666667,  -0.33333333,  -0.66666667],
       [ -0.          ,  0.89442719,  -0.4472136 ],
       [ -0.74535599,  0.2981424 ,  0.59628479]]))
```

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# Outline

1 Matrices

**2 Least Squares Fit**

3 Random numbers

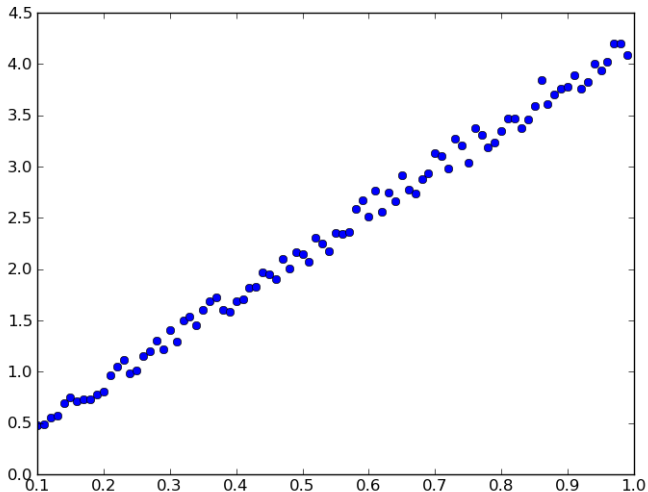
4 Summary

# Simple pendulum

- $T \approx 2\pi\sqrt{L/g}$
- $L \propto T^2$

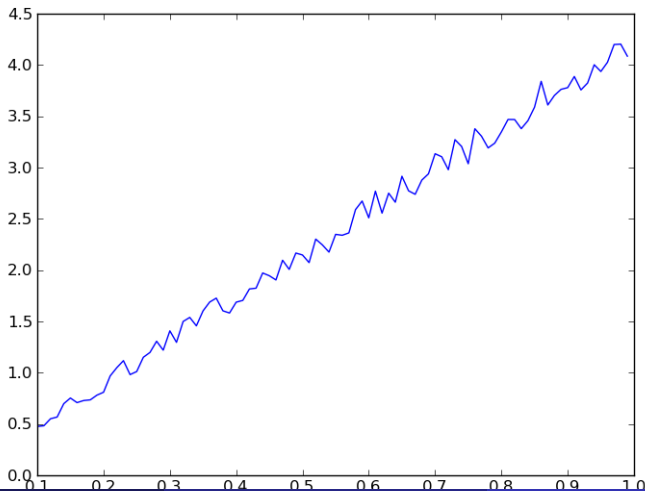
# $L$ vs. $T^2$ - Scatter

Linear trend visible.



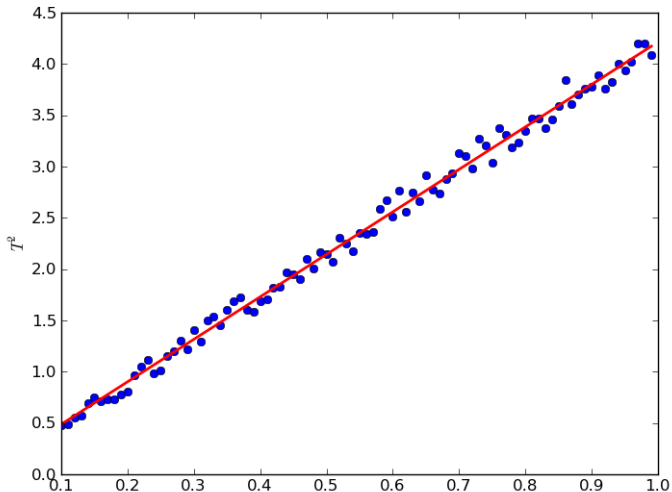
# $L$ vs. $T^2$ - Line

This line does not make any mathematical sense.



# $L$ vs. $T^2$ - Least Square Fit

This is what our intention is.



# Matrix Formulation

- We need to fit a line through points for the equation  $T^2 = mL + c$

- We have data in this form:

$$T_1^2 = mL_1 + c$$

$$T_2^2 = mL_2 + c$$

$$T_3^2 = mL_3 + c$$

...

- Find “best”  $m$  and  $c$

# Matrix Formulation

- In matrix form, the equation can be represented as

$$T_{sq} = A \cdot p, \text{ where } T_{sq} \text{ is } \begin{bmatrix} T_1^2 \\ T_2^2 \\ \vdots \\ T_N^2 \end{bmatrix}, \text{ A is } \begin{bmatrix} L_1 & 1 \\ L_2 & 1 \\ \vdots & \vdots \\ L_N & 1 \end{bmatrix} \text{ and}$$

$$p \text{ is } \begin{bmatrix} m \\ c \end{bmatrix}$$

- We need to find  $p$  to plot the line

# Getting $L$ and $T^2$

```
In []: L, t = loadtxt('pendulum.txt',  
    ...:              unpack=True)  
In []: tsq = t*t
```



# Generating A

```
In []: A = array([L, ones_like(L)])  
In []: A = A.T
```

# lstsq...

- Now use the `lstsq` function
- Along with a lot of things, it returns the least squares solution

```
In []: result = lstsq(A, tsq)
```

```
In []: coef = result[0]
```

# Least Square Fit Line ...

We get the points of the line from `coef`

```
In []: Tline = coef[0]*L + coef[1]
```

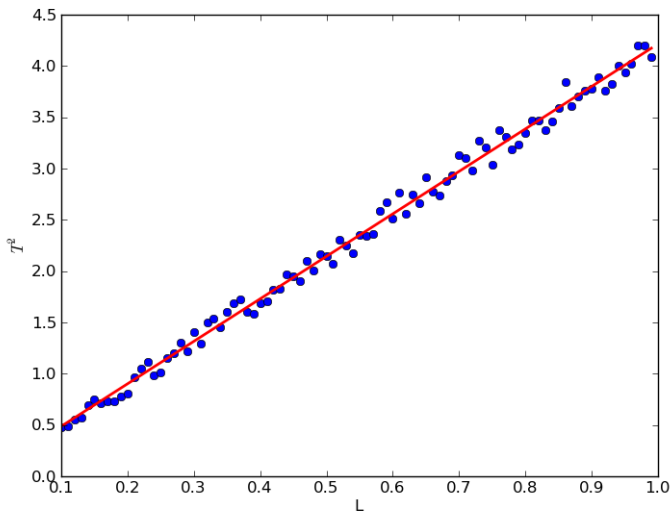
```
In []: Tline.shape
```

- Now plot `Tline` vs. `L`, to get the least squares fit line.

```
In []: plot(L, Tline, 'r')
```

```
In []: plot(L, tsq, 'o')
```

# Least Squares Fit



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# numpy.random

- Easy random number generation

In []: `random?`

Or:

In []: `import numpy`

In []: `numpy.random`

- `random.random`: produces uniform deviates in  $[0, 1)$
- `random.normal`: draws random samples from a Gaussian distribution
- Useful to create a random matrix of any shape

# Using the `random` module

```
In []: x = random.random(size=1000)
```

```
In []: y = random.random(size=1000)
```

```
In []: scatter(x, y) # Scatter plot it.
```

```
In []: x,y = random.normal(size=(2, 1000))
```

```
In []: clf()
```

```
In []: scatter(x, y)
```

Note that `size` can be a tuple.

# Using the `random` module

```
In []: img = random.random(  
        .                               size=(200, 200))  
In []: clf()  
In []: imshow(img)
```

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# Outline

1 Matrices

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# What did we learn?

- Matrices
- Least Squares
- Random numbers