21 Aug 2019

ANL 251 Python Programming

L5:Scientific Computing and Plotting (Supplementary readings)

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Class Schedule

S/N	Course Code	Group	Delivery Style	Date	Day	From	To	Venue
1	ANL251	T06	SEMINAR	24-Jul-2019	Wed	07:00 PM	10:00 PM	HQ BLK B-LAB B.4.15
2	ANL251	T06	37	Wed	31/07/2019	HQ BLK C	SR C.6.09/C.6.10	SR C.6.09
3	ANL251	T06	37	Wed	07/08/2019	HQ BLK C	SR C.3.14	
4	ANL251	T06	37	Wed	14/08/2019	HQ BLK C	SR C.4.12/C.4.13	
5	ANL251	T06	37	Wed	21/08/2019	HQ BLK C	SR C.4.12/C.4.13	SR C.4.12
6	ANL251	T06	37	Wed	28/08/2019	HQ BLK C	SR C.6.09/C.6.10	SR C.6.09

Seminar Sessions: 5

Topics to be Covered	**Learning Outcomes to be Achieved***	**Summary and Discussion of Key Concepts, Theories, Principles.**	**Class Activities to Enhance Learning**
Study Unit 5: Scientific computing and plotting with Python	1. Use NumPy arrays and vectorized operations 2. Implement subsetting NumPy arrays using index or Boolean mask 3. Exam and explain the basic NumPy array attributes 4. Apply NumPy functions for statistics and random sampling 5. Create basic plots and choose appropriate matplotlib.pyplot functions for customization.	11: Numpy 12: Matplotlib	Access e-learning material: Study Unit 5 and recommended online readings, recommended open-access videos. Seminars: discussion and activities to reinforce students' understanding

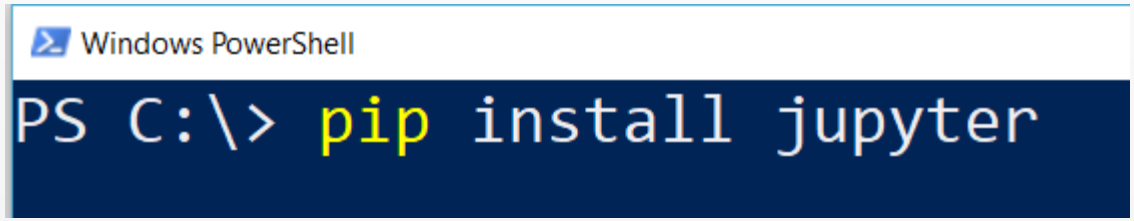
References

- https://www.numpy.org/devdocs/user/quickstart.html
- https://docs.scipy.org/doc/numpy/reference/
- Numpy cheat sheet, https://datacamp-community-prod.s3.amazonaws.com/e9f83f72-a81b-42c7-af44-4e35b48b20b7
- Markdown, https://github.com/adam-p/markdown-here/wiki/Markdown-Here-Cheatsheet
- https://guides.github.com/pdfs/markdown-cheatsheet-online.pdf

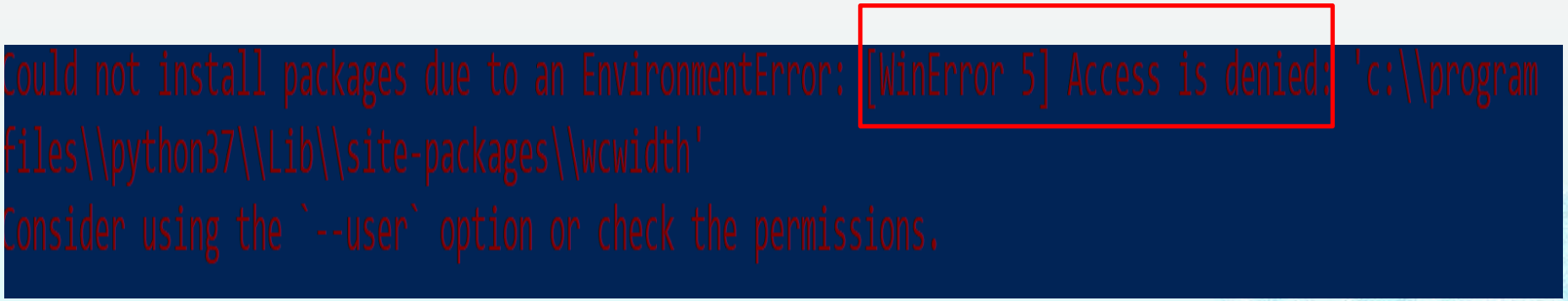
Jupyter notebook

Make sure that your internet is connected.

pip: Package Installer for Python



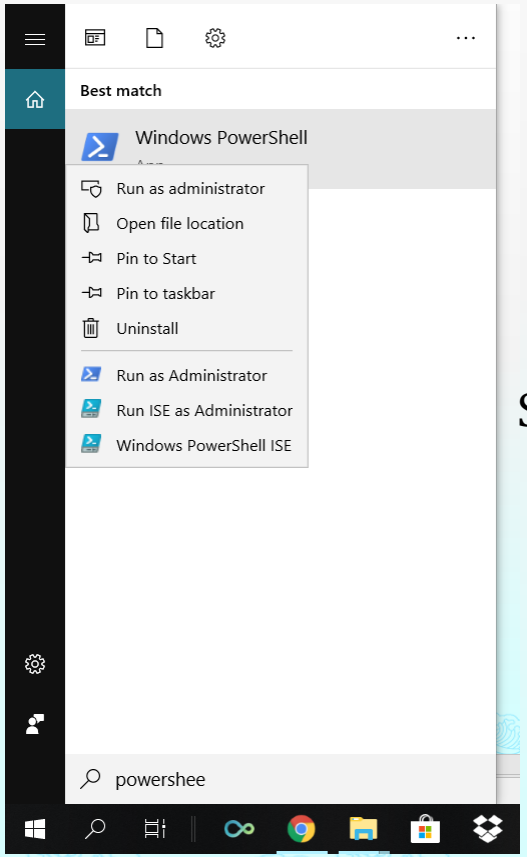
for more information,
> pip help
> pip list



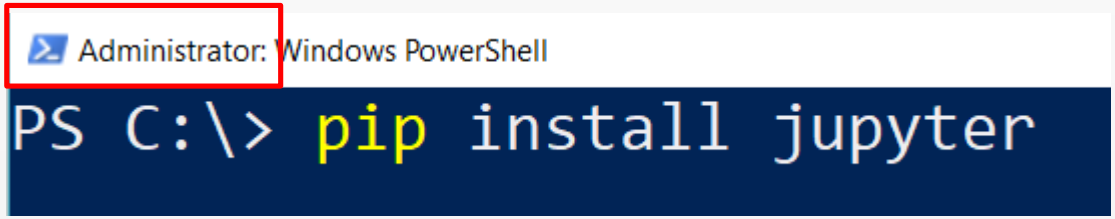
So?

First time to Jupyter notebook

Step 1: right click
Windows PowerShell
and *run as administrator*

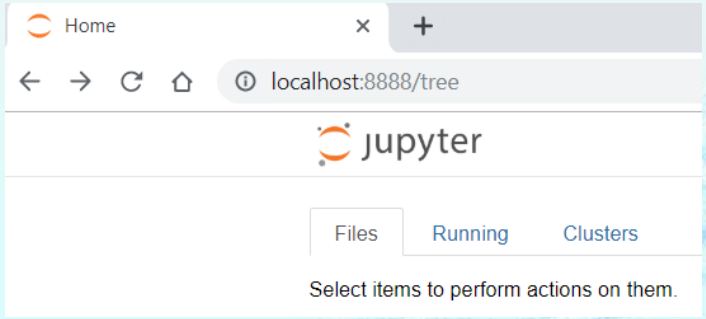


Step 2: pip install jupyter

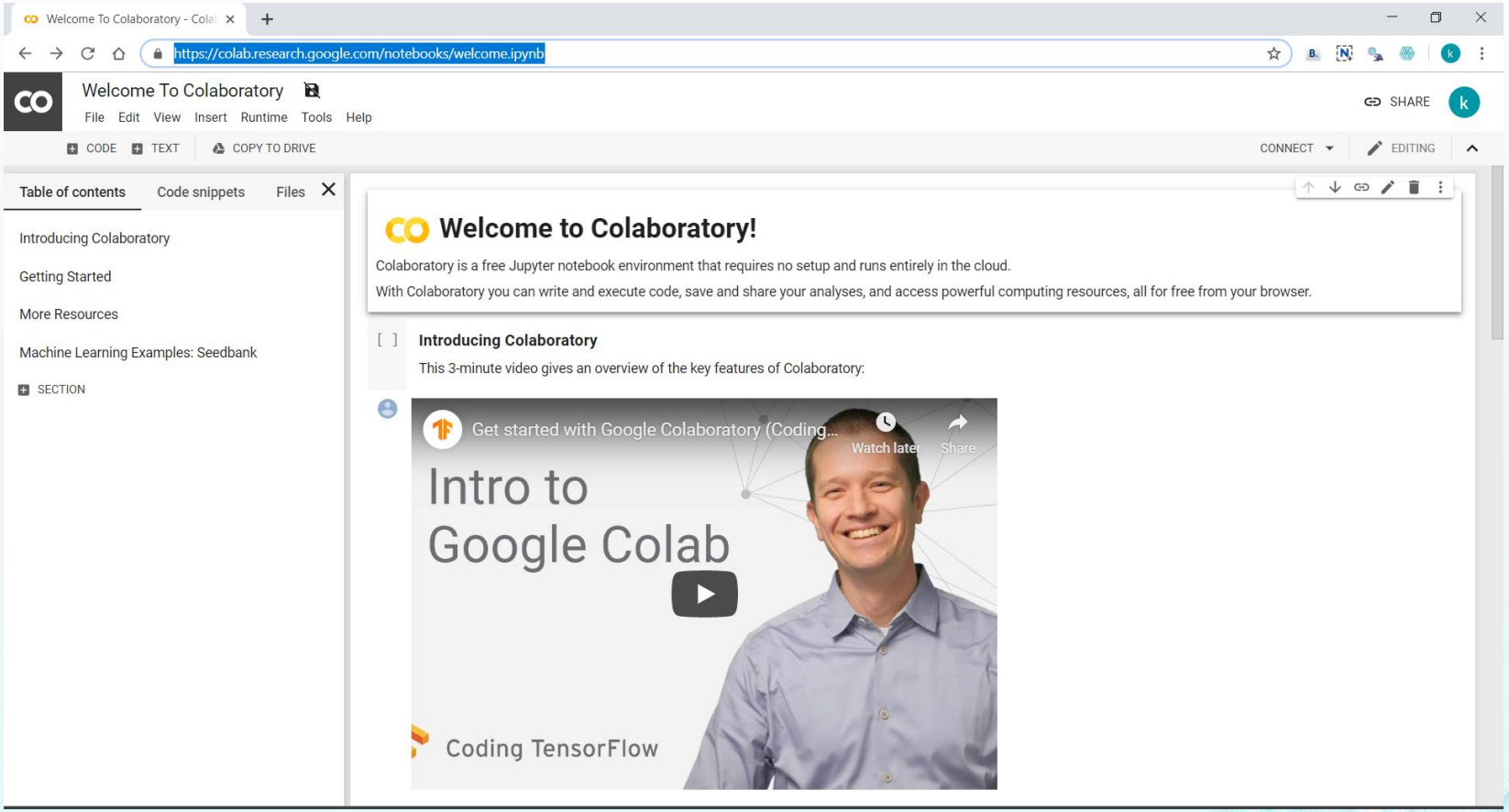


Make sure that your internet is connected.

Step 3: type **jupyter notebook** to start the web application.

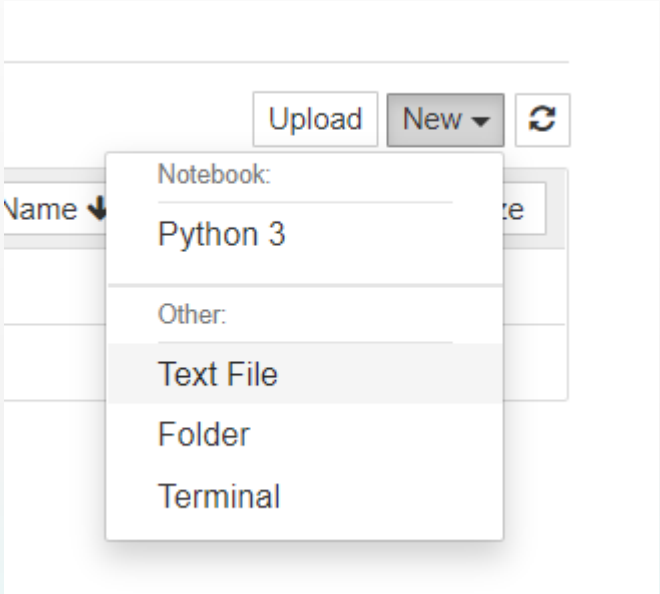


Alternative: Google colab



https://colab.research.google.com

- Create a **Folder**, named ANL251
- Under ANL251, create a *Python 3* file with your preferred name.



```
# Markdown Introduction
```

Markdown language

```
## Normalization function
There are different ways to normalize the data. one of the methods is shown as below.
$$\hat{x}_{ij} =\frac{{{x_{ij}} - \min {x_{kj}}}}{{\max {x_{kj}} - \min {x_{kj}}}}, k \in \{ 1,2,...,m\}$$
```

Source

```
def normFun(x):
    min_x = min(x)
    max_x = max(x)
    result = []
    for j in x:
        xj = (j - min_x) / (max_x - min_x )
        result.append(xj)

    return result
```

Python language

```
x = [1, 2, 3, 4, 5, 6]
normFun(x)
```

1 Markdown Introduction

1.1 Normalization function

There are different ways to normalize the data. one of the methods is shown as below.

$$\hat{x}_{ij} = \frac{x_{ij} - \min x_{kj}}{\max x_{kj} - \min x_{kj}}, k \in \{1,2,\ldots,m\}$$

Output

In [1]:
```
def normFun(x):
    min_x = min(x)
    max_x = max(x)
    result = []
    for j in x:
        xj = (j - min_x) / (max_x - min_x )
        result.append(xj)

    return result
```

In [2]:
```
x = [1, 2, 3, 4, 5, 6]
normFun(x)
```

Out[2]:
```
[0.0, 0.2, 0.4, 0.6, 0.8, 1.0]
```

- https://guides.github.com/pdfs/markdown-cheatsheet-online.pdf

Markdown is a way to style text on the web. You control the display of the document; formatting words as bold or italic, adding images, and creating lists are just a few of the things we can do with Markdown. Mostly, Markdown is just regular text with a few non-alphabetic characters thrown in, like # or *.

HEADERS

```
# This is an <h1> tag
## This is an <h2> tag
###### This is an <h6> tag
```

EMPHASIS

```
*This text will be italic*
_This will also be italic_

**This text will be bold**
__This will also be bold__

*You **can** combine them*
```

LISTS

Unordered

```
* Item 1
* Item 2
  * Item 2a
  * Item 2b
```

Ordered

```
1. Item 1
2. Item 2
3. Item 3
   * Item 3a
   * Item 3b
```

IMAGES

```
![GitHub Logo](/images/logo.png)

Format: ![Alt Text](url)
```

LINKS

```
http://github.com - automatic!

[GitHub](http://github.com)
```

BLOCKQUOTES

```
As Grace Hopper said:

> I've always been more interested
> in the future than in the past.
```

As Grace Hopper said:

> I've always been more interested in the future than in the past.

BACKSLASH ESCAPES

Markdown allows you to use backslash escapes to generate literal characters which would otherwise have special meaning in Markdown's formatting syntax.

```
\*literal asterisks\*
```

literal asterisks

Markdown provides backslash escapes for the following characters:

\	backslash	()	parentheses
`	backtick	#	hash mark
*	asterisk	+	plus sign
_	underscore	-	minus sign (hyphen)
{}	curly braces	.	dot
[]	square brackets	!	exclamation mark

USERNAME @MENTIONS

Typing an `@` symbol, followed by a username, will notify that person to come and view the comment. This is called an "@mention", because you're mentioning the individual. You can also @mention teams within an organization.

FENCED CODE BLOCKS

Markdown coverts text with four leading spaces into a code block; with GFM you can wrap your code with ``` to create a code block without the leading spaces. Add an optional language identifier and your code will get syntax highlighting.

````
```javascript
function test() {
 console.log("look ma', no spaces");
}
```
````

```javascript
function test() {
  console.log("look ma', no spaces");
}
```

ISSUE REFERENCES

Any number that refers to an Issue or Pull Request will be automatically converted into a link.

```
#1
github-flavored-markdown#1
defunkt/github-flavored-markdown#1
```

TASK LISTS

```
- [x] this is a complete item
- [ ] this is an incomplete item
- [x] @mentions, #refs, [links](),
**formatting**, and <del>tags</del>
supported
- [x] list syntax required (any
unordered or ordered list
supported)
```

- [x] this is a complete item
- [ ] this is an incomplete item
- [x] @mentions, #refs, links, **formatting**, and ~~tags~~ supported
- [x] list syntax required (any unordered or ordered list supported)

TABLES

You can create tables by assembling a list of words and dividing them with hyphens `-` (for the first row), and then separating each column with a pipe `|` :

```
First Header | Second Header
------------ | -------------
Content cell 1 | Content cell 2
Content column 1 | Content column 2
```

First Header	Second Header
Content cell 1	Content cell 2
Content column 1	Content column 2

EMOJI

To see a list of every image we support, check out **www.emoji-cheat-sheet.com**

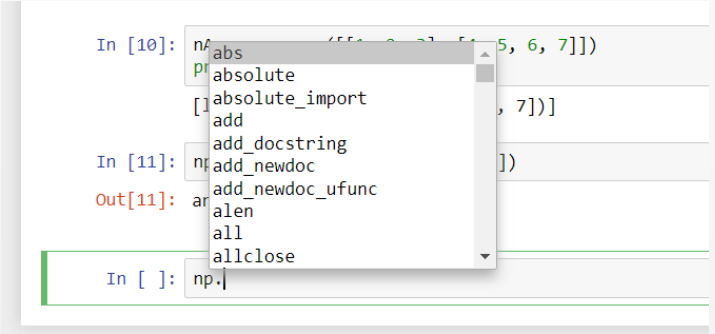
```
GitHub supports emoji!
:+1: :sparkles: :camel: :tada:
:rocket: :metal: :octocat:
```

GitHub supports emoji!

Auto-completion

Hit “Tab” when you use it.

If not work, try this first and then hit Tab.
%config IPCompleter.greedy=True



Or install bnextensions package for Jupyter to work without “Tab”

https://jupyter-contrib-nbextensions.readthedocs.io/en/latest/install.html

- Shut down Jupyter:
  - Click kernel -> Shutdown or
  - Press two times, Ctr + C, in PowerShell to shut down Jupyter.

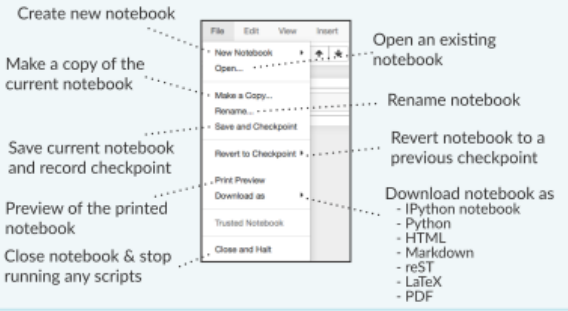
https://s3.amazonaws.com/assets.datacamp.com/blog_assets/Jupyter_Notebook_Cheat_Sheet.pdf

Python For Data Science *Cheat Sheet*

Jupyter Notebook

Learn More Python for Data Science Interactively at www.DataCamp.com

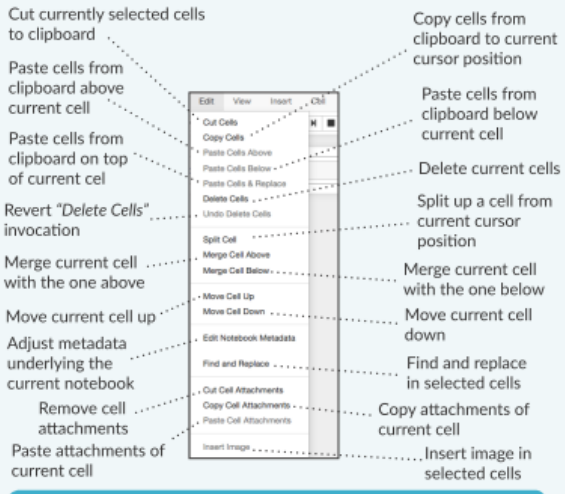
Saving/Loading Notebooks



Writing Code And Text

Code and text are encapsulated by 3 basic cell types: markdown cells, code cells, and raw NBConvert cells.

Edit Cells



Insert Cells

Working with Different Programming Languages

Kernels provide computation and communication with front-end interfaces like the notebooks. There are three main kernels:

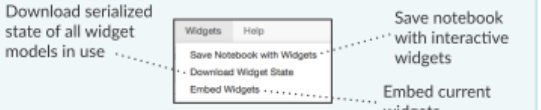
IP[y]: IPython | IRkernel | IJ[a] IJulia

Installing Jupyter Notebook will automatically install the IPython kernel.

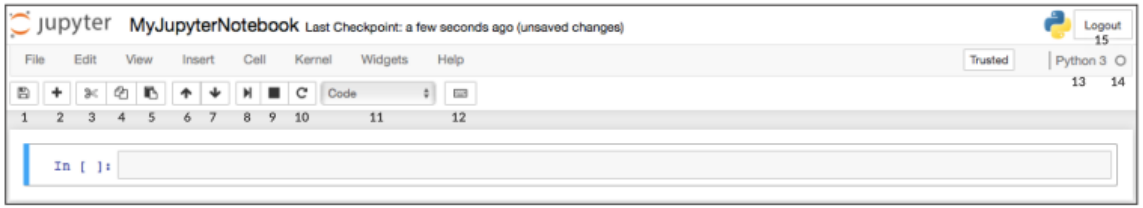
Widgets

Notebook widgets provide the ability to visualize and control changes in your data, often as a control like a slider, textbox, etc.

You can use them to build interactive GUIs for your notebooks or to synchronize stateful and stateless information between Python and JavaScript.



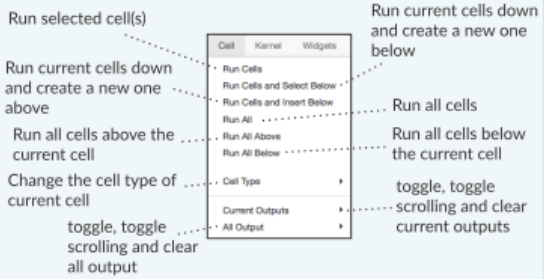
Command Mode:



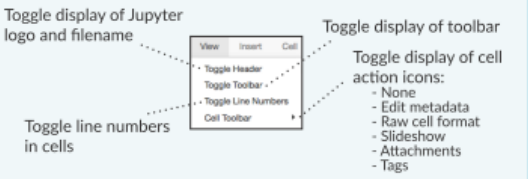
Edit Mode:

1. Save and checkpoint
2. Insert cell below
3. Cut cell
4. Copy cell(s)
5. Paste cell(s) below
6. Move cell up
7. Move cell down
8. Run current cell
9. Interrupt kernel
10. Restart kernel
11. Display characteristics
12. Open command palette
13. Current kernel
14. Kernel status
15. Log out from notebook server

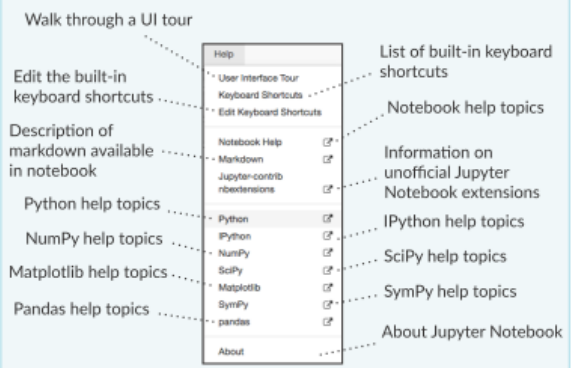
Executing Cells



View Cells



Asking For Help



DataCamp
Learn Python for Data Science Interactively

1. NUMPY ARRAY AND VECTORISED OPERATIONS
2. SUBSETTING NUMPY ARRAY
3. NUMPY ARRAY ATTRIBUTES

Python For Data Science *Cheat Sheet*

NumPy Basics

Learn Python for Data Science Interactively at www.DataCamp.com

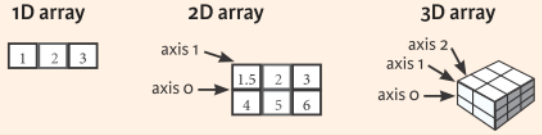
NumPy

The **NumPy** library is the core library for scientific computing in Python. It provides a high-performance multidimensional array object, and tools for working with these arrays.

Use the following import convention:

```
>>> import numpy as np
```

NumPy Arrays



Creating Arrays

```
>>> a = np.array([1,2,3])
>>> b = np.array([(1.5,2,3), (4,5,6)], dtype = float)
>>> c = np.array([[(1.5,2,3), (4,5,6)], [(3,2,1), (4,5,6)]],
                 dtype = float)
```

Initial Placeholders

```
>>> np.zeros((3,4))                 Create an array of zeros
>>> np.ones((2,3,4),dtype=np.int16) Create an array of ones
>>> d = np.arange(10,25,5)          Create an array of evenly
                                    spaced values (step value)
>>> np.linspace(0,2,9)              Create an array of evenly
                                    spaced values (number of samples)
>>> e = np.full((2,2),7)            Create a constant array
>>> f = np.eye(2)                   Create a 2X2 identity matrix
>>> np.random.random((2,2))         Create an array with random values
>>> np.empty((3,2))                 Create an empty array
```

I/O

Saving & Loading On Disk

```
>>> np.save('my_array', a)
>>> np.savez('array.npz', a, b)
>>> np.load('my_array.npy')
```

Saving & Loading Text Files

```
>>> np.loadtxt("myfile.txt")
>>> np.genfromtxt("my_file.csv", delimiter=',')
>>> np.savetxt("myarray.txt", a, delimiter=" ")
```

Data Types

```
>>> np.int64      Signed 64-bit integer types
>>> np.float32    Standard double-precision floating point
>>> np.complex    Complex numbers represented by 128 floats
>>> np.bool       Boolean type storing TRUE and FALSE values
>>> np.object     Python object type
>>> np.string_    Fixed-length string type
>>> np.unicode_   Fixed-length unicode type
```

Inspecting Your Array

```
>>> a.shape          Array dimensions
>>> len(a)           Length of array
>>> b.ndim           Number of array dimensions
>>> e.size           Number of array elements
>>> b.dtype          Data type of array elements
>>> b.dtype.name     Name of data type
>>> b.astype(int)    Convert an array to a different type
```

Asking For Help

```
>>> np.info(np.ndarray.dtype)
```

Array Mathematics

Arithmetic Operations

```
>>> g = a - b                       Subtraction
  array([[-0.5,  0. ,  0. ],
         [-3. , -3. , -3. ]])
>>> np.subtract(a,b)                Subtraction
>>> b + a                           Addition
  array([[ 2.5,  4. ,  6. ],
         [ 5. ,  7. ,  9. ]])
>>> np.add(b,a)                     Addition
>>> a / b                           Division
  array([[ 0.66666667,  1.        ,  1.        ],
         [ 0.25      ,  0.4       ,  0.5       ]])
>>> np.divide(a,b)                  Division
>>> a * b                           Multiplication
  array([[  1.5,   4. ,   9. ],
         [  4. ,  10. ,  18. ]])
>>> np.multiply(a,b)                Multiplication
>>> np.exp(b)                       Exponentiation
>>> np.sqrt(b)                      Square root
>>> np.sin(a)                       Print sines of an array
>>> np.cos(b)                       Element-wise cosine
>>> np.log(a)                       Element-wise natural logarithm
>>> e.dot(f)                        Dot product
  array([[ 7.,  7.],
         [ 7.,  7.]])
```

Comparison

```
>>> a == b                          Element-wise comparison
  array([[False,  True,  True],
         [False, False, False]], dtype=bool)
>>> a < 2                           Element-wise comparison
  array([True, False, False], dtype=bool)
>>> np.array_equal(a, b)            Array-wise comparison
```

Aggregate Functions

```
>>> a.sum()          Array-wise sum
>>> a.min()          Array-wise minimum value
>>> b.max(axis=0)    Maximum value of an array row
>>> b.cumsum(axis=1) Cumulative sum of the elements
>>> a.mean()         Mean
>>> b.median()       Median
>>> a.corrcoef()     Correlation coefficient
>>> np.std(b)        Standard deviation
```

Copying Arrays

```
>>> h = a.view()     Create a view of the array with the same data
>>> np.copy(a)       Create a copy of the array
>>> h = a.copy()     Create a deep copy of the array
```

Sorting Arrays

```
>>> a.sort()         Sort an array
>>> c.sort(axis=0)   Sort the elements of an array's axis
```

Subsetting, Slicing, Indexing

Also see Lists

Subsetting

```
>>> a[2]                            Select the element at the 2nd index
  3
>>> b[1,2]                          Select the element at row 1 column 2
  6.0                               (equivalent to b[1][2])
```

Slicing

```
>>> a[0:2]                          Select items at index 0 and 1
  array([1, 2])
>>> b[0:2,1]                        Select items at rows 0 and 1 in column 1
  array([ 2.,  5.])
>>> b[:1]                           Select all items at row 0
  array([[1.5, 2., 3.]])            (equivalent to b[0:1, :])
>>> c[1,...]                        Same as [1,:,:]
  array([[[ 3.,  2.,  1.],
          [ 4.,  5.,  6.]]])
>>> a[ : :-1]                       Reversed array a
  array([3, 2, 1])
```

Boolean Indexing

```
>>> a[a<2]                          Select elements from a less than 2
  array([1])
```

Fancy Indexing

```
>>> b[[1, 0, 1, 0],[0, 1, 2, 0]]   Select elements (1,0),(0,1),(1,2) and (0,0)
  array([ 4. , 2. , 6. , 1.5])
>>> b[[1, 0, 1, 0]][:,[0,1,2,0]]   Select a subset of the matrix's rows
  array([[ 4. , 5. , 6. , 4. ],     and columns
         [ 1.5, 2. , 3. , 1.5],
         [ 4. , 5. , 6. , 4. ],
         [ 1.5, 2. , 3. , 1.5]])
```

Array Manipulation

Transposing Array

```
>>> i = np.transpose(b)             Permute array dimensions
>>> i.T                             Permute array dimensions
```

Changing Array Shape

```
>>> b.ravel()                       Flatten the array
>>> g.reshape(3,-2)                 Reshape, but don't change data
```

Adding/Removing Elements

```
>>> h.resize((2,6))                 Return a new array with shape (2,6)
>>> np.append(h,g)                  Append items to an array
>>> np.insert(a, 1, 5)              Insert items in an array
>>> np.delete(a,[1])                Delete items from an array
```

Combining Arrays

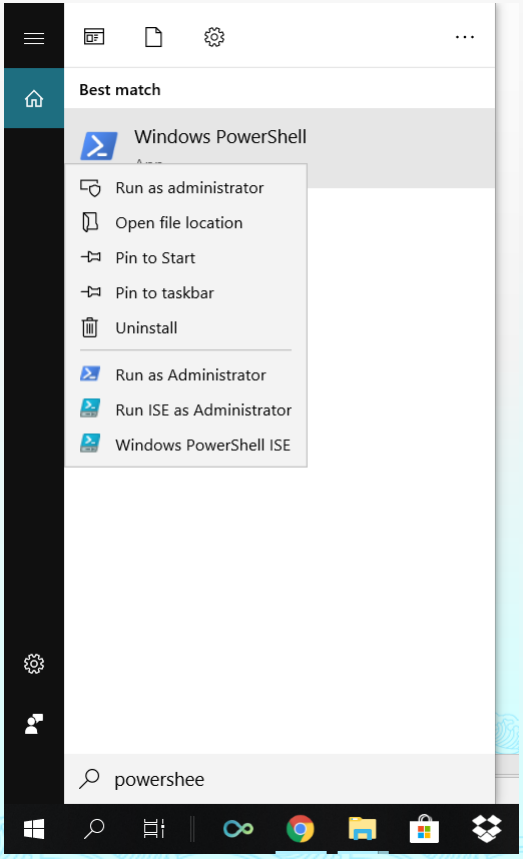
```
>>> np.concatenate((a,d),axis=0)    Concatenate arrays
  array([ 1,  2,  3, 10, 15, 20])
>>> np.vstack((a,b))                Stack arrays vertically (row-wise)
  array([[ 1. ,  2. ,  3. ],
         [ 1.5,  2. ,  3. ],
         [ 4. ,  5. ,  6. ]])
>>> np.r_[e,f]                      Stack arrays vertically (row-wise)
>>> np.hstack((e,f))                Stack arrays horizontally (column-wise)
  array([[ 7.,  7.,  1.,  0.],
         [ 7.,  7.,  0.,  1.]])
>>> np.column_stack((a,d))          Create stacked column-wise arrays
  array([[ 1, 10],
         [ 2, 15],
         [ 3, 20]])
>>> np.c_[a,d]                      Create stacked column-wise arrays
```

Splitting Arrays

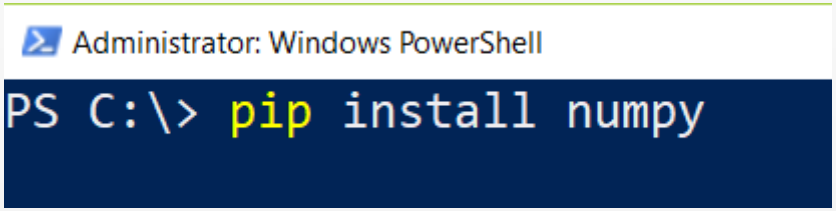
```
>>> np.hsplit(a,3)                  Split the array horizontally at the 3rd
  [array([1]),array([2]),array([3])] index
>>> np.vsplit(c,2)                  Split the array vertically at the 2nd index
[array([[[ 1.5,  2. ,  1. ],
         [ 4. ,  5. ,  6. ]]]),
 array([[[ 3.,  2.,  3.],
         [ 4.,  5.,  6.]]])]
```

First time to use numpy

Step 1: right click
Windows PowerShell
and *run as administrator*



Step 2: pip install numpy



Step 3 (optional): where the package installed?

C:\Program Files\Python37\Lib\site-packages\numpy

List vs numpy array

In [1]:
```
import numpy as np
# create a list
a = [1, 2, 3]
print(a * 2)
```

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

In [2]:
```
# convert a list to numpy array
na = np.array(a)
print(na * 2)
```

```
[2 4 6]
```

Discussion 1

Using Numpy's arrays can be 10 times faster than Python's lists. To enable the speed,

- Numpy arrays are fixed in size (but can change the values), unlike lists which can change in size.
- Numpy arrays must all be the same type whereas lists can hold any type. By restricting ndarrays in this way, it makes ndarrays both much more space efficient than lists, but also opens up a range of memory and computational optimizations.

About the size

In [ ]:
```
1 A1 = np.array([[1, 2, 3], [4, 5, 6, 7]])
2 print(A1)
```

In [ ]:
```
1 print(A1[0])
```

In [ ]:
```
1 print(A1 * 2)
```

In [ ]:
```
1 A2 = np.array([[1, 2, 3], [4, 5, 6]])
2 print(A2)
```

In [ ]:
```
1 print(A2[0, 1])
```

In [ ]:
```
1 print(A2 * 2)
```

4.2 About the type

In [ ]:
```
1 listType = ["a", True, 1, (1, 2, 3), ['a', 'b', 'c']]
```

In [ ]:
```
1 print(listType)
```

In [ ]:
```
1 arrayType = np.array( ["a", True, 1, (1, 2, 3), ['a', 'b', 'c']])
```

In [ ]:
```
1 print(type(arrayType))
```

In [ ]:
```
1 print(arrayType)
```

In [ ]:
```
1 arrayType * 2
```

In [ ]:
```
1 print(type(arrayType[0]), type(arrayType[1]), type(arrayType[2]), type(arrayType[3]))
```

Quiz 1

Which of the following is correct to create a 2D array?

np.array([[11,12,13],[21,22,23]])

np.array([11,12,13],[21,22,23])

np.array([11,12,13,21,22,23])

np.array[[11,12,13,21,22,23]]

```
In [36]: 1 np.array([[11,12,13],[21,22,23]])

Out[36]: array([[11, 12, 13],
                [21, 22, 23]])

In [37]: 1 np.array([11,12,13],[21,22,23])

---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-37-0584aa6c4d7a> in <module>
----> 1 np.array([11,12,13],[21,22,23])

TypeError: data type not understood

In [38]: 1 np.array([11,12,13,21,22,23])

Out[38]: array([11, 12, 13, 21, 22, 23])

In [39]: 1 np.array[[11,12,13,21,22,23]]

---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-39-82183304a2f6> in <module>
----> 1 np.array[[11,12,13,21,22,23]]

TypeError: 'builtin_function_or_method' object is not subscriptable
```

Quiz 2

Do the two NumPy arrays have the same shape?

first_array = np.array([3, 33, 333])

second_array = np.array([[3, 33, 333]])

```
In [ ]: 1 first_array = np.array([3, 33, 333])

In [ ]: 1 second_array = np.array([[3, 33, 333]])

In [ ]: 1 print(first_array)

In [ ]: 1 first_array.shape

In [ ]: 1 print(second_array)

In [ ]: 1 second_array.shape
```

Discussion 2

Other ways to create NumPy arrays?(https://www.numpy.org/devdocs/user/quickstart.html#array-creation)

Write code to create each of the following NumPy arrays.

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

array([10, 15, 20, 25])

array([ 0.  ,  0.25,  0.5 ,  0.75,  1.  ,  1.25,  1.5 ,  1.75,  2.  ])
```

```
In [2]:  1  np.zeros( (3,4) )
Out[2]: array([[0., 0., 0., 0.],
               [0., 0., 0., 0.],
               [0., 0., 0., 0.]])

In [3]:  1  np.arange( 10, 30, 5 )
Out[3]: array([10, 15, 20, 25])

In [4]:  1  np.linspace( 0, 2, 9 )
Out[4]: array([0.  , 0.25, 0.5 , 0.75, 1.  , 1.25, 1.5 , 1.75, 2.  ])
```

Discussion 3

```
a = np.array( [20,30,40,50] )
b = np.arange( 4 )
```

What does each of the following evaluate to?

```
a-b
b**2
a<35
```

```
In [5]:  1 a = np.array( [20,30,40,50] )
         2 b = np.arange( 4 )

In [6]:  1 print(a)
[20 30 40 50]

In [7]:  1 print(b)
[0 1 2 3]

In [8]:  1 a - b
Out[8]: array([20, 29, 38, 47])

In [9]:  1 b ** 2
Out[9]: array([0, 1, 4, 9], dtype=int32)

In [10]:  1 a < 35
Out[10]: array([ True,  True, False, False])
```

Discussion 4

```
a = np.array([[0,0],[0,0]])
b1 = np.array([1,1])
b2 = 1
```

Do print(a+b1) and print(a+b2) result in the same matrix?

```
In [ ]:
1  a = np.array([[0,0],[0,0]])
2  b1 = np.array([1,1])
3  b2 = 1

In [ ]:
1  print(a, b1, b2)

In [ ]:
1  print(a + b1)

In [ ]:
1  print(a + b2)
```

Discussion 5

What's printed after executing the code below?

```
arrA = np.array([[1,2,3,4],[5,6,7,8],[9,10,11,12]])
arrB = [0,1,0,2]
print(arrA + arrB)
```

```
In [22]:
1 arrA = np.array([[1,2,3,4],[5,6,7,8],[9,10,11,12]])
2 arrB = [0,1,0,2]

In [23]:
1 print(arrA, " + ", arrB, " = ")

[[ 1  2  3  4]
 [ 5  6  7  8]
 [ 9 10 11 12]]  +  [0, 1, 0, 2]  =

In [24]:
1 print( arrA + arrB)

[[ 1  3  3  6]
 [ 5  7  7 10]
 [ 9 11 11 14]]
```

Quiz 3

After the code below has been executed, what value does a[i] refer to?

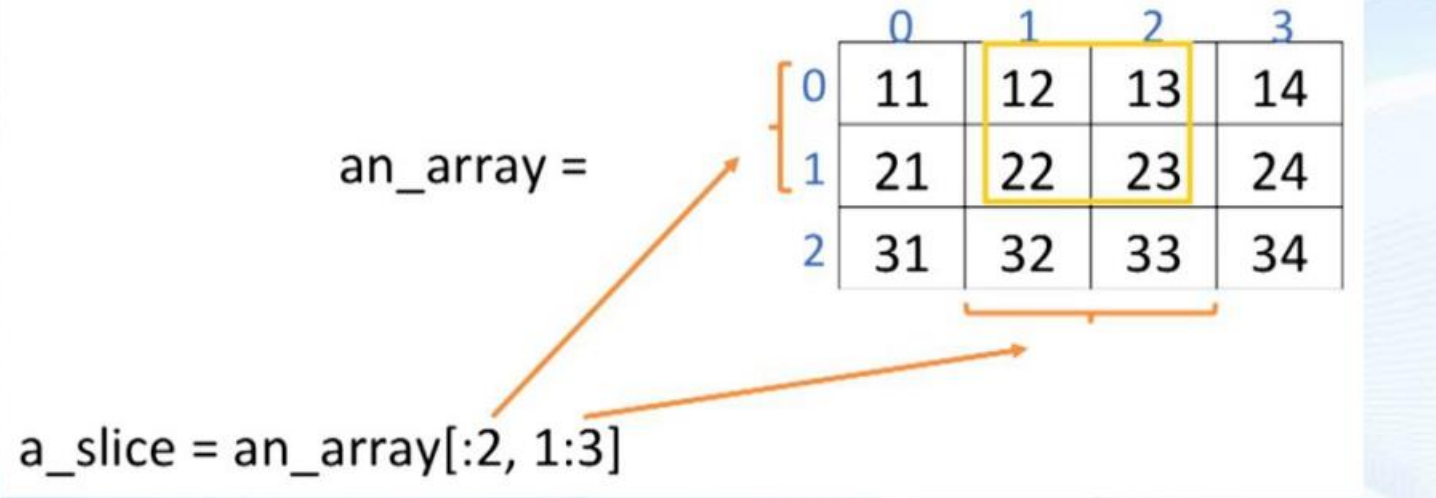
```
a = np.arange(12)**2
i = np.array( [ 1,1,3,8,5 ] )
print(a[i])
```

Then execute the code below. What will happen?

```
a[i] = 'OK'
```

```
In [2]:
1 a = np.arange(12)**2
2 i = np.array( [ 1,1,3,8,5 ] )

In [3]:
1 print(a)
2 print(i)

[  0   1   4   9  16  25  36  49  64  81 100 121]
[1 1 3 8 5]

In [4]:
1 print(a[i])

[ 1  1  9 64 25]

In [6]:
1 a[i] = 'OK'

---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
<ipython-input-6-3cfea04ff6ba> in <module>
----> 1 a[i] = 'OK'

ValueError: invalid literal for int() with base 10: 'OK'
```

Subsetting NumPy 2D arrays



[Inclusive, exclusive]
Or
[index a, index b -1] in

Quiz 4

Given a 3-by-3 NumPy array called “arr”, how many rows will be returned by calling arr[:2,]?

2

3

IndexError: index out of bounds

1

```
In [7]:  1  arr = np.arange(9).reshape(3, 3)

In [8]:  1  print(arr)

[[0 1 2]
 [3 4 5]
 [6 7 8]]

In [9]:  1  arr[:2,]

Out[9]: array([[0, 1, 2],
               [3, 4, 5]])
```

Quiz 5

an_array = np.array([[11,12,13,14], [21,22,23,24], [31,32,33,34]])

What does each of the following evaluate to?

an_array.shape
an_array[1, :]
an_array[1:2, :]
an_array[:, 1]
an_array[:, 1:2]

```
In [2]:
1 an_array = np.array([[11,12,13,14], [21,22,23,24], [31,32,33,34]])
2 print(an_array)

[[11 12 13 14]
 [21 22 23 24]
 [31 32 33 34]]

In [3]:
1 an_array.shape

Out[3]: (3, 4)

In [4]:
1 an_array[1, :]

Out[4]: array([21, 22, 23, 24])

In [5]:
1 an_array[1:2, :]

Out[5]: array([[21, 22, 23, 24]])

In [6]:
1 an_array[:, 1]

Out[6]: array([12, 22, 32])

In [7]:
1 an_array[:, 1:2]

Out[7]: array([[12],
               [22],
               [32]])
```

Quiz 6

an_array = np.array([[11,12,13,14], [21,22,23,24], [31,32,33,34]])

Write code to print

elements greater than 15

elements greater than 15 and less than 30

elements which are even

```
In [3]:
an_array = np.array([[11,12,13,14], [21,22,23,24], [31,32,33,34]])
print(an_array)

[[11 12 13 14]
 [21 22 23 24]
 [31 32 33 34]]

In [4]:
an_array > 15

Out[4]: array([[False, False, False, False],
               [ True,  True,  True,  True],
               [ True,  True,  True,  True]])

In [5]:
an_array[an_array > 15]

Out[5]: array([21, 22, 23, 24, 31, 32, 33, 34])

In [6]:
index = (30 > an_array) & (an_array > 15)
index

Out[6]: array([[False, False, False, False],
               [ True,  True,  True,  True],
               [False, False, False, False]])

In [7]:
an_array[index]

Out[7]: array([21, 22, 23, 24])
```

```
In [8]:
an_array %  2

Out[8]: array([[1, 0, 1, 0],
               [1, 0, 1, 0],
               [1, 0, 1, 0]], dtype=int32)

In [9]:
an_array %  2 == 0

Out[9]: array([[False,  True, False,  True],
               [False,  True, False,  True],
               [False,  True, False,  True]])

In [10]:
an_array[an_array %  2 == 0]

Out[10]: array([12, 14, 22, 24, 32, 34])
```

Discussion 6

an_array = np.array([[11,12,13,14], [21,22,23,24], [31,32,33,34]])

Write code to change the elements in an_array to

[[100011 12 13] [21 100022 23] [31 32 100033] [100041 42 43]]

```
In [2]:
1 an_array = np.array([[11,12,13,14], [21,22,23,24], [31,32,33,34]])

In [3]:
1 print(an_array)

[[11 12 13 14]
 [21 22 23 24]
 [31 32 33 34]]

In [4]:
1 an_array.resize(4,3)

In [5]:
1 print(an_array)

[[11 12 13]
 [14 21 22]
 [23 24 31]
 [32 33 34]]
```

```
In [12]:
1 an_array[1,] = [21, 10022, 23]
2 an_array[2,] = [31, 32, 100033]
3 an_array[3,] = [100041, 42, 43]

In [13]:
1 print(an_array)

[[ 10011     12     13]
 [    21  10022     23]
 [    31     32 100033]
 [100041     42     43]]
```

4. NUMPY FUNCTIONS FOR STATISTICS AND RANDOM SAMPLING

Discussion 7

Working with NumPy arrays' methods

https://www.numpy.org/devdocs/reference/arrays.ndarray.html#array-methods

Many operations are implemented as methods of the NumPy array objects.

```
b = np.arange(12).reshape(3,4)
b.sum(axis=0)
b.min(axis=1)
b.cumsum(axis=1)
```

```
In [16]:  1  b = np.arange(12).reshape(3,4)
          2  print(b)

[[ 0  1  2  3]
 [ 4  5  6  7]
 [ 8  9 10 11]]

In [17]:  1  b.sum(axis=0)

Out[17]: array([12, 15, 18, 21])

In [18]:  1  b.min(axis=1)

Out[18]: array([0, 4, 8])

In [19]:  1  b.cumsum(axis=1)

Out[19]: array([[ 0,  1,  3,  6],
                [ 4,  9, 15, 22],
                [ 8, 17, 27, 38]], dtype=int32)
```

5. PLOTTING WITH MATPLOTLIB

https://matplotlib.org/gallery/index.html

In [ ]:
```
# !pip install matplotlib
```

Source: https://www.numpy.org/devdocs/user/quickstart.html#histograms

In [3]:
```
import numpy as np
import matplotlib.pyplot as plt
```

In [4]:
```
# Build a vector of 10000 normal deviates with variance 0.5^2 and mean 2
mu, sigma = 2, 0.5
```

In [5]:
```
v = np.random.normal(mu,sigma,10000)
v
```

Out[5]:
```
array([2.31192204, 1.92572497, 2.57443487, ..., 1.87154162, 2.21761945,
       1.8429948 ])
```

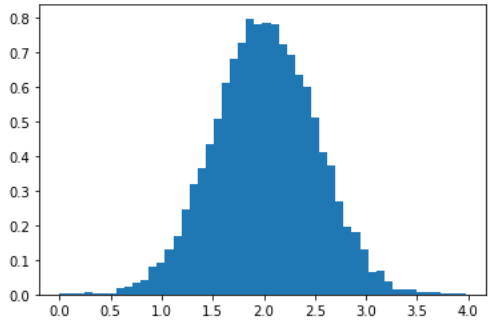
In [7]:
```
v.mean()
```

Out[7]:
```
2.010053755796068
```

In [8]:
```
v.std()
```

Out[8]:
```
0.49719348966733545
```

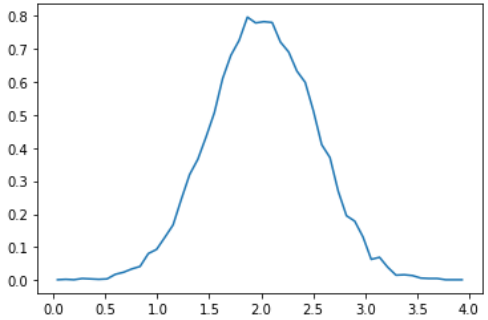
In [11]:
```
plt.hist(v, bins=50, density=1)
plt.show()
```



[13]:
```
# Compute the histogram with numpy and then plot it
(n, bins) = np.histogram(v, bins=50, density=True)  # NumPy version (no plot)
print(n)
print(bins)
```

```
[0.00125829 0.00251657 0.00125829 0.00503314 0.00377486 0.00251657
 0.00377486 0.017616   0.02390742 0.03397371 0.04152342 0.08053026
 0.09311312 0.12960339 0.16735196 0.24536565 0.31960449 0.36616105
 0.43410846 0.50708901 0.61026841 0.68073239 0.72603066 0.79649465
 0.77887865 0.78265351 0.78013694 0.72099752 0.69079867 0.63291755
 0.59894384 0.51212215 0.41020103 0.37119419 0.26927307 0.19503423
 0.17867652 0.13086168 0.06291427 0.0692057  0.03900685 0.01509942
 0.01635771 0.01384114 0.00629143 0.00503314 0.00503314 0.00125829
 0.00125829 0.00125829]
[-7.84441858e-04  7.86887854e-02  1.58162013e-01  2.37635240e-01
  3.17108467e-01  3.96581694e-01  4.76054921e-01  5.55528149e-01
  6.35001376e-01  7.14474603e-01  7.93947830e-01  8.73421057e-01
  9.52894285e-01  1.03236751e+00  1.11184074e+00  1.19131397e+00
  1.27078719e+00  1.35026042e+00  1.42973365e+00  1.50920688e+00
  1.58868010e+00  1.66815333e+00  1.74762656e+00  1.82709978e+00
  1.90657301e+00  1.98604624e+00  2.06551947e+00  2.14499269e+00
  2.22446592e+00  2.30393915e+00  2.38341237e+00  2.46288560e+00
  2.54235883e+00  2.62183206e+00  2.70130528e+00  2.78077851e+00
  2.86025174e+00  2.93972496e+00  3.01919819e+00  3.09867142e+00
  3.17814465e+00  3.25761787e+00  3.33709110e+00  3.41656433e+00
  3.49603756e+00  3.57551078e+00  3.65498401e+00  3.73445724e+00
  3.81393046e+00  3.89340369e+00  3.97287692e+00]
```

[14]:
```
plt.plot(.5*(bins[1:]+bins[:-1]), n)
plt.show()
```



https://matplotlib.org/gallery/index.html

A lot of examples with source codes

matplotlib.org/gallery/index.html

matplotlib Version 3.1.1

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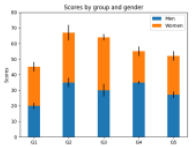
modules | index

Gallery

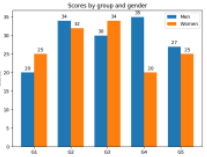
This gallery contains examples of the many things you can do with Matplotlib. Click on any image to see the full image and source code.

For longer tutorials, see our tutorials page. You can also find external resources and a FAQ in our user guide.

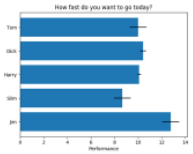
Lines, bars and markers



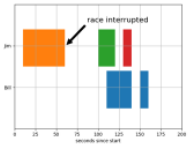
Stacked Bar Graph



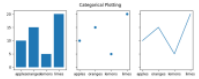
Grouped bar chart with labels

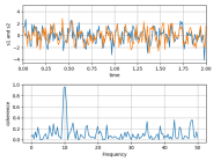


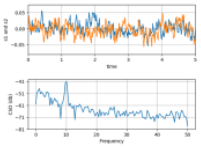
Horizontal bar chart

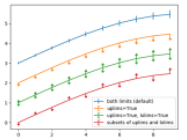


Broken Barh









Quick search

Go

Table of Contents

Discussion 8

Refer to the code in Figure 5.7

- How to set the min and max of x and y axes?

  https://matplotlib.org/api/_as_gen/matplotlib.pyplot.axis.html#matplotlib.pyplot.axis

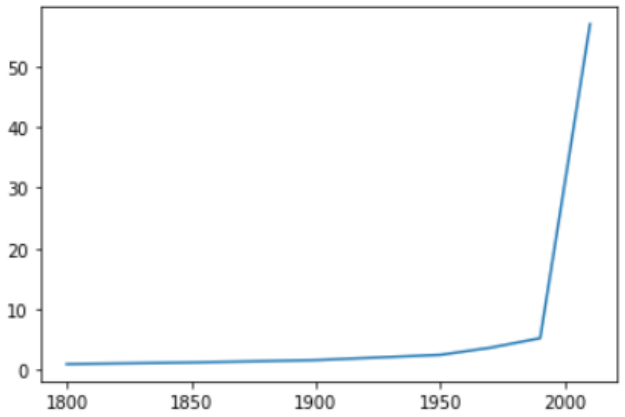
- How to customize the color, marker and line style?

  https://matplotlib.org/api/_as_gen/matplotlib.pyplot.plot.html#matplotlib.pyplot.plot

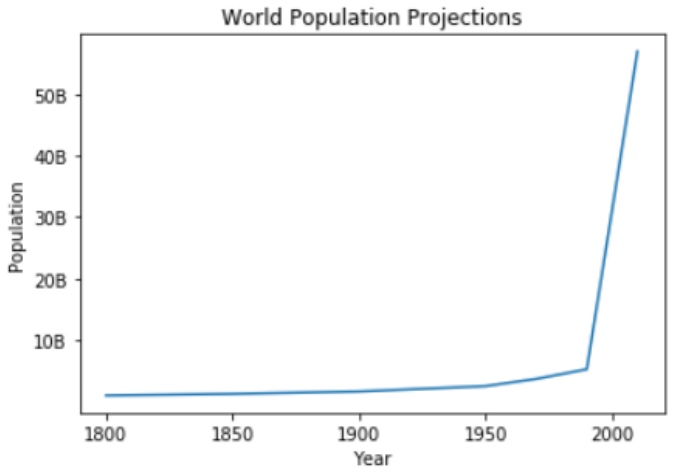
```
1  import matplotlib.pyplot as plt
2  x = [1800, 1850, 1900, 1950, 1970, 1990, 2010]
3  y = [1.0, 1.262, 1.650, 2.519, 3.692, 5.263, 56.972]
```

```
1  plt.plot(x, y)
```

```
[<matplotlib.lines.Line2D at 0x1ef55ab8688>]
```




```
1  plt.plot(x, y)
2  plt.xlabel('Year')
3  plt.ylabel('Population')
4  plt.title("World Population Projections")
5  plt.yticks([10,20,30,40,50], ['10B','20B','30B','40B','50B'])
6  plt.show()
```



https://matplotlib.org/api/_as_gen/matplotlib.pyplot.axis.html#matplotlib.pyplot.axis

matplotlib.pyplot.axis

`matplotlib.pyplot.axis(*args, **kwargs)` [source]

Convenience method to get or set some axis properties.

Call signatures:

```
xmin, xmax, ymin, ymax = axis()
xmin, xmax, ymin, ymax = axis([xmin, xmax, ymin, ymax])
xmin, xmax, ymin, ymax = axis(option)
xmin, xmax, ymin, ymax = axis(**kwargs)
```

Parameters:

xmin, xmax, ymin, ymax : float, optional

The axis limits to be set. Either none or all of the limits must be given. This can also be achieved using

```
ax.set(xlim=(xmin, xmax), ylim=(ymin, ymax))
```

option : bool or str

If a bool, turns axis lines and labels on or off. If a string, possible values are:

Value	Description
'on'	Turn on axis lines and labels. Same as `True`.
'off'	Turn off axis lines and labels. Same as `False`.
'equal'	Set equal scaling (i.e., make circles circular) by changing axis limits.
'scaled'	Set equal scaling (i.e., make circles circular) by changing dimensions of the plot box.
'tight'	Set limits just large enough to show all data.
'auto'	Automatic scaling (fill plot box with data).
'normal'	Same as 'auto'; deprecated.

https://matplotlib.org/api/_as_gen/matplotlib.pyplot.plot.html#matplotlib.pyplot.plot

matplotlib.pyplot.plot

matplotlib.pyplot.plot(*args, scalex=True, scaley=True, data=None, **kwargs) [sou

Plot y versus x as lines and/or markers.

Call signatures:

```
plot([x], y, [fmt], *, data=None, **kwargs)
plot([x], y, [fmt], [x2], y2, [fmt2], ..., **kwargs)
```

The coordinates of the points or line nodes are given by *x*, *y*.

The optional parameter *fmt* is a convenient way for defining basic formatting like color, marker and linestyle. It's a shortcut string notation described in the *Notes* section below.

fmt = '[marker][line][color]'

fmt = '[marker][line][color]'
order for argument string is not important

example

'g+--'

Line Styles

character	description
'-'	solid line style
'--'	dashed line style
'-.'	dash-dot line style
':'	dotted line style

Colors

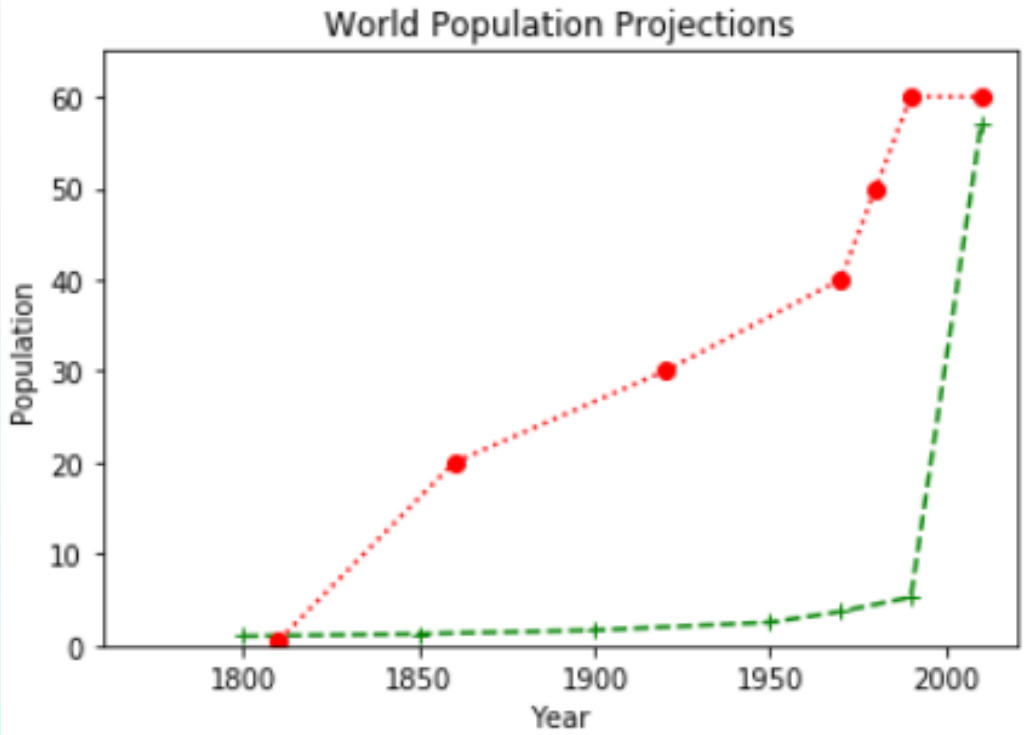
The supported color abbreviations are the single letter codes

character	color
'b'	blue
'g'	green
'r'	red
'c'	cyan
'm'	magenta
'y'	yellow
'k'	black
'w'	white

Markers

character	description
'.'	point marker
','	pixel marker
'o'	circle marker
'v'	triangle_down marker
'^'	triangle_up marker
'<'	triangle_left marker
'>'	triangle_right marker
'1'	tri_down marker
'2'	tri_up marker
'3'	tri_left marker
'4'	tri_right marker
's'	square marker
'p'	pentagon marker
'*'	star marker
'h'	hexagon1 marker
'H'	hexagon2 marker
'+'	plus marker
'x'	x marker
'D'	diamond marker
'd'	thin_diamond marker
'|'	vline marker
'_'	hline marker

```
1  x2 = [1810, 1860, 1920, 1970, 1980, 1990, 2010]
2  y2 = [0.5, 20, 30, 40, 50, 60, 60]
3  plt.plot(x, y, 'g+--', x2, y2, 'ro:')
4  plt.xlabel('Year')
5  plt.ylabel('Population')
6  plt.title("World Population Projections")
7  plt.axis([1760,2020,0,65])
8  plt.show()
```



Discussion 9

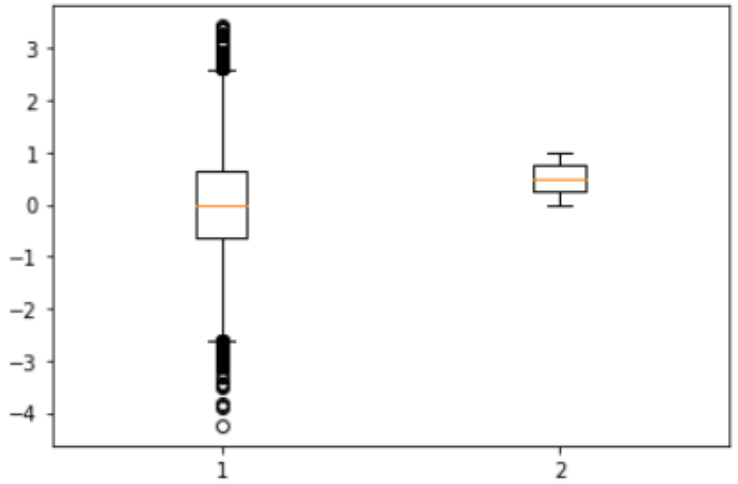
Box plot

Understand the code below

normal_sample = np.random.normal(loc=0.0,scale=1.0,size=10000)
random_sample = np.random.random(size = 10000)
plt.figure()
plt.boxplot([normal_sample,random_sample])

Discuss the purposes of parameter *whis*, *showfliers*.
(https://matplotlib.org/api/_as_gen/matplotlib.pyplot.boxplot.html#matplotlib.pyplot.boxplot)

```
1  normal_sample = np.random.normal(loc=0.0,scale=1.0,size=10000)
2  random_sample = np.random.random(size = 10000)
3  plt.figure()
4  plt.boxplot([normal_sample,random_sample])
5  plt.show()
```



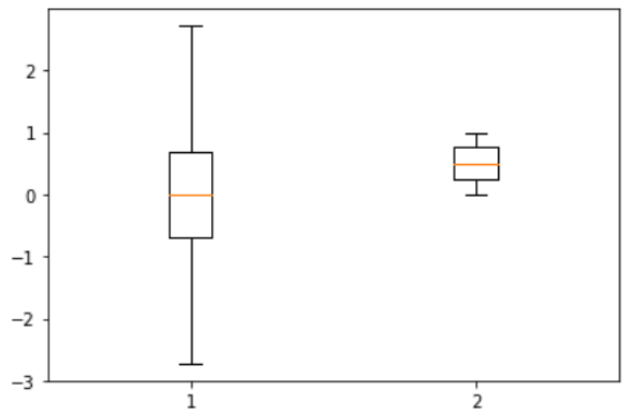
whis : float, sequence, or string (default = 1.5)

As a float, determines the reach of the whiskers to the beyond the first and third quartiles. In other words, where IQR is the interquartile range (`Q3-Q1`), the upper whisker will extend to last datum less than `Q3 + whis*IQR`). Similarly, the lower whisker will extend to the first datum greater than `Q1 - whis*IQR`. Beyond the whiskers, data are considered outliers and are plotted as individual points. Set this to an unreasonably high value to force the whiskers to show the min and max values. Alternatively, set this to an ascending sequence of percentile (e.g., [5, 95]) to set the whiskers at specific percentiles of the data. Finally, `whis` can be the string `'range'` to force the whiskers to the min and max of the data.

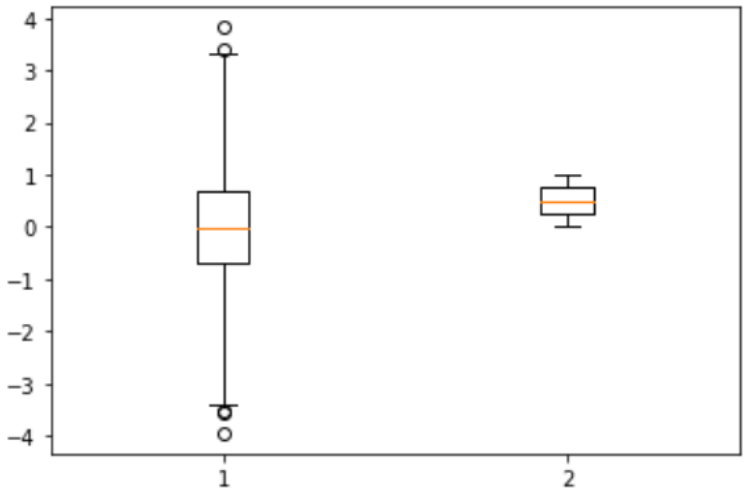
showfliers : bool, optional (True)

Show the outliers beyond the caps.

```
# Hide Outlier Points with showfliers=False
plt.figure()
plt.boxplot([normal_sample,random_sample], showfliers=False)
plt.show()
```




```
plt.figure()
plt.boxplot([normal_sample,random_sample], whis = 2)
plt.show()
```



Discussion 10

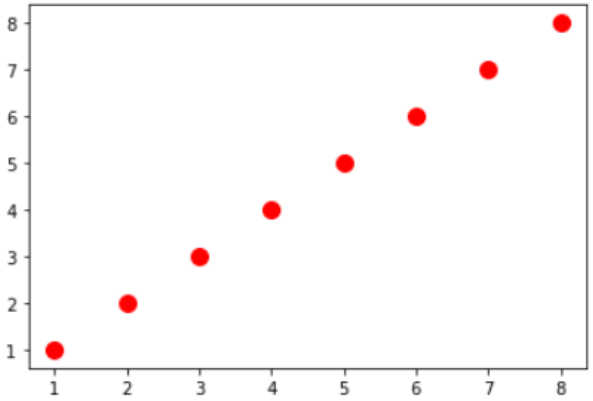
Scatter plot
(https://matplotlib.org/api/_as_gen/matplotlib.pyplot.scatter.html#matplotlib.pyplot.scatter)

Understand the code below

```
x = np.arange(1,9)
y = x
plt.figure()
plt.scatter(x,y,s=100,c='red')
```

```
1  x = np.arange(1,9)
2  y = x
3  plt.figure()
4  plt.scatter(x,y,s=100,c='red')
```

```
<matplotlib.collections.PathCollection at 0x1ef55e7c948>
```



Read the example at https://matplotlib.org/gallery/shapes_and_collections/scatter.html#sphx-glr-gallery-shapes-and-collections-scatter-py and customize the color, size and transparency.

s : scalar or array_like, shape (n,), optional

The marker size in points**2. Default is `rcParams['lines.markersize'] ** 2`.

c : color, sequence, or sequence of color, optional

The marker color. Possible values:

- A single color format string.
- A sequence of color specifications of length n.
- A sequence of n numbers to be mapped to colors using *cmap* and *norm*.
- A 2-D array in which the rows are RGB or RGBA.

Note that *c* should not be a single numeric RGB or RGBA sequence because that is indistinguishable from an array of values to be colormapped. If you want to specify the same RGB or RGBA value for all points, use a 2-D array with a single row. Otherwise, value- matching will have precedence in case of a size matching with *x* and *y*.

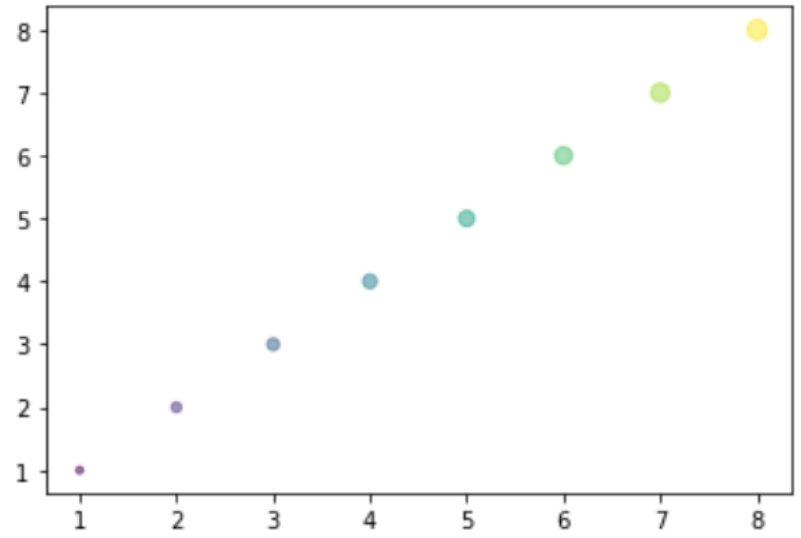
Defaults to `None`. In that case the marker color is determined by the value of `color`, `facecolor` or `facecolors`. In case those are not specified or `None`, the marker color is determined by the next color of the `Axes`' current "shape and fill" color cycle. This cycle defaults to `rcParams["axes.prop_cycle"]`.

alpha : scalar, optional, default: None

The alpha blending value, between 0 (transparent) and 1 (opaque).

```
1 ▾ #plt.figure()
2   plt.scatter(x,y,s=x*10,c=x*10,alpha=0.5)
```

```
<matplotlib.collections.PathCollection at 0x234b0570588>
```



Discussion 11

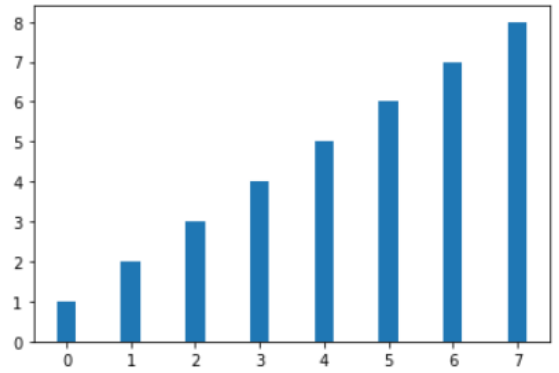
Bar chart
(https://matplotlib.org/api/_as_gen/matplotlib.pyplot.bar.html#matplotlib.pyplot.bar)

Understand the code below

```
plt.figure()
linear_data = np.arange(1,9)
quadratic_data = linear_data ** 2
xvals = np.arange(len(linear_data))
plt.bar(xvals, linear_data, width = 0.3)
```

```
1  plt.figure()
2  linear_data = np.arange(1,9)
3  quadratic_data = linear_data ** 2
4  xvals = np.arange(len(linear_data))
5  plt.bar(xvals, linear_data, width = 0.3)
```

```
<BarContainer object of 8 artists>
```



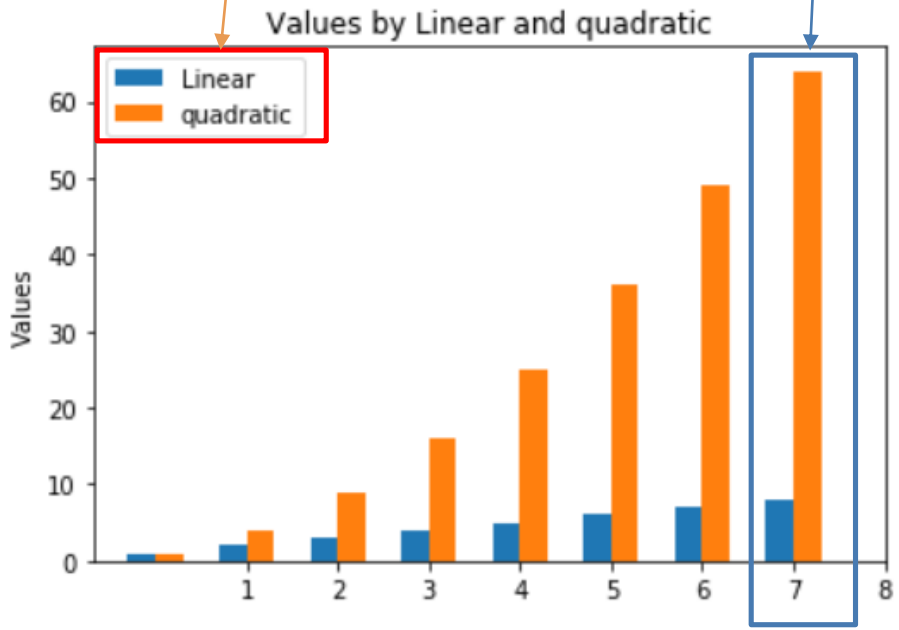
To plot the two arrays of data: linear_data and quadratic_data

- Create a side-by-side bar chat
- Read the example at https://matplotlib.org/gallery/lines_bars_and_markers/bar_stacked.html#sphx-glr-gallery-lines-bars-and-markers-bar-stacked-py, and
  - create a stacked bar chart.
  - add legend

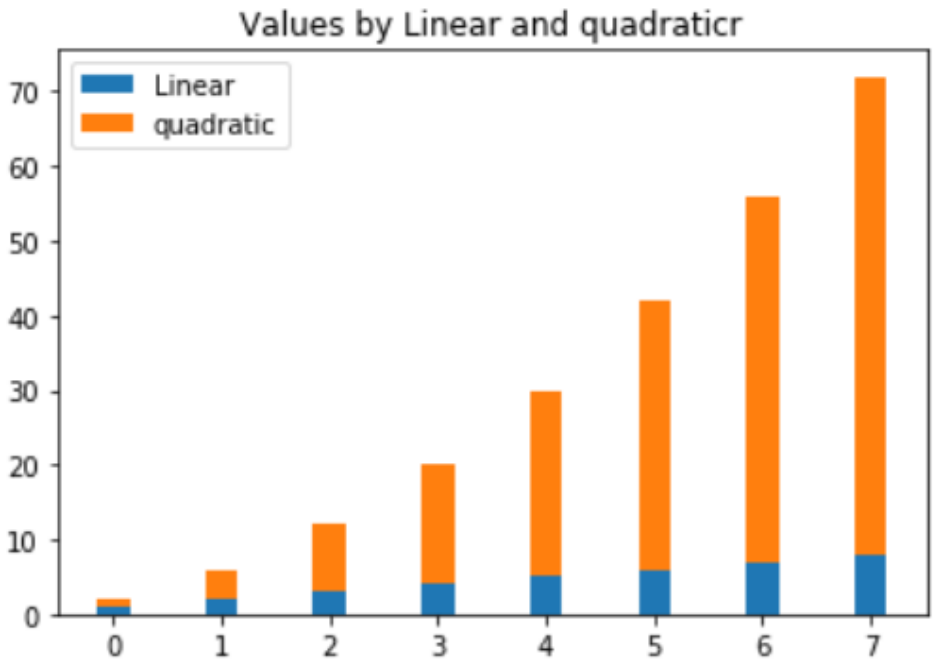
```
# data
linear_data = np.arange(1,9)
quadratic_data = linear_data ** 2
xvals = np.arange(len(linear_data))
# plot
fig, ax = plt.subplots()
# why 0.15 and 0.3?
plt.bar(xvals-0.15, linear_data, width = 0.3, label = 'Linear')
plt.bar(xvals+0.15, quadratic_data, width = 0.3, label = 'quadratic')
ax.set_ylabel('Values')
ax.set_title('Values by Linear and quadratic')
ax.set_xticks(x)
ax.legend()

```

```
<matplotlib.legend.Legend at 0x234b58eb148>
```



```python
# data
linear_data = np.arange(1,9)
quadratic_data = linear_data ** 2
xvals = np.arange(len(linear_data))
# plot
plt.bar(xvals, linear_data, width = 0.3, label = 'Linear')
plt.bar(xvals, quadratic_data, width = 0.3, label = 'quadratic', bottom=linear_data)
plt.title('Values by Linear and quadraticr')
plt.legend()
plt.show()
```



THANK YOU!