Sessions 03-05

Data Manipulation and Visualization

(in Python and MATLAB)

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QF666
Programming and Computational Finance

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Of Quantitative Finance

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- ✓ Python Basics
- ✓ MATLAB Basics

Next, …

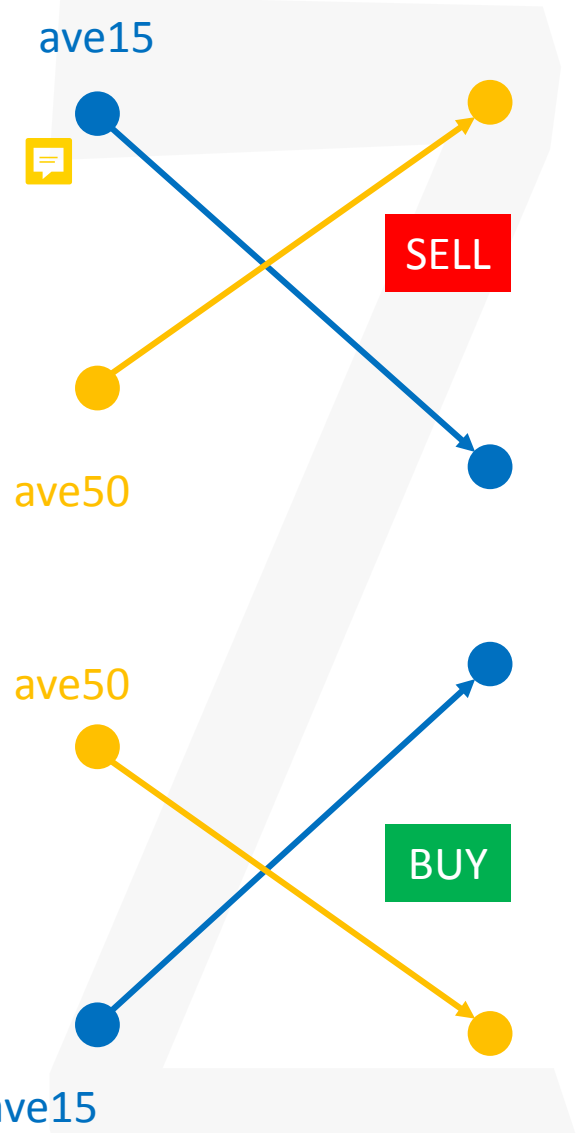
002

CC3.SI.csv - Excel

FILE | HOME | INSERT | PAGE LA | FORMUL | DATA | REVIEW | VIEW | DEVELOP | ACROB

A1 | Date

	A	B	C	D	E	F	G
1	Date	Open	High	Low	Close	Adj Close	Volume
2	1/7/2015	3.96	3.97	3.92	3.93	3.492484	2238400
3	2/7/2015	3.96	3.96	3.92	3.92	3.483597	1430100
4	3/7/2015	3.93	3.97	3.93	3.95	3.510257	1702400
5	6/7/2015	3.95	3.95	3.92	3.95	3.510257	1183600
6	7/7/2015	3.96	4	3.96	3.98	3.536918	1724600
7	8/7/2015	3.96	4.02	3.96	3.98	3.536918	4134900
8	9/7/2015	3.91	3.98	3.9	3.97	3.528031	2363600
9	10/7/2015	3.98	4	3.93	3.94	3.501371	1961800
10	13/7/2015	3.95	3.97	3.94	3.96	3.519144	808000
11	14/7/2015	3.96	4	3.96	3.98	3.536918	1250100



.csv ⇨ Moving Average Crossover

001

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MATLAB

001

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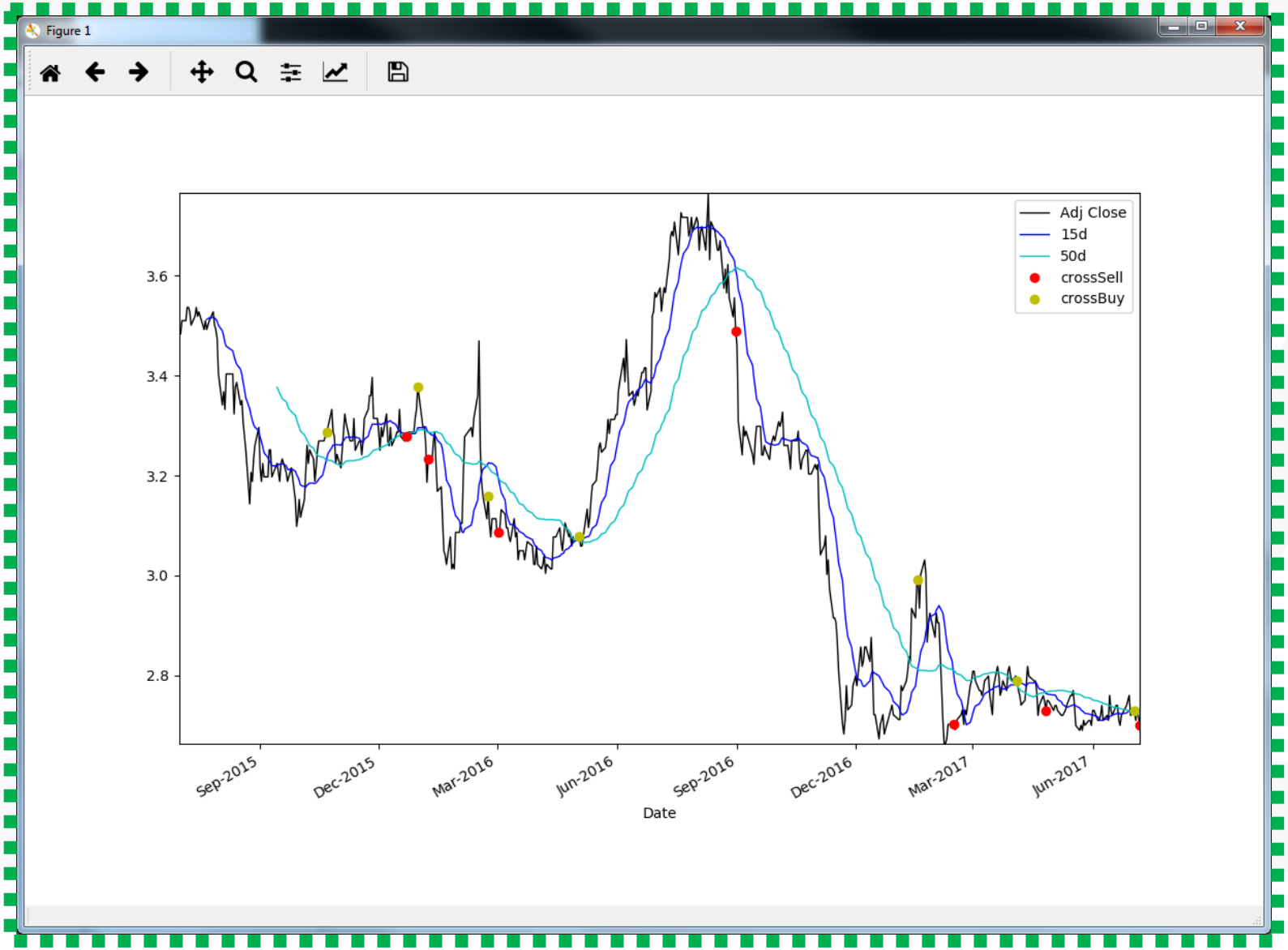
Python

001



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How to …

1. Import data from a CSV file to a Table/DataFrame
2. Manipulate data in a Table/DataFrame
   - Remove/Insert data
   - Compare data
   - Select data
   - Apply (other) operations/functions on data
3. Visualize data

001

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003

```python
# Moving Average Crossover
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
plt.rcParams["figure.figsize"]=[12,8] # (optional)
data=pd.read_csv('CC3.SI.csv',index_col=0,parse_dates=True)
data.drop(data.index[data['Volume']==0],inplace=True)
data['15d']= np.round(data['Adj Close'].rolling(window=15).mean(),3)
data['50d']= np.round(data['Adj Close'].rolling(window=50).mean(),3)
x=data['15d']-data['50d']
x[x>0]=1
x[x<=0]=0
y=x.diff()
idxSell=y.index[y<0]
idxBuy=y.index[y>0]
data['crossSell']=np.nan
data.loc[idxSell,'crossSell']=data.loc[idxSell,'Adj Close']
data['crossBuy']=np.nan
data.loc[idxBuy,'crossBuy']=data.loc[idxBuy,'Adj Close']
fig, ax = plt.subplots()
data[['Adj Close', '15d', '50d','crossSell','crossBuy']].plot(
        ax=ax,
        style=['k-','b-','c-','ro','yo'],
        linewidth=1)
plt.autoscale(enable=True, axis='x', tight=True)
plt.autoscale(enable=True, axis='y', tight=True)
ax.xaxis.set_major_formatter(mdates.DateFormatter('%b-%Y'))
plt.show()
```

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004

```
clear;
clc;
figure('Name','Figure 1', 'units','inch','position',[1.5,1.5,12,8]);
data=readtable('CC3.SI.csv');
data(data.Volume==0,:)=[];
X=datetime(data.Date);
Y=data.AdjClose;
plot(X,Y,'k-','LineWidth',1);
hold on;
ave15=round(movmean(Y,15,'Endpoints','discard'),3);
ave15(1:35)=[];
ave50=round(movmean(Y,50,'Endpoints','discard'),3);
daxis=X(50:end);
paxis=Y(50:end);
plot(daxis,ave15,'b-');
plot(daxis,ave50,'c-');
x=ave15-ave50;
x(x>0)=1;
x(x<=0)=0;
y=diff(x); %size is reduced by 1
idxSell=find(y<0)+1;
idxBuy=find(y>0)+1;
plot(daxis(idxBuy),paxis(idxBuy), ...
     'y.','MarkerSize',20,'Linewidth',1);
plot(daxis(idxSell),paxis(idxSell), ...
     'r.','MarkerSize',20,'Linewidth',1);
legend('Adj Close', '15d', '50d', 'crossSell', 'crossBuy');
xlabel('Date');
axis tight
set(gca,'XTickLabelRotation',30)
```

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Spyder (Python 3.6)

File Edit Search Source Run Debug Consoles Projects Tools View Help

Variable explorer

Name	Type
ax	axes._subplots.AxesSubplot
data	DataFrame
fig	figure.Figure
idxBuy	DatetimeIndex
idxSell	DatetimeIndex
mdates	module
np	module
pd	module
plt	module
x	Series
y	Series

Editor - MAC.py

MAC.py*

```
1  # Moving Average Crossover
2  import pandas as pd
3  import numpy as np
4  import matplotlib.pyplot as plt
5  import matplotlib.dates as mdates
6  plt.rcParams["figure.figsize"]=[12,8] # (optional)
7  data=pd.read_csv('CC3.SI.csv',index_col=0,parse_dates=True)
8  data.drop(data.index[data['Volume']==0],inplace=True)
9  data['15d']= np.round(data['Adj Close'].rolling(window=15).mean(),3)
10 data['50d']= np.round(data['Adj Close'].rolling(window=50).mean(),3)
11 x=data['15d']-data['50d']
12 x[x>0]=1
13 x[x<=0]=0
14 y=x.diff()
15 idxSell=y.index[y<0]
16 idxBuy=y.index[y>0]
17 data['crossSell']=np.nan
18 data.loc[idxSell,'crossSell']=data.loc[idxSell,'Adj Close']
19 data['crossBuy']=np.nan
20 data.loc[idxBuy,'crossBuy']=data.loc[idxBuy,'Adj Close']
21 fig, ax = plt.subplots()
22 data[['Adj Close', '15d', '50d','crossSell','crossBuy']].plot(
23         ax=ax,
24         style=['k-','b-','c-','ro','yo'],
25         linewidth=1)
26 plt.autoscale(enable=True, axis='x', tight=True)
27 plt.autoscale(enable=True, axis='y', tight=True)
28 ax.xaxis.set_major_formatter(mdates.DateFormatter('%b-%Y'))
29 plt.show()
```

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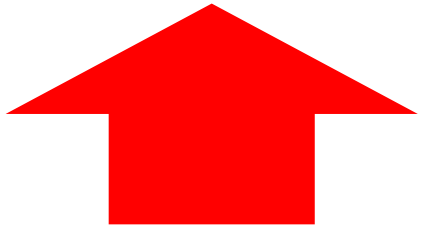
Name	Value	Size	Cl
ave15	457x1 double	457x1	do
ave50	457x1 double	457x1	do
data	506x7 table	506x7	tab
daxis	457x1 datetime	457x1	dat
idxBuy	[28;76;111;159;3...	7x1	do
idxSell	[70;81;117;243;3...	7x1	do
paxis	457x1 double	457x1	do
x	457x1 double	457x1	do
X	506x1 datetime	506x1	dat
y	456x1 double	456x1	do
Y	506x1 double	506x1	do



006

MA.m

```
clear;
clc;
figure('Name','Figure 1', 'units','inch','position',[1.5,1.5,12,8]);
data=readtable('CC3.SI.csv');
data(data.Volume==0,:)=[];
X=datetime(data.Date);
Y=data.AdjClose;
plot(X,Y,'k-','LineWidth',1);
hold on;
ave15=round(movmean(Y,15,'Endpoints','discard'),3);
ave15(1:35)=[];
ave50=round(movmean(Y,50,'Endpoints','discard'),3);
daxis=X(50:end);
paxis=Y(50:end);
plot(daxis,ave15,'b-');
plot(daxis,ave50,'c-');
x=ave15-ave50;
x(x>0)=1;
x(x<=0)=0;
y=diff(x); %size is reduced by 1
idxSell=find(y<0)+1;
idxBuy=find(y>0)+1;
plot(daxis(idxBuy),paxis(idxBuy), ...
     'y.','MarkerSize',20,'Linewidth',1);
plot(daxis(idxSell),paxis(idxSell), ...
     'r.','MarkerSize',20,'Linewidth',1);
legend('Adj Close', '15d', '50d', 'crossSell', 'crossBuy');
xlabel('Date');
axis tight
set(gca,'XTickLabelRotation',30)
```

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Python First!

007

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import … as …

008

```
02 import pandas as pd
03 import numpy as np
04 import matplotlib.pyplot as plt
05 import matplotlib.dates as mdates

   plt.rcParams["figure.figsize"]=[12,8]
```

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In-Class Exercise 01: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
plt.rcParams["figure.figsize"]=[12,8] # (optional)
dir()
```

```
['In',
 'Out',
 '',
 '_',
 '_1',
 '',
 '__',
 '___',
 '__builtin__',
 '__builtins__',
 '__doc__',
 '__loader__',
 '__name__',
 '__package__',
 '__spec__',
 '_dh',
 '_i',
 '_i1',
 '_i2',
 '_ih',
 '_ii',
 '_iii',
 '_oh',
 'exit',
 'get_ipython',
 'mdates',
 'np',
 'pd',
 'plt',
 'quit']
```

009

In-Class Exercise 02: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
dir(pd)
```

pd.read_csv

```
'pnow',
'qcut',
'read_clipboard',
'read_csv',
'read_excel',
'read_fwf',
'read_gbq',
'read_hdf',
'read_html',
'read_json',
'read_msgpack',
'read_pickle',
'read_sas',
'read_sql',
'read_sql_query',
'read_sql_table',
'read_stata',
'read_table',
'reset_option',
'rolling_apply',
```

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pd.read_csv

https://pandas.pydata.org/pandas-docs/stable/generated/pandas.read_csv.html

Read CSV (comma separated values) file into DataFrame

```
pandas.read_csv(filepath_or_buffer, sep=', ', delimiter=None,
header='infer', names=None, index_col=None, usecols=None,
squeeze=False, prefix=None, mangle_dupe_cols=True, dtype=None,
engine=None, converters=None, true_values=None, false_values=None,
skipinitialspace=False, skiprows=None, nrows=None, na_values=None,
keep_default_na=True, na_filter=True, verbose=False,
skip_blank_lines=True, parse_dates=False,
infer_datetime_format=False, keep_date_col=False, date_parser=None,
dayfirst=False, iterator=False, chunksize=None,
compression='infer', thousands=None, decimal=b'.',
lineterminator=None, quotechar='"', quoting=0, escapechar=None,
comment=None, encoding=None, dialect=None, tupleize_cols=False,
error_bad_lines=True, warn_bad_lines=True, skipfooter=0,
skip_footer=0, doublequote=True, delim_whitespace=False,
as_recarray=False, compact_ints=False, use_unsigned=False,
low_memory=True, buffer_lines=None, memory_map=False,
float_precision=None)
```

010

011

013

(Dr. Z: Is there a *- or **- paremeter?)

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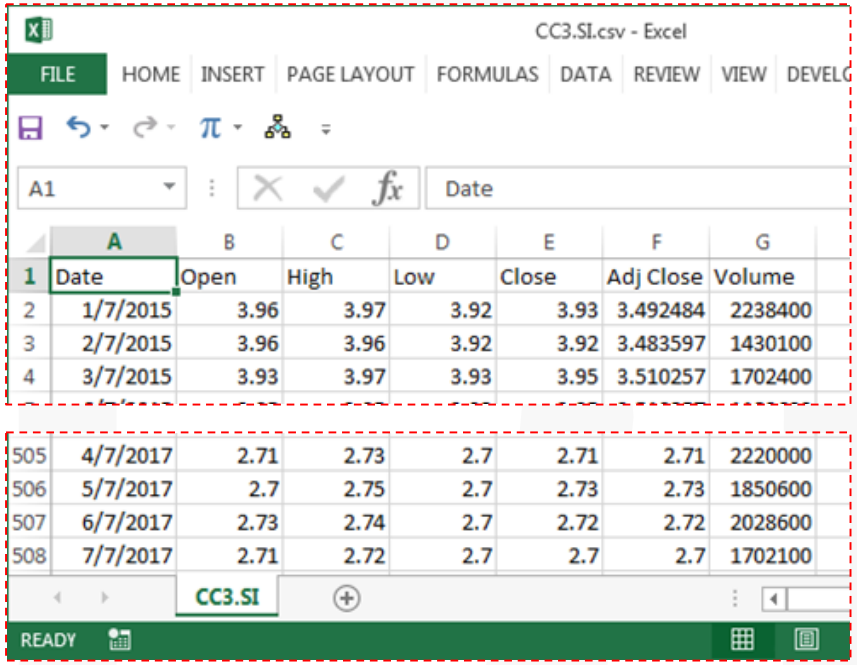
header : *int or list of ints, default 'infer'*

Row number(s) to use as the column names, and the start of the data. Default behavior is to infer the column names: if no names are passed the behavior is identical to `header=0` and column names are inferred from the first line of the file, if column names are passed explicitly then the behavior is identical to `header=None`. Explicitly pass `header=0` to be able to replace existing names. The header can be a list of integers that specify row locations for a multi-index on the columns e.g. [0,1,3]. Intervening rows that are not specified will be skipped (e.g. 2 in this example is skipped). Note that this parameter ignores commented lines and empty lines if `skip_blank_lines=True`, so header=0 denotes the first line of data rather than the first line of the file.

`data=pd.read_csv('CC3.SI.csv', header='infer')`

⇔ `header=0`



`header='infer'`

`header=0, w/o name`

In-Class Exercise 03: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data=pd.read_csv('CC3.SI.csv')
data
```

	Date	Open	High	Low	Close	Adj Close	Volume
0	2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400
1	2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100
2	2015-07-03	3.96	3.97	3.93	3.95	3.510257	1702400
3	2015-07-06	3.95	3.96	3.91	3.95	3.510257	1183600
4	2015-07-07	3.96	4.00	3.96	3.98	3.536918	1724600
5	2015-07-08	3.96	4.02	3.96	3.98	3.536918	4134900

dataframe

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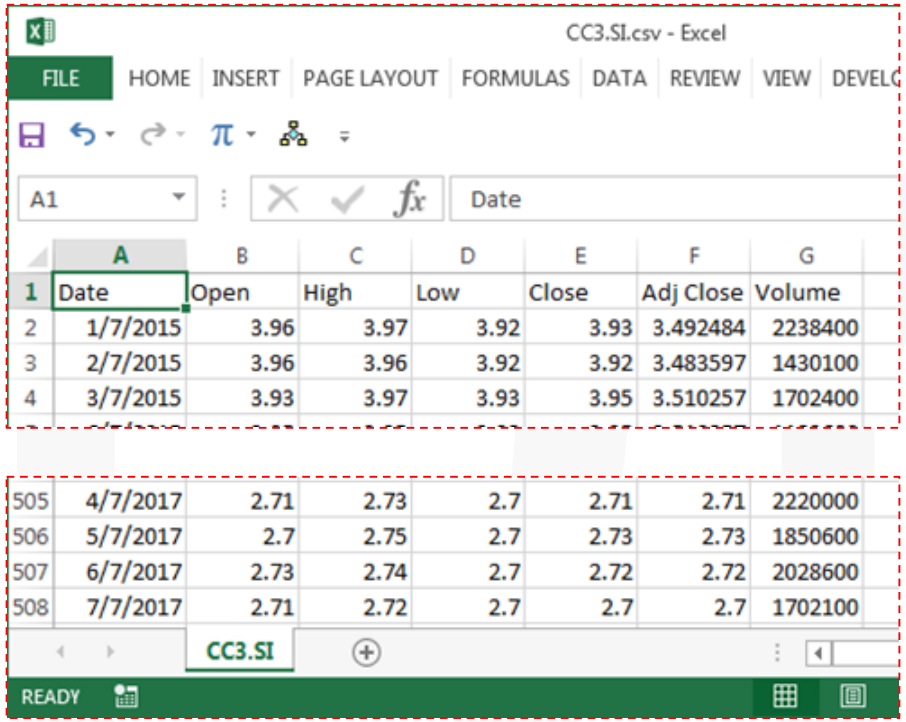
data=pd.read_csv('CC3.SI.csv', header=None)



header=None

In-Class Exercise 04: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data=pd.read_csv('CC3.SI.csv', header=None)
data
```

	0	1	2	3	4	5	6
0	Date	Open	High	Low	Close	Adj Close	Volume
1	2015-07-01	3.960000	3.970000	3.920000	3.930000	3.492484	2238400
2	2015-07-02	3.960000	3.960000	3.920000	3.920000	3.483597	1430100
3	2015-07-03	3.930000	3.970000	3.930000	3.950000	3.510257	1702400
4	2015-07-06	3.950000	3.970000	3.930000	3.950000	3.510257	1683600
5	2015-07-07	3.960000	4.000000	3.960000	3.980000	3.536918	1724600
6	2015-07-08	3.960000	4.020000	3.960000	3.980000	3.536918	4134900
7	2015-07-09	3.910000	3.980000	3.900000	3.970000	3.528031	2363600
8	2015-07-10	3.980000	4.000000	3.930000	3.940000	3.501371	1961800

dataframe

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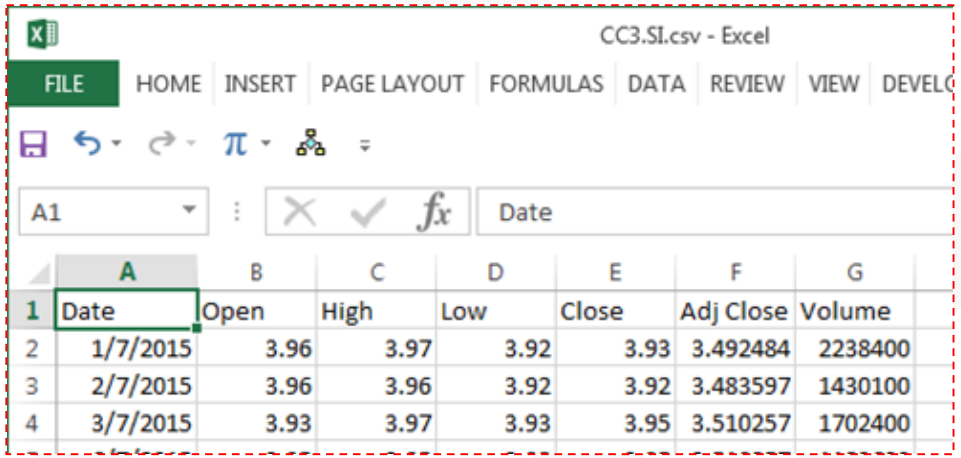
data=pd.read_csv('CC3.SI.csv', names=range(7,0,-1))



In-Class Exercise 05: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data=pd.read_csv('CC3.SI.csv',  names=range(7,0,-1))
data
```

	7	6	5	4	3	2	1
0	Date	Open	High	Low	Close	Adj Close	Volume
1	2015-07-01	3.960000	3.970000	3.920000	3.930000	3.492484	2238400
2	2015-07-02	3.960000	3.960000	3.920000	3.920000	3.483597	1430100
3	2015-07-03	3.930000	3.970000	3.930000	3.950000	3.510257	1702400
4	2015-07-06	3.950000	3.950000	3.920000	3.950000	3.510257	1702400
5	2015-07-07	3.950000	4.000000	3.960000	3.980000	3.536918	1734600
6	2015-07-08	3.960000	4.020000	3.960000	3.980000	3.536918	4134900
7	2015-07-09	3.910000	3.980000	3.900000	3.970000	3.528031	2363600
8	2015-07-10	3.980000	4.000000	3.930000	3.940000	3.501371	1961800

dataframe

names=range(7,0,-1)

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```
data=pd.read_csv('CC3.SI.csv', header=0, names=range(7,0,-1))
```

In-Class Exercise 06: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data=pd.read_csv('CC3.SI.csv', header=0, names=range(7,0,-1))
data
```

	7	6	5	4	3	2	1
0	2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400
1	2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100
2	2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400
3	2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600
4	2015-07-07	3.96	4.00	3.96	3.98	3.536918	1724600
5	2015-07-08	3.96	4.02	3.96	3.98	3.536918	4134900
6	2015-07-09	3.91	3.98	3.90	3.97	3.528031	2363600
7	2015-07-10	3.98	4.00	3.93	3.94	3.501371	1961800
8	2015-07-13	3.95	3.97	3.94	3.96	3.519144	808000

header=0

+

012

names=range(7,0,-1)

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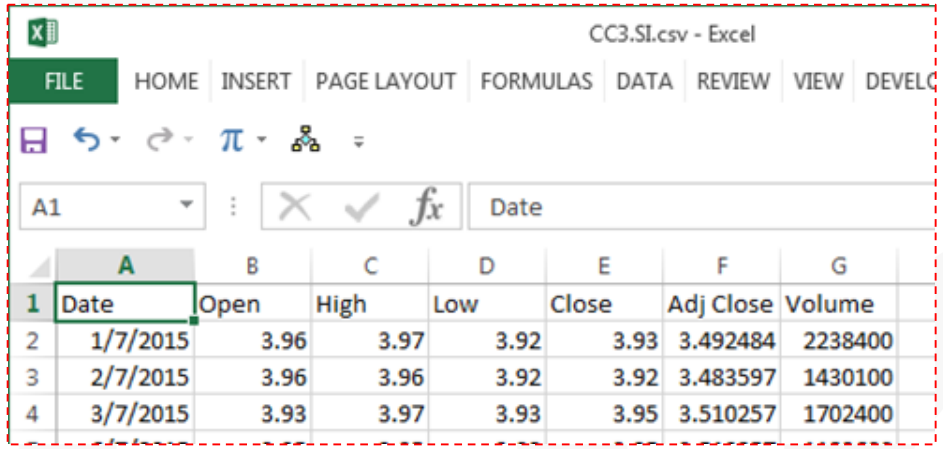

	7	6	5	4	3	2	1
0	Date	Open	High	Low	Close	Adj Close	Volume
1	2015-07-01	3.960000	3.970000	3.920000	3.930000	3.492484	2238400
2	2015-07-02	3.960000	3.960000	3.920000	3.920000	3.483597	1430100
3	2015-07-03	3.930000	3.970000	3.930000	3.950000	3.510257	1702400
4	2015-07-06	3.950000	3.950000	3.920000	3.950000	3.510257	1183600
5	2015-07-07	3.960000	4.000000	3.960000	3.980000	3.536918	1724600
6	2015-07-08	3.960000	4.020000	3.960000	3.980000	3.536918	4134900
7	2015-07-09	3.910000	3.980000	3.900000	3.970000	3.528031	2363600
8	2015-07-10	3.980000	4.000000	3.930000	3.940000	3.501371	1961800

```
(A) data=pd.read_csv('CC3.SI.csv', header=0, names=range(7,0,-1))
```

```
(B) data=pd.read_csv('CC3.SI.csv', names=range(7,0,-1))
```

```
(C) data=pd.read_csv('CC3.SI.csv', header=0)
```

```
(D) data=pd.read_csv('CC3.SI.csv')
```

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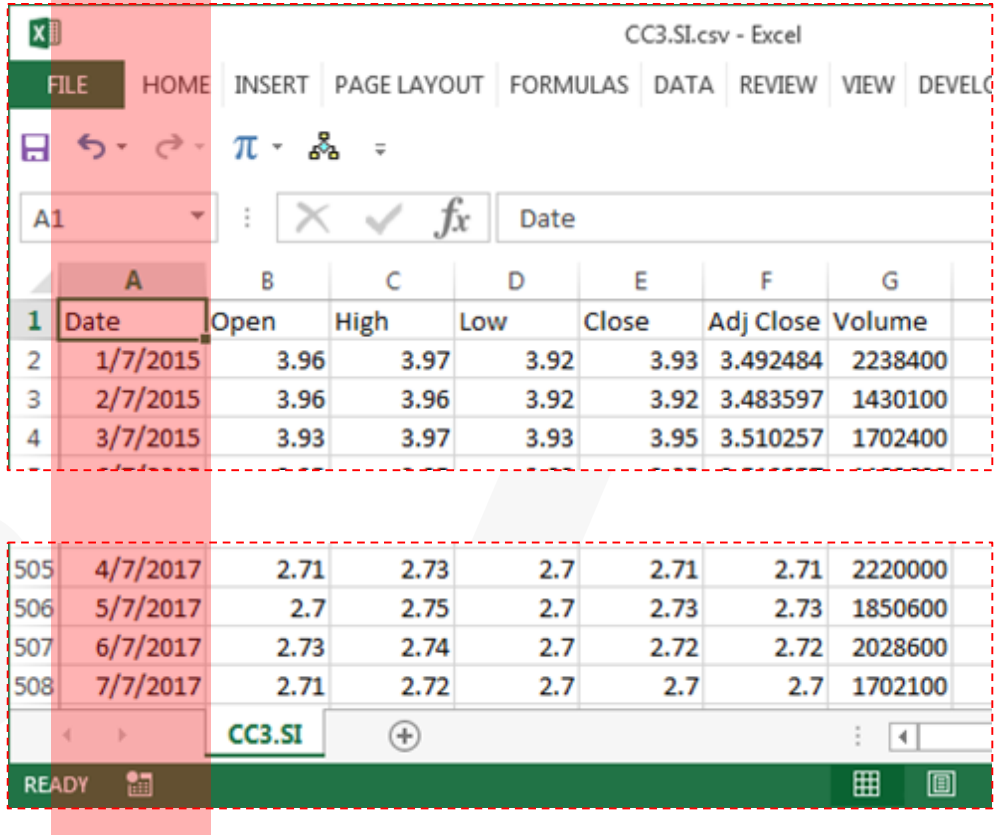
In-Class Exercise 07: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data=pd.read_csv('CC3.SI.csv', index_col=0)
data
```

	Open	High	Low	Close	Adj Close	Volume
Date						
2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400
2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100
2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400
2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600
2015-07-07	3.96	4.00	3.96	3.98	3.536918	1724600



012

index_col=0

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index_col : *int or sequence or False, default None*

Column to use as the row labels of the DataFrame. If a sequence is given, a MultiIndex is used. If you have a malformed file with delimiters at the end of each line, you might consider index_col=False to force pandas to _not_ use the first column as the index (row names)

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DataFrame (data)

014

data.columns

	Open	High	Low	Close	Adj Close	Volume
Date						
2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400
2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100
2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400
2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600
2015-07-07	3.96	4.00	3.96	3.98	3.536918	1724600
2015-07-08	3.96	4.02	3.96	3.98	3.536918	4134900
2015-07-09	3.91	3.98	3.90	3.97	3.528031	2363600
2015-07-10	3.98	4.00	3.93	3.94	3.501371	1961800

data.index

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In-Class Exercise 08: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data.columns, data.columns[0], data.columns[-3:]
```

```
(Index(['Open', 'High', 'Low', 'Close', 'Adj Close', 'Volume'], dtype='object'),
 'Open',
 Index(['Close', 'Adj Close', 'Volume'], dtype='object'))
```


pandas.Index:

- ✓ list-like object (Python)
- ✓ array-like object, 1-D (Numpy)

- ✓ Indexing
- ✓ Slicing

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In-Class Exercise 09: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data.index, data.index[0], data.index[45:55]
```

```
data.index, data.index[0], data.index[45:55]
```

```
(Index(['2015-07-01', '2015-07-02', '2015-07-03', '2015-07-06', '2015-07-07',
        '2015-07-08', '2015-07-09', '2015-07-10', '2015-07-13', '2015-07-14',
        ...
        '2017-06-23', '2017-06-27', '2017-06-28', '2017-06-29', '2017-06-30',
        '2017-07-03', '2017-07-04', '2017-07-05', '2017-07-06', '2017-07-07'],
       dtype='object', name='Date', length=507),
 '2015-07-01',
 Index(['2015-09-04', '2015-09-07', '2015-09-08', '2015-09-09', '2015-09-10',
        '2015-09-14', '2015-09-15', '2015-09-16', '2015-09-17', '2015-09-18'],
       dtype='object', name='Date'))
```

- ✓ Indexing
- ✓ Slicing

014

pandas.Index: list-like/array-like

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```
data['Open']
data.Open
```

syntactic sugar

```
data['Adj Close']
```

016

	Open	High	Low	Close	Adj Close	Volume
Date						
2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400
2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100
2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400
2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600

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In-Class Exercise 10: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data.Open
```

```
data.Open
```

```
Date
2015-07-01    3.96
2015-07-02    3.96
2015-07-03    3.93
2015-07-06    3.95
2015-07-07    3.96
2015-07-08    3.96
2015-07-09    3.91
2015-07-10    3.98
2015-07-13    3.95
2015-07-14    3.96
2015-07-15    3.95
2015-07-16    3.97
2015-07-20    3.97
2015-07-21    3.95
2015-07-22    3.97
2015-07-23    3.94
2015-07-24    3.96
2015-07-27    3.97
```

This is a Series.

016

In-Class Exercise 11: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data['Open']
```

```
data['Open']
```

```
Date
2015-07-01    3.96
2015-07-02    3.96
2015-07-03    3.93
2015-07-06    3.95
2015-07-07    3.96
2015-07-08    3.96
2015-07-09    3.91
2015-07-10    3.98
2015-07-13    3.95
2015-07-14    3.96
2015-07-15    3.95
2015-07-16    3.97
2015-07-20    3.97
2015-07-21    3.95
2015-07-22    3.97
2015-07-23    3.94
2015-07-24    3.96
2015-07-27    3.97
```

This is a Series.

In-Class Exercise 12: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
type(data.Open), type(data['Open'])
```

```
type(data.Open), type(data['Open'])
```

```
(pandas.core.series.Series, pandas.core.series.Series)
```

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- ✓ `pandas.Series`: One-dimensional ndarray with axis labels.
- ✓ `pandas.DataFrame`: Two-dimensional size-mutable, tabular data structure with labeled axes (rows and columns). Can be thought of as a dict-like container for Series objects.

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⇦ Slide 72

DataFrame[colname]:

Series corresponding to colname

(Example: `data['Open']`)

016

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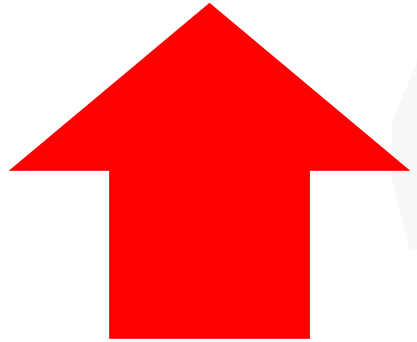
In-Class Exercise 13: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
type(data.index), data.index[0], type(data.index[0])
```

```
type(data.index), data.index[0], type(data.index[0])
```

```
(pandas.core.indexes.base.Index, '2015-07-01', str)
```



017

In-Class Exercise 14: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data=pd.read_csv('CC3.SI.csv', index_col=0, parse_dates=True)
data
```


```
data=pd.read_csv('CC3.SI.csv', index_col=0, parse_dates=True)
data
```


	Open	High	Low	Close	Adj Close	Volume
Date						
2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400
2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100
2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400
2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600
2015-07-07	3.96	4.00	3.96	3.98	3.536918	1724600
2015-07-08	3.96	4.02	3.96	3.98	3.536918	4134900
2015-07-09	3.91	3.98	3.90	3.97	3.528031	2363600
2015-07-10	3.98	4.00	3.93	3.94	3.501371	1961800
2015-07-13	3.95	3.97	3.94	3.96	3.519144	808000

In-Class Exercise 15: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
type(data.index), data.index[0]
```

```
In [15]:
type(data.index), data.index[0]
Out[15]:
(pandas.core.indexes.datetimes.DatetimeIndex,
Timestamp('2015-07-01 00:00:00'))
```

018 012

parse_dates=True

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	Open	High	Low	Close	Adj Close	Volume
Date						
2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400
2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100
2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400
2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600
2015-07-07	3.96	4.00	3.96	3.98	3.536918	1724600
2015-07-08	3.96	4.02	3.96	3.98	3.536918	4134900
2015-07-09	3.91	3.98	3.90	3.97	3.528031	2363600
2015-07-10	3.98	4.00	3.93	3.94	3.501371	1961800
2015-07-13	3.95	3.97	3.94	3.96	3.519144	808000

data.values (numpy.ndarray)

In-Class Exercise 16: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
type(data.values)
```

```
In [16]:
type(data.values)
Out[16]:
numpy.ndarray
```

019

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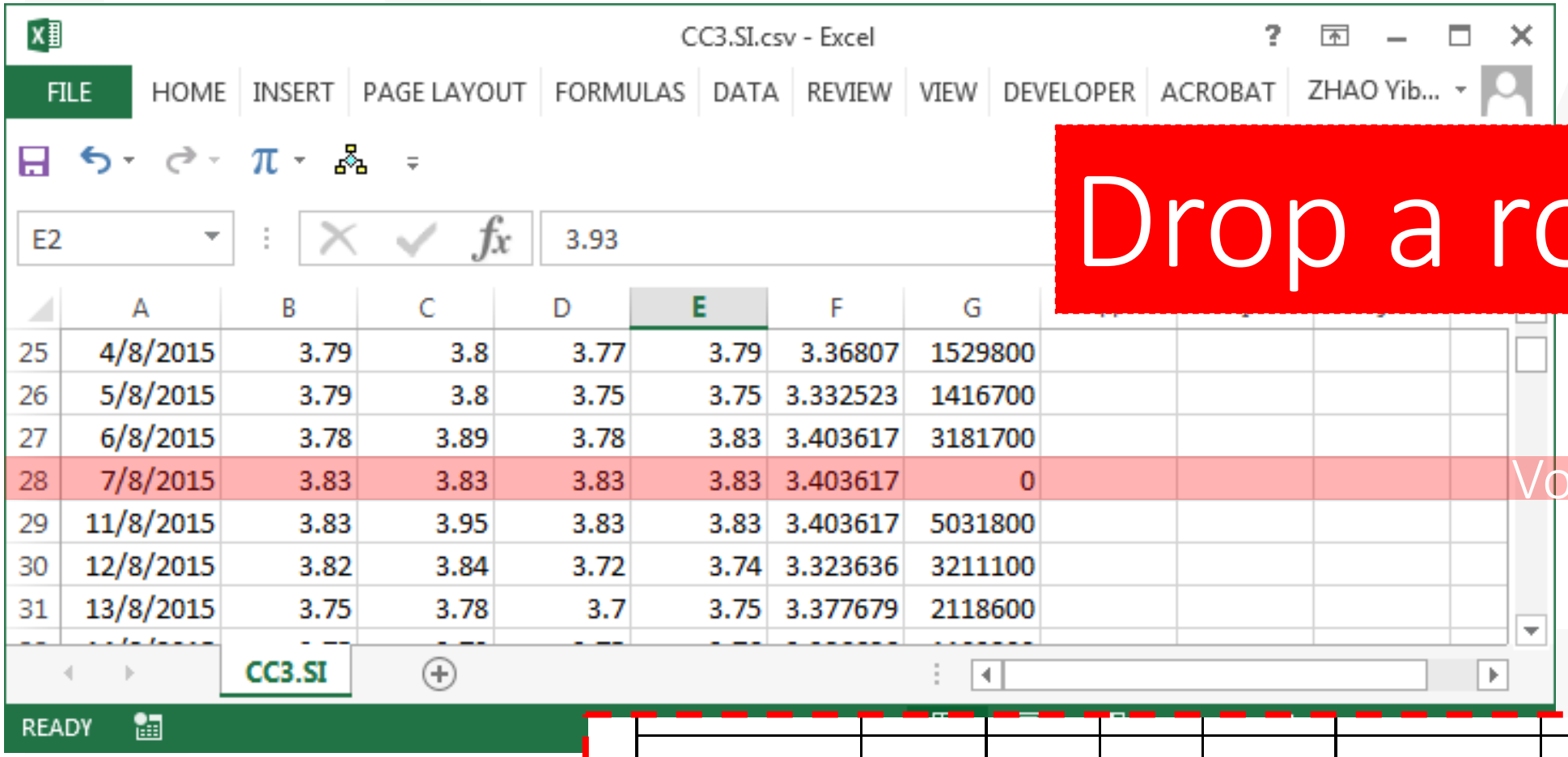
```
DataFrame.drop(labels, axis=0, level=None, inplace=False, errors='raise')
```

https://pandas.pydata.org/pandas-docs/stable/generated/pandas.DataFrame.drop.html

```
data.drop(data.index[data['Volume']==0],inplace=True)
```



	A	B	C	D	E	F	G
25	4/8/2015	3.79	3.8	3.77	3.79	3.36807	1529800
26	5/8/2015	3.79	3.8	3.75	3.75	3.332523	1416700
27	6/8/2015	3.78	3.89	3.78	3.83	3.403617	3181700
28	7/8/2015	3.83	3.83	3.83	3.83	3.403617	0
29	11/8/2015	3.83	3.95	3.83	3.83	3.403617	5031800
30	12/8/2015	3.82	3.84	3.72	3.74	3.323636	3211100
31	13/8/2015	3.75	3.78	3.7	3.75	3.377679	2118600

Drop a row.

Volume=0

020

2015-08-07	3.83	3.83	3.83	3.83	3.403617	0

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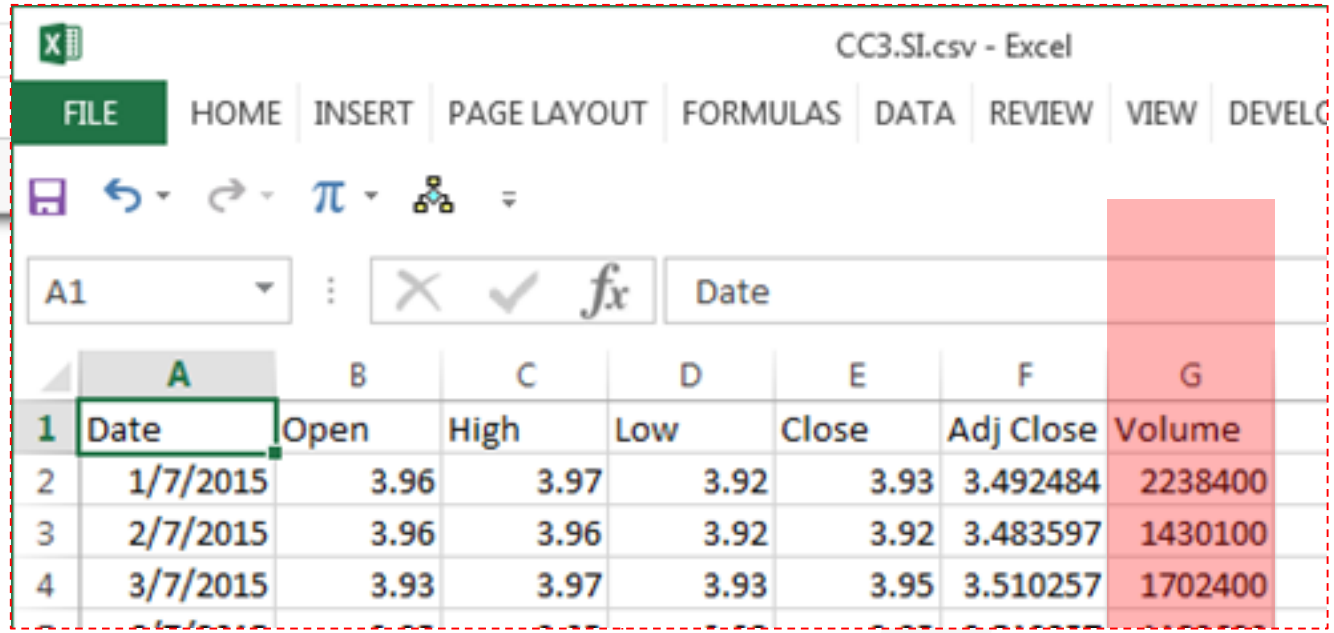
```
data.drop(data.index[data['Volume']==0],inplace=True)
```

In-Class Exercise 17: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data['Volume']
```

```
data['Volume']
```

```
Date
2015-07-01     2238400
2015-07-02     1430100
2015-07-03     1702400
2015-07-06     1183600
2015-07-07     1724600
2015-07-08     4134900
2015-07-09     2363600
2015-07-10     1961800
2015-07-13      808000
2015-07-14     1250100
2015-07-15      957300
2015-07-16     1621600
2015-07-20     2457000
2015-07-21     2794500
2015-07-22      761300
2015-07-23      765800
2015-07-24      671500
2015-07-27     1720900
```



	A	B	C	D	E	F	G
1	Date	Open	High	Low	Close	Adj Close	Volume
2	1/7/2015	3.96	3.97	3.92	3.93	3.492484	2238400
3	2/7/2015	3.96	3.96	3.92	3.92	3.483597	1430100
4	3/7/2015	3.93	3.97	3.93	3.95	3.510257	1702400

021

`data['Volume']` is a Series.

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```
data.drop(data.index[data['Volume']==0],inplace=True)
```

In-Class Exercise 19: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data['Volume']==0
```

```
data['Volume']==0
2015-07-15    False
2015-07-16    False
2015-07-20    False
2015-07-21    False
2015-07-22    False
2015-07-23    False
2015-07-24    False
2015-07-27    False
2015-07-28    False
2015-07-29    False
2015-07-30    False
2015-07-31    False
2015-08-03    False
2015-08-04    False
2015-08-05    False
2015-08-06    False
2015-08-07     True
2015-08-11    False
2015-08-12    False
2015-08-13    False
```

`data['Volume']` is a Series.

`data['Volume']==0` returns a Series of `True` and `False` with the same labels.

022

Comparison between a Series and a scalar results a Series.

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Boolean Indexing


```
>>> x=[1, 2, 3, 4, 5]
>>> x[[True,True,False,False,True]]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: list indices must be integers or slices, not list
```

Lists do not support Boolean indexing.

```
>>> import numpy as np
>>> y=np.array(x)
>>> y[[True,True,False,False,True]]
array([1, 2, 5])
```

Numpy ndarrays support Boolean indexing.

```
>>> import pandas as pd
>>> z=pd.Series(x)
>>> z[[True,True,False,False,True]]
0    1
1    2
4    5
dtype: int64
```

Serieses also support Boolean indexing.

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(continued)

```
>>> z[[True,True,False,False]]
Traceback (most recent call last):
  File "C:\Continuum\anaconda3\lib\site-packages\pandas\core\series.py", line 87
7, in _get_values
    return self._constructor(self._data.get_slice(indexer),
  File "C:\Continuum\
 4706, in get_slice
    return self.__cla
  File "C:\Continuum\
 312, in _slice
    return self.value
IndexError: boolean i
on is 5 but correspon

During handling of th

Traceback (most recen
  File "<stdin>", lin
  File "C:\Continuum\
0, in __getitem__
    return self._get_with(key)
  File "C:\Continuum\anaconda3\lib\site-packages\pandas\core\series.py", line 84
6, in _get_with
    return self._get_values(key)
  File "C:\Continuum\anaconda3\lib\site-packages\pandas\core\series.py", line 88
0, in _get_values
    return self._values[indexer]
IndexError: boolean index did not match indexed array along dimension 0; dimensi
on is 5 but corresponding boolean dimension is 4
```

IndexError: **boolean index** did not match indexed array along dimension 0; dimension is 5 but corresponding boolean dimension is 4

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```
data.drop(data.index[data['Volume']==0],inplace=True)
```

data.index

2015-08-07	3.83	3.83	3.83	3.83	3.403617	0

In-Class Exercise 20: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data.index[data['Volume']==0]
```

024

```
data.index[data['Volume']==0]
```

```
DatetimeIndex(['2015-08-07'], dtype='datetime64[ns]', name='Date', freq=None)
```

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data.drop(data.index[data['Volume']==0],inplace=True)

In-Class Exercise 21: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data.drop(data.index[data['Volume']==0],inplace=True)
```

```
data.drop(data.index[data['Volume']==0],inplace=True)
data
```

2015-08-06	3.78	3.89	3.78	3.83	3.403617	3181700
2015-08-11	3.83	3.95	3.83	3.83	3.403617	5031800
2015-08-12	3.82	3.84	3.72	3.74	3.323636	3211100
2015-08-13	3.75	3.78	3.70	3.75	3.377679	2118600
2015-08-14	3.75	3.79	3.75	3.76	3.386686	1103200
...	...	...	...	...	...	...
2017-05-26	2.72	2.72	2.69	2.70	2.700000	2767100
2017-05-29	2.70	2.71	2.68	2.71	2.710000	1995800
2017-05-30	2.71	2.72	2.68	2.71	2.710000	1707900
2017-05-31	2.71	2.74	2.70	2.70	2.700000	13187900
2017-06-01	2.73	2.75	2.72	2.73	2.730000	2969600
2017-06-02	2.73	2.74	2.72	2.73	2.730000	2102000

2015-08-07	3.83	3.83	3.83	3.83	3.403617	0

It's gone!

025

If using "`inplace=False`", we'll get a copy. `data` will remain unchanged.

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```
>>> import numpy as np
>>> import pandas as pd
>>> df=pd.DataFrame(np.arange(12).reshape(3,4),
...                 columns=list('ABCD')); df
   A  B   C   D
0  0  1   2   3
1  4  5   6   7
2  8  9  10  11
>>> df.drop([0, 2], axis=0)
   A  B  C  D
1  4  5  6  7
>>>
>>>
>>> df.drop(['B','C'], axis=1)
   A   D
0  0   3
1  4   7
2  8  11
```

(default value)

026

DataFrame.drop(labels, axis=0)

0/'index'

DataFrame.drop(labels, axis=1)

1/'columns'

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```
Series.rolling(window, min_periods=None, freq=None,
center=False, win_type=None, on=None, axis=0,
closed=None)
```

Provides rolling window calculations. (`.sum()`, `.mean()`, …)

```
data['15d']= np.round(data['Adj Close'].rolling(window=15).mean(),3)
data['50d']= np.round(data['Adj Close'].rolling(window=50).mean(),3)
```

We cannot use the "dot notation" to add a column to a DataFrame.

029

```
data['15d']= np.round(data['Adj Close'].rolling(15).mean(),3)
data['50d']= np.round(data['Adj Close'].rolling(50).mean(),3)
```

- ✓ Series.rolling ⇨ Rolling Object
- ✓ RollingObject.mean() ⇨ Series

027 028

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In-Class Exercise 22: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
# Series.rolling(window, min_periods=None, freq=None, center=False,
#                                win_type=None, on=None, axis=0, closed=None)
data['15d']= np.round(data['Adj Close'].rolling(15).mean(),3)
data['50d']= np.round(data['Adj Close'].rolling(50).mean(),3)
data
```

029


```
# Series.rolling(window, min_periods=None, freq=None, center=False,
#                                win_type=None, on=None, axis=0, closed=None)
data['15d']= np.round(data['Adj Close'].rolling(15).mean(),3)
data['50d']= np.round(data['Adj Close'].rolling(50).mean(),3)
data
```


Date	Open	High	Low	Close	Adj Close	Volume	15d	50d
2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400	NaN	NaN
2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100	NaN	NaN
2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400	NaN	NaN
2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600	NaN	NaN
2015-07-07	3.96	4.00	3.96	3.98	3.536918	1724600	NaN	NaN
2015-07-08	3.96	4.02	3.96	3.98	3.536918	4134900	NaN	NaN
2015-07-09	3.91	3.98	3.90	3.97	3.528031	2363600	NaN	NaN
2015-07-10	3.98	4.00	3.93	3.94	3.501371	1961800	NaN	NaN
2015-07-13	3.95	3.97	3.94	3.96	3.519144	808000	NaN	NaN

Two columns were added.

dict-like

(Dr. Z: How to add a new item in a dictionary?)

NaN?

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Of Quantitative Finance

Date	Open	High	Low	Close	Adj Close	Volume	15d	50d	
2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400	NaN	NaN	1
2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100	NaN	NaN	2
2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400	NaN	NaN	3
2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600	NaN	NaN	4
2015-07-07	3.96	4.00	3.96	3.98	3.536918	1724600	NaN	NaN	5
2015-07-08	3.96	4.02	3.96	3.98	3.536918	4134900	NaN	NaN	6
2015-07-09	3.91	3.98	3.90	3.97	3.528031	2363600	NaN	NaN	7
2015-07-10	3.98	4.00	3.93	3.94	3.501371	1961800	NaN	NaN	8
2015-07-13	3.95	3.97	3.94	3.96	3.519144	808000	NaN	NaN	9
2015-07-14	3.96	4.00	3.96	3.98	3.536918	1250100	NaN	NaN	10
2015-07-15	3.95	3.98	3.95	3.96	3.519144	957300	NaN	NaN	11
2015-07-16	3.97	3.98	3.95	3.97	3.528031	1621600	NaN	NaN	12
2015-07-20	3.97	3.98	3.91	3.93	3.492484	2457000	NaN	NaN	13
2015-07-21	3.95	3.98	3.94	3.95	3.510257	2794500	NaN	NaN	14
2015-07-22	3.97	3.97	3.93	3.93	3.492484	761300	3.513	NaN	15
2015-07-23	3.94	3.97	3.94	3.94	3.501371	765800	3.514	NaN	

030

```
.rolling(15).mean()
```

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In-Class Exercise 23: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data['Adj Close'].rolling(15).mean().round(3)
```


```
data['Adj Close'].rolling(15).mean().round(3)
```


```
Date
2015-07-01       NaN
2015-07-02       NaN
2015-07-03       NaN
2015-07-06       NaN
2015-07-07       NaN
2015-07-08       NaN
2015-07-09       NaN
2015-07-10       NaN
2015-07-13       NaN
2015-07-14       NaN
2015-07-15       NaN
2015-07-16       NaN
2015-07-20       NaN
2015-07-21       NaN
2015-07-22     3.513
2015-07-23     3.514
2015-07-24     3.516
2015-07-27     3.517
```

031

```
np.round(Series, 3)
        ⇕
Series.round(3)
```

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In-Class Exercise 24: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
x=data['15d']-data['50d']
type(x), x
```

x=data['15d']-data['50d']
type(x), x

```
(pandas.core.series.Series, Date
 2015-07-01      NaN
 2015-07-02      NaN
 2015-07-03      NaN
 2015-07-06      NaN
 2015-07-07      NaN
 2015-07-08      NaN
 2015-07-09      NaN
 2015-07-10      NaN
 2015-07-13      NaN
 2015-07-14      NaN
 2015-07-15      NaN
 2015-07-16      NaN
 2015-07-20      NaN
 2015-07-21      NaN
 2015-07-22      NaN
 2015-07-23      NaN
 2015-07-24      NaN
 2015-07-27      NaN
```

032

Subtraction of Two Series (having the same labels)

(Dr. Z: What if they have different labels?)

X: pandas.core.series.Series

```
>>> import numpy as np
>>> np.nan-1
nan
>>> np.nan-np.nan
nan
```

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Boolean Indexing

Assignment

In-Class Exercise 25: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
x[x>0]=1
x[x<=0]=0
x
```

```
x[x>0]=1
x[x<=0]=0
x
```

```
Date
2015-07-01    NaN
2015-07-02    NaN
2015-07-03    NaN
2015-07-06    NaN
2015-07-07    NaN
2015-07-08    NaN
2015-07-09    NaN
2015-07-10    NaN
2015-07-13    NaN
2015-07-14    NaN
2015-07-15    NaN
2015-07-16    NaN
2015-07-20    NaN
2015-07-21    NaN
2015-07-22    NaN
2015-07-23    NaN
2015-07-24    NaN
2015-07-27    NaN
```

```
len(x[x>0])
```

```
143
```

```
x[x>0]=range(1,144)
x[x>0]
```

```
Date
2015-10-23      1.0
2015-10-26      2.0
2015-10-27      3.0
2015-10-28      4.0
2015-10-29      5.0
2015-10-30      6.0
```

033

```
x[x>0]=[1,2]
```

```
---------------------------------------------------------------------------
ValueError
<ipython-input-23-de15ae361d6b>
----> 1 x[x>0]=[1,2]
```

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Series.diff(periods=1, axis=0)

https://pandas.pydata.org/pandas-docs/stable/generated/pandas.Series.diff.html

In-Class Exercise 26: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

034

```
y=x.diff()
print(len(x), len(y))
y
```

```
506 506

Date
2015-07-01    NaN
2015-07-02    NaN
2015-07-03    NaN
2015-07-06    NaN
2015-07-07    NaN
```

Series.diff returns a Series of the same length (and same labels).

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In-Class Exercise 27: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
y[(y>0) | (y<0)]
```


```
y[(y>0) | (y<0)]
```


- Boolean Indexing
- Bitwise Logical OR: |

NEW

```
Date
2015-10-22     1.0
2015-12-22    -1.0
2015-12-31     1.0
2016-01-08    -1.0
2016-02-23     1.0
2016-03-02    -1.0
2016-05-03     1.0
2016-08-31    -1.0
2017-01-18     1.0
2017-02-14    -1.0
2017-04-04     1.0
2017-04-26    -1.0
2017-07-03     1.0
2017-07-07    -1.0
dtype: float64
```

Operator	Description
lambda	Lambda expression
if – else	Conditional expression
or	Boolean OR
and	Boolean AND
not x	Boolean NOT
in, not in, is, is not, <, <=, >, >=, !=, ==	Comparisons, including membership tests and identity tests
|	Bitwise OR
^	Bitwise XOR
&	Bitwise AND
<<, >>	Shifts
+, -	Addition and subtraction
*, @, /, //, %	Multiplication, matrix multiplication division, remainder [5]
+x,	Positive, negative, bitwise NOT
**	
awai	
x[index], x[index:index], x(arguments...), x.attribute	Subscription, slicing, call, attribute reference
(expressions...), [expressions...], {key: value...}, {expressions...}	Binding or tuple display, list display, dictionary display, set display

035

036

???Bitwise OR ⇔ Element-wise OR???

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Python: `or` (not element-wise)

`2 or 3:`

These are the Boolean operations, ordered by ascending priority:

Operation	Result	Notes
`x or y`	if *x* is false, then *y*, else *x*	(1)
`x and y`	if *x* is false, then *x*, else *y*	(2)
`not x`	if *x* is false, then `True`, else `False`	(3)

Truth Table (2)

x	y	x and y	x or y
True	True	True	True
True	False	False	True
False	True	False	True
False	False	False	False

```
>>> 2 or 3
2
>>> [2, 2] or [3, 3]
[2, 2]
>>> [0, 0] or [3, 3]
[0, 0]
>>> [] or [3, 3]
[3, 3]
```

037

New!

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Python: | (bitwise OR)

(for integers only)

(not element-wise)

```
1: 00000001
2: 00000010
1|2: 00000011
1&2: 00000000
```

```
>>> 1.1 | 2.2
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unsupported operand type(s) for |: 'float' and 'float'
>>> 1|2
3
>>> 1&2
0
>>> [1, 1] | [2, 2]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unsupported operand type(s) for |: 'list' and 'list'
>>> [1, 1] & [2, 2]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unsupported operand type(s) for &: 'list' and 'list'
```

Do Not Test

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Numpy logical_or

https://docs.scipy.org/doc/numpy-1.15.0/reference/generated/numpy.logical_or.html

```
>>> 2 or 3
2
>>> [2, 2] or [3, 3]
[2, 2]
>>> [0, 0] or [3, 3]
[0, 0]
>>> [] or [3, 3]
[3, 3]
>>> 2 or [3, 3]
2
```

Element-wise OR

039

```
>>> import numpy as np
>>> np.logical_or(2,3)
True
>>> np.logical_or([2,2],[3,3])
array([ True,  True])
>>> np.logical_or([0,0],[3,3])
array([ True,  True])
>>> np.logical_or([],[3,3])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: operands could not be broadcast together with shapes (0,) (2,)
>>> np.logical_or([True,True,False],[True,False,False])
array([ True,  True, False])
>>> np.logical_or(True,[True,False,False])
array([ True,  True,  True])
```

ndarray has no OR

```
>>> np.array([2,2]) or np.array([3,3])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: The truth value of an array with more than one element is ambiguous.
 Use a.any() or a.all()
```

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Numpy | (bitwise OR)

(element-wise)

```
0: 00000000
1: 00000001
2: 00000010
3: 00000011
```

```
>>> import numpy as np
>>> x=np.array([0, 1, 2])
>>> y=np.array([1, 2, 3])
>>> x|y
array([1, 3, 3], dtype=int32)
>>> x=np.array([True, True, False])
>>> y=np.array([True, False, False])
>>> x|y
array([ True,  True, False])
>>> int(True)
1
>>> int(False)
0
```

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It is a common practice to use the Bitwise OR operator (|) on Numpy Logical ndarrays for the "Element-Wise OR" operation on logical arrays.

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In-Class Exercise 28: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
idxSell=y.index[y<0]
idxSell
```

```
idxSell=y.index[y<0]
idxSell
```

```
DatetimeIndex(['2015-12-22', '2016-01-08', '2016-03-02', '2016-08-31',
               '2017-02-14', '2017-04-26', '2017-07-07'],
              dtype='datetime64[ns]', name='Date', freq=None)
```

- ✓ y is a Series
- ✓ y.index is DatetimeIndex type
- ✓ Boolean Indexing

In-Class Exercise 29: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
idxBuy=y.index[y>0]
idxBuy
```

```
idxBuy=y.index[y>0]
idxBuy
```

```
DatetimeIndex(['2015-10-22', '2015-12-31', '2016-02-23', '2016-05-03',
               '2017-01-18', '2017-04-04', '2017-07-03'],
              dtype='datetime64[ns]', name='Date', freq=None)
```

- ✓ idxBuy
- ✓ idxSell

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In-Class Exercise 30: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data['crossSell']=np.nan
data
```

	Open	High	Low	Close	Adj Close	Volume	15d	50d	crossSell
Date									
2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400	NaN	NaN	NaN
2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100	NaN	NaN	NaN
2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400	NaN	NaN	NaN
2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600	NaN	NaN	NaN
2015-07-07	3.96	4.00	3.96	3.98	3.536				
2015-07-08	3.96	4.02	3.96	3.98	3.536				
2015-07-09	3.91	3.98	3.90	3.97	3.528031	2363600	NaN	NaN	NaN
2015-07-10	3.98	4.00	3.93	3.94	3.501371	1961800	NaN	NaN	NaN
2015-07-13	3.95	3.97	3.94	3.96	3.519144	808000	NaN	NaN	NaN

```
'2015-12-22', '2016-01-08', '2016-03-02', '2016-08-31',
'2017-02-14', '2017-04-26', '2017-07-07'],
```

✓ np.nan

Another column is created.

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In-Class Exercise 31: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data.loc[idxSell,'crossSell']=data['Adj Close'][idxSell]
data
```

✓ Chained Index

- .loc Indexing
- Assignment

```
data.loc[idxSell,'crossSell']=data['Adj Close'][idxSell]
data
```

Date	Open	High	Low	Close	Adj Close	Volume	15d	50d	crossSell
2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400	NaN	NaN	NaN
2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100	NaN	NaN	NaN
2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400	NaN	NaN	NaN
2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600	NaN	NaN	NaN
2015-07-07	3.96	4.00	3.96	3.98	3.536918	1724600	NaN	NaN	NaN
2015-07-08	3.96	4.02	3.96	3.98	3.536				
2015-07-09	3.91	3.98	3.90	3.9					
2015-07-10	3.98	4.00	3.93	3.94	3.501		NaN	NaN	NaN
2015-07-13	3.95	3.97	3.94	3.96	3.519144	808000	NaN	NaN	NaN

(Dr. Z: Later, we'll discuss a commonly seen problem for beginners, which is called "chained assignment".)

```
'2015-12-22', '2016-01-08', '2016-03-02', '2016-08-31',
'2017-02-14', '2017-04-26', '2017-07-07'],
```


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In-Class Exercise 32: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
data['crossBuy']=np.nan
data.loc[idxBuy,'crossBuy']=data['Adj Close'][idxBuy]
data
```

Similarly,

'crossBuy'

```
data['crossBuy']=np.nan
data.loc[idxBuy,'crossBuy']=data['Adj Close'][idxBuy]
data
```

Date	Open	High	Low	Close	Adj Close	Volume	15d	50d	crossSell	crossBuy
2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400	NaN	NaN	NaN	NaN
2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100	NaN	NaN	NaN	NaN
2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400	NaN	NaN	NaN	NaN
2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600	NaN	NaN	NaN	NaN
2015-07-07	3.96	4.00	3.96	3.98	3.536918	1724600	NaN	NaN	NaN	NaN
2015-07-08	3.96	4.02	3.96	3.98	3.536918	4134900	NaN	NaN	NaN	NaN
2015-07-09	3.91	3.98	3.90	3.97	3.528031	2363600	NaN	NaN	NaN	NaN
2015-07-10	3.98	4.00	3.93	3.94	3.501371	1961800	NaN	NaN	NaN	NaN
2015-07-13	3.95	3.97	3.94	3.96	3.519144	808000	NaN	NaN	NaN	NaN

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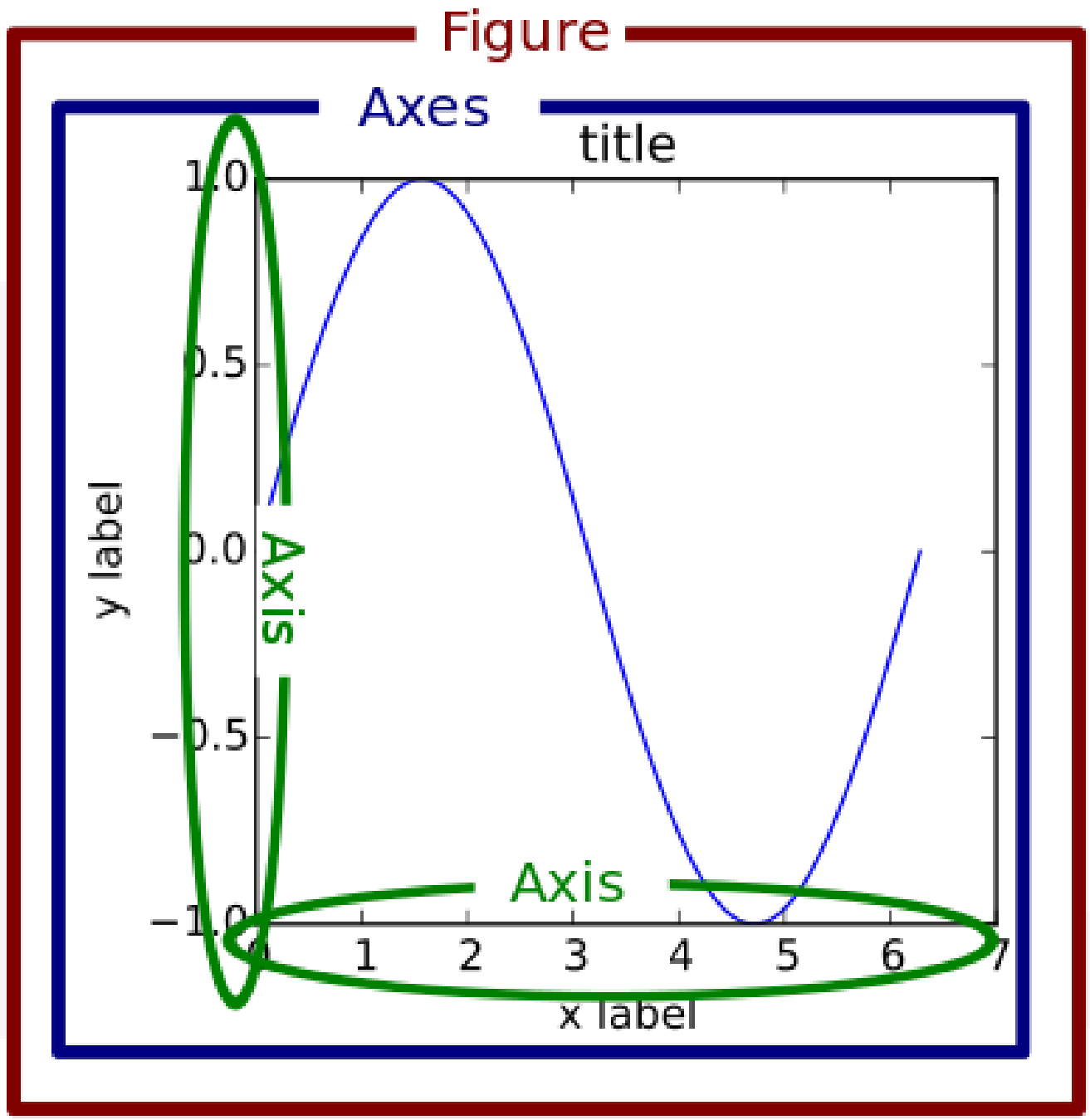
✓ Data Manipulation

⇨ Visualization

What is …

042

- ✓ Figure
- ✓ Axes
- ✓ Axis



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fig, ax = plt.subplots()

https://matplotlib.org/api/_as_gen/matplotlib.pyplot.subplots.html

matplotlib.pyplot.subplots

```
matplotlib.pyplot.subplots(nrows=1, ncols=1, sharex=False, sharey=False,
squeeze=True, subplot_kw=None, gridspec_kw=None, **fig_kw)        [source]
```

Create a figure and a set of subplots

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```
nrows=2, ncols=2
⇨ Numpy ndarray of Axes objects
ax[0, 0] or ax[0][0]
ax[0, 1] or ax[0][1]
ax[1, 0] or ax[1][0]
ax[1, 1] or ax[1][1]
```

✓ Figure: fig

✓ Axes: ax

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```
python

(base) C:\Users\ybzhao>python
Python 3.6.4 |Anaconda custom (64-bit)| (default, Jan 16 2018, 10:22:32) [MSC v.
1900 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> import matplotlib.pyplot as plt
>>> fig, ax = plt.subplots(2,2)
>>> fig
<matplotlib.figure.Figure object at 0x000000000002B0F2B0>
>>> ax
array([[<matplotlib.axes._subplots.AxesSubplot object at 0x0000000005C8B8D0>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000005CF16A0>],
       [<matplotlib.axes._subplots.AxesSubplot object at 0x0000000005D2E6A0>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x00000000061566A0>]],
      dtype=object)
>>>
```

- ✓ Figure: fig
- ✓ Axes: ax

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```
fig = plt.figure()
```

Alternatively, …

matplotlib.pyplot.figure

matplotlib.pyplot.figure(*num=None, figsize=None, dpi=None, facecolor=None, edgecolor=None, frameon=True, FigureClass=<class 'matplotlib.figure.Figure'>, clear=False, **kwargs*)

[source]

Creates a new figure.

and make it the current figure.

✓ Figure: fig

✓ Axes: ax

044

```
ax=plt.axes()
```

matplotlib.pyplot.axes

matplotlib.pyplot.axes(*arg=None, **kwargs*) [source]

Add an axes to the current figure and make it the current axes.

✓ Current Figure

✓ Current Axes

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Confusing Matplotlib

https://realpython.com/python-matplotlib-guide/

045

Almost all functions from pyplot, such as plt.plot(), are implicitly either referring to an existing current Figure and current Axes, or creating them anew if none exist.

Therefore, everything in matplotlib is organized in a hierarchy. At the top of the hierarchy is the matplotlib "state-machine environment" which is provided by the `matplotlib.pyplot` module.

At this level, simple functions are used to add plot elements (lines, images, text, etc.) to the current axes in the current figure.

At this level, simple functions are used to add plot elements (lines, images, text, etc.) to **the current axes in the current figure**.

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For a complicated plot, it will be **clearer** and **more convenient**, if we

046

- ✓ Create figures with names

```
e.g. fig1=plt.figure()
```

- ✓ Add axes with names to a specific figure

```
e.g. ax1=fig1.add_axes([0.1, 0.1, 0.8, 0.8])
  or ax1=fig1.add_subplot(2, 2, 3)
```

[left, bottom, width, height]

nrows, ncols, index

1	2
3	4

- ✓ Plot on axes

```
plt.plot ⇨ ax1.plot
```

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https://matplotlib.org/api/_as_gen/matplotlib.pyplot.subplot2grid.html

matplotlib.pyplot.subplot2grid

Do Not Test

```
matplotlib.pyplot.subplot2grid(shape, loc, rowspan=1, colspan=1, fig=None, **kwargs)
```

Create an axis at specific location inside a regular grid.

shape : sequence of 2 ints

Shape of grid in which to place axis. First entry is number of rows, second entry is number of columns.

loc : sequence of 2 ints

Location to place axis within grid. First entry is row number, second entry is column number.

rowspan : int

Number of rows for the axis to span to the right.

colspan : int

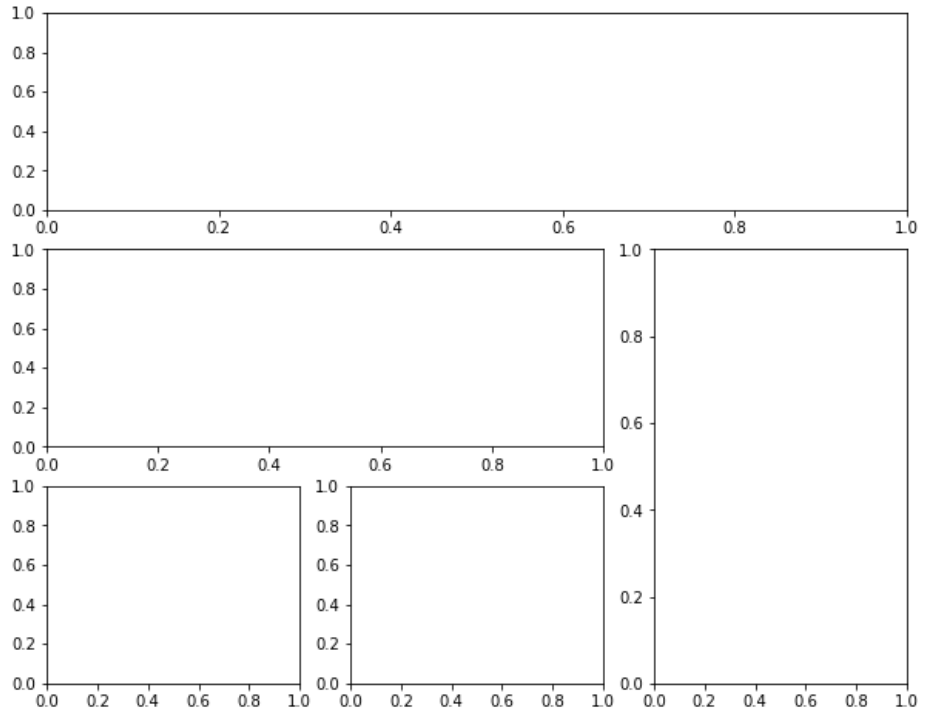
Number of columns for the axis to span downwards.

fig : `Figure`, optional

Figure to place axis in. Defaults to current figure.

047

```
f1=plt.figure(figsize=[10,8])
ax1=plt.subplot2grid((3,3),(0,0),colspan=3,fig=f1)
ax2=plt.subplot2grid((3,3),(1,0),colspan=2,fig=f1)
ax3=plt.subplot2grid((3,3),(1,2),rowspan=2,fig=f1)
ax4=plt.subplot2grid((3,3),(2,0),fig=f1)
ax5=plt.subplot2grid((3,3),(2,1),fig=f1)
```



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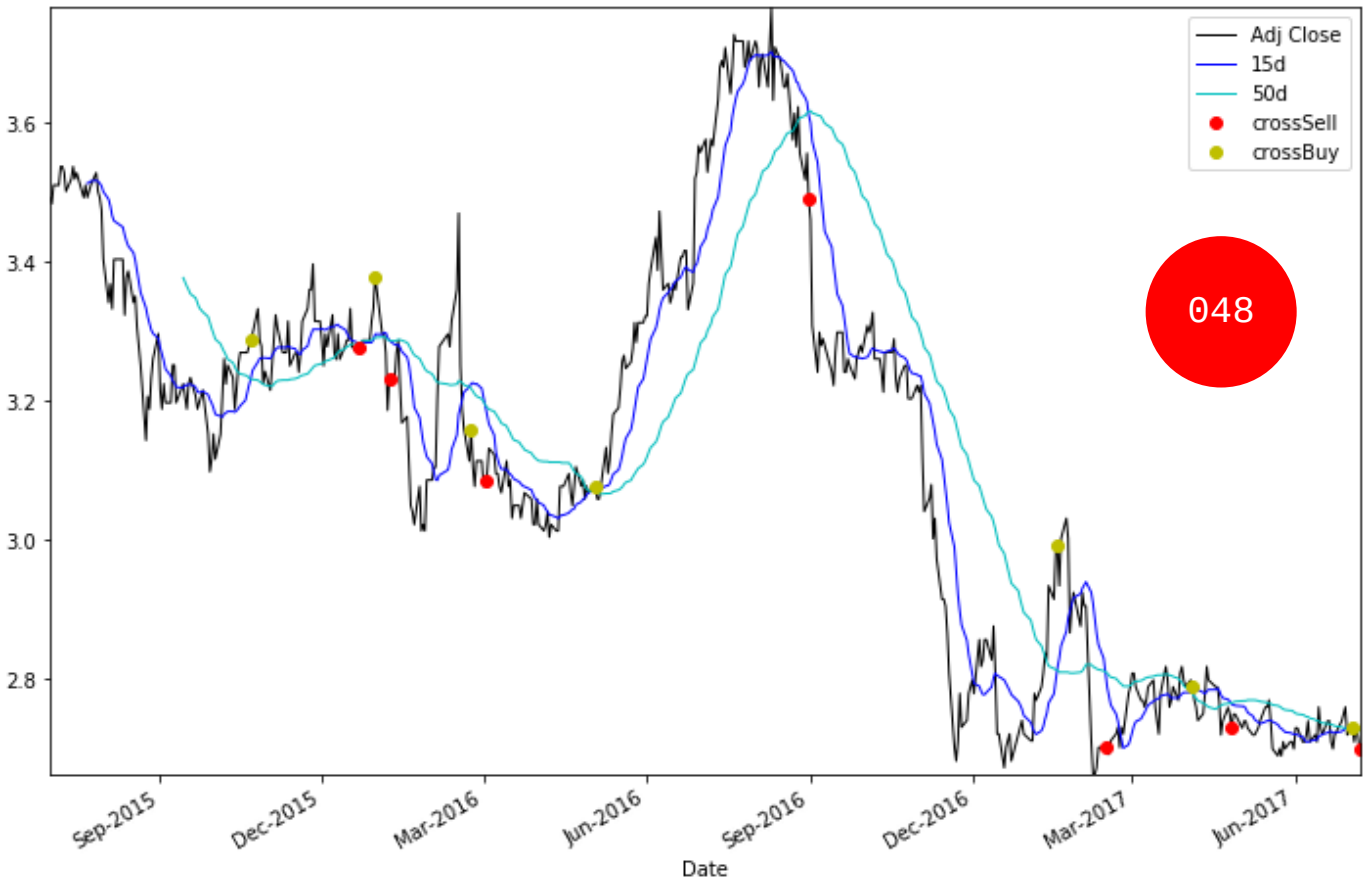
pandas.DataFrame.plot

```
DataFrame.plot(x=None,
y=None, kind='line',
ax=None, subplots=False,
sharex=None, sharey=False,
layout=None, figsize=None,
use_index=True,
title=None, grid=None,
legend=True, style=None,
logx=False, logy=False,
loglog=False, xticks=None,
yticks=None, xlim=None,
ylim=None, rot=None,
fontsize=None,
colormap=None,
table=False, yerr=None,
xerr=None,
secondary_y=False,
sort_columns=False,
**kwds)
```

In-Class Exercise 33: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
fig, ax=plt.subplots()
data[['Adj Close', '15d', '50d','crossSell','crossBuy']].plot(
        ax=ax,
        figsize=[12, 8],
        style=['k-','b-','c-','ro','yo'],
        linewidth=1)
plt.autoscale(enable=True, axis='x', tight=True)
plt.autoscale(enable=True, axis='y', tight=True)
ax.xaxis.set_major_formatter(mdates.DateFormatter('%b-%Y'))
```

? ax=ax



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https://matplotlib.org/api/_as_gen/matplotlib.axes.Axes.plot.html

Format Strings

A format string consists of a part for color, marker and line:

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

Each of them is optional. If not provided, the value from the style cycle is used. Exception: If `line` is given, but no `marker`, the data will be a line without markers.

Colors

The following color abbreviations are supported:

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

If the color is the only part of the format string, you can additionally use any `matplotlib.colors` spec, e.g. full names (`'green'`) or hex strings (`'#008000'`).

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

Line Styles

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

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Colors

The following color abbreviations are supported:

character	color
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'y'	yellow
'k'	black
'w'	white

If the color is the only part of the format string, you can additionally use any `matplotlib.colors` spec, e.g. full names (`'green'`) or hex strings (`'#008000'`).

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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

050

Line Styles

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

Example format strings:

```
'b'    # blue markers with default shape
'ro'   # red circles
'g-'   # green solid line
'--'   # dashed line with default color
'k^:'  # black triangle_up markers connected by a dotted line
```

051

In-Class Exercise 34: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
type(data[['Adj Close', '15d', '50d','crossSell','crossBuy']])
```

052

```
type(data[['Adj Close', '15d', '50d','crossSell','crossBuy']])
```

```
pandas.core.frame.DataFrame
```

	Open	High	Low	Close	Adj Close	Volume	15d	50d	crossSell	crossBuy
Date										
2015-07-01	3.96	3.97	3.92	3.93	3.492484	2238400	NaN	NaN	NaN	NaN
2015-07-02	3.96	3.96	3.92	3.92	3.483597	1430100	NaN	NaN	NaN	NaN
2015-07-03	3.93	3.97	3.93	3.95	3.510257	1702400	NaN	NaN	NaN	NaN
2015-07-06	3.95	3.95	3.92	3.95	3.510257	1183600	NaN	NaN	NaN	NaN
2015-07-07	3.96	4.00	3.96	3.98	3.536918	1724600	NaN	NaN	NaN	NaN
2015-07-08	3.96	4.02	3.96	3.98	3.536918	4134900	NaN	NaN	NaN	NaN
2015-07-09	3.91	3.98	3.90	3.97	3.528031	2363600	NaN	NaN	NaN	NaN
2015-07-10	3.98	4.00	3.93	3.94	3.501371	1961800	NaN	NaN	NaN	NaN
2015-07-13	3.95	3.97	3.94	3.96	3.519144	808000	NaN	NaN	NaN	NaN

DataFrame

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⇨ Slide 31

`DataFrame[list_colnames]`:

DataFrame corresponding to `list_colnames`.

(Example: `data[['Adj Close', '15d']]`)

(Dr. Z: It is also known as “fancy indexing”.)

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https://matplotlib.org/devdocs/api/_as_gen/matplotlib.pyplot.show.html

matplotlib.pyplot.show

matplotlib.pyplot.show(*args, **kw)

Display a figure. When running in ipython with its pylab mode, display all figures and return to the ipython prompt.

In non-interactive mode, display all figures and block until the figures have been closed; in interactive mode it has no effect unless figures were created prior to a change from non-interactive to interactive mode (not recommended). In that case it displays the figures but does not block.

A single experimental keyword argument, *block*, may be set to True or False to override the blocking behavior described above.

%matplotlib inline

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That's all for the explanation of the sample Python code.

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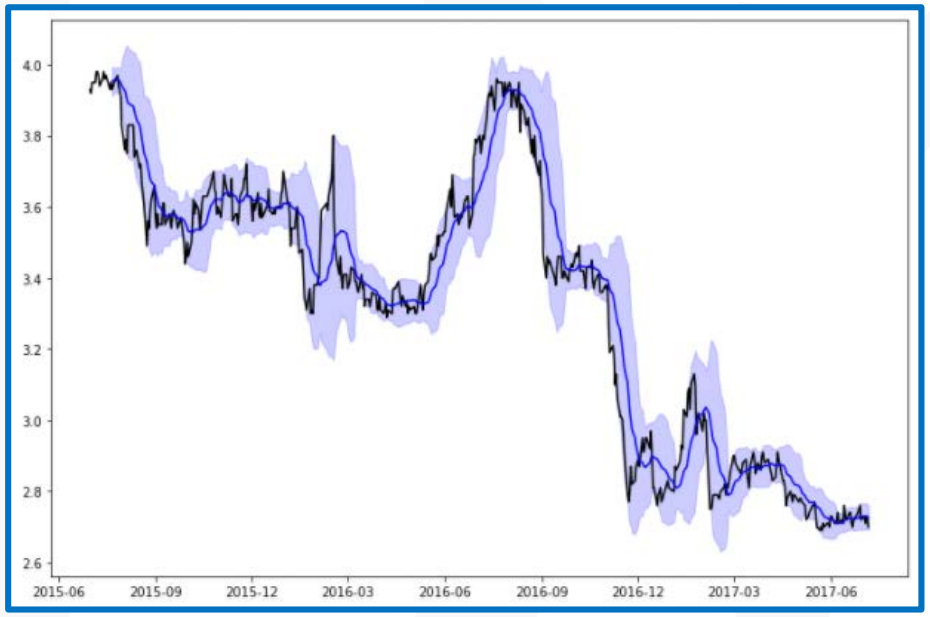
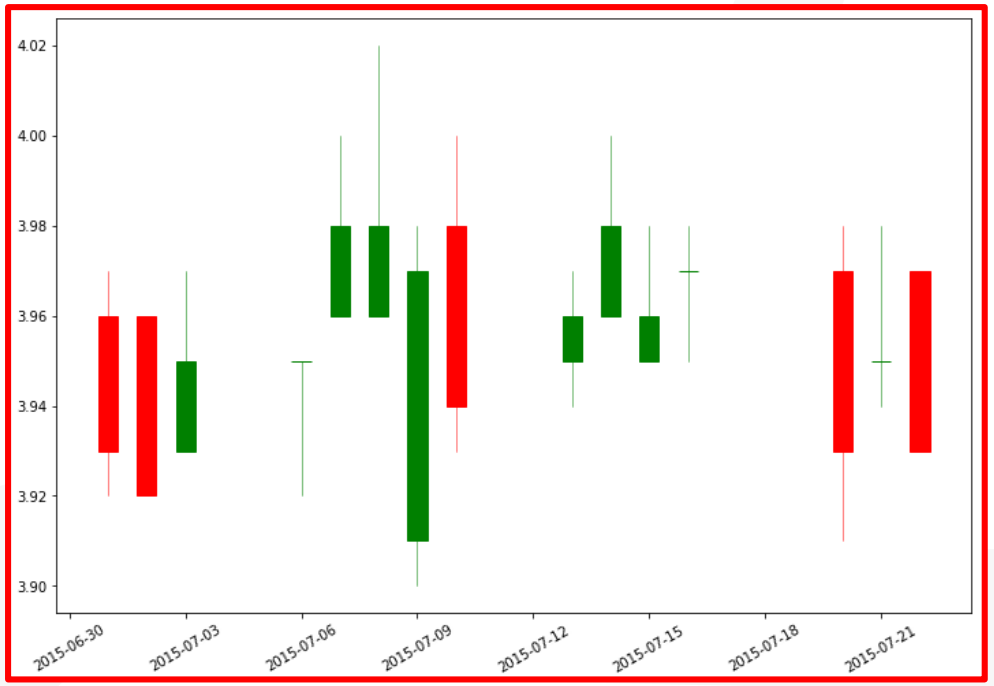
Next, …



`fill_between`

`candlestick_ohlc`



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https://matplotlib.org/api/_as_gen/matplotlib.pyplot.fill_between.html

x, y1, y2=0

**kwargs

home | examples | tutorials | pyplot | docs » The Matplotlib API » matplotlib.pyplot

plt

matplotlib.pyplot.fill_between

matplotlib.pyplot.fill_between(x, y1, y2=0, where=None, interpolate=False, step=None, hold=None, data=None, **kwargs)

Make filled polygons between two curves.

Create a PolyCollection filling the regions between y1 and y2 where where==True

053 054

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https://matplotlib.org/api/_as_gen/matplotlib.axes.Axes.fill_between.html

Another `fill_between`.

matplotlib
Version 2.1.2

home | examples | tutorials | pyplot | docs » The Matplotlib API » `Axes` class »

053

054

matplotlib.axes.Axes.fill_between

`Axes.fill_between`(*x*, *y1*, *y2=0*, *where=None*, *interpolate=False*, *step=None*, *, *data=None*, ***kwargs*)

Make filled polygons between two curves.

Create a `PolyCollection` filling the regions between *y1* and *y2* where `where==True`

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Parameters:

x : array

An N-length array of the x data

y1 : array

An N-length array (or scalar) of the y data

y2 : array

An N-length array (or scalar) of the y data

where : array, optional

If `None`, default to fill between everywhere. If not `None`, it is an N-length numpy boolean array and the fill will only happen over the regions where `where==True`.

interpolate : bool, optional

If `True`, interpolate between the two lines to find the precise point of intersection. Otherwise, the start and end points of the filled region will only occur on explicit values in the *x* array.

step : {'pre', 'post', 'mid'}, optional

If not None, fill with step logic.

List also can! ☺

y1 can also be a scalar! ☺

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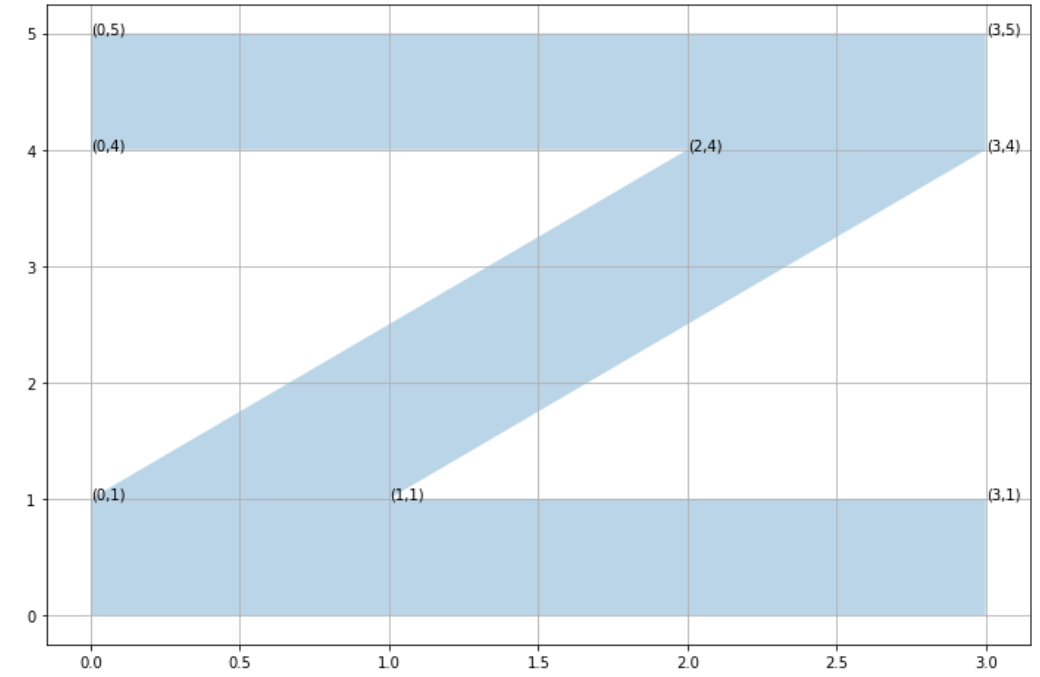
Let's play play.

Dr. Z: Are you confused by the xy in the code.

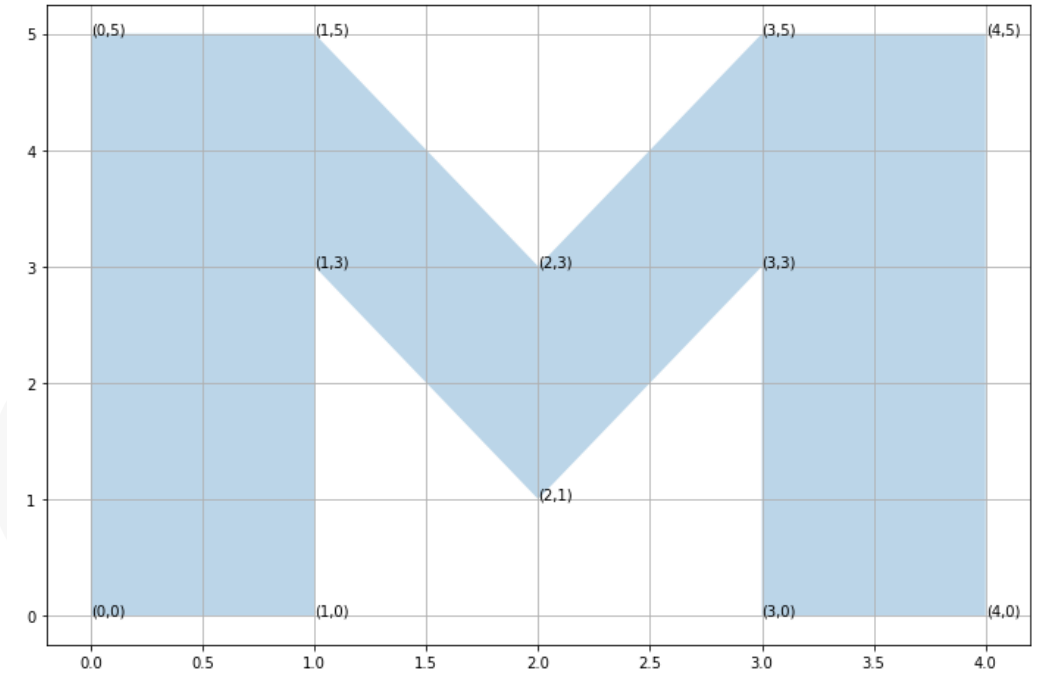
055

- ✓ list
- ✓ tuple
- ✓ np.array
- ✓ pd.Series

```
#fill_between
x=[0,2,0,0,3,3,1,3]
y1=[1,4,4,5,5,4,1,1]
plt.fill_between(x,y1,alpha=0.3)
plt.grid(which='major')
for xy in zip(x,y1):
    plt.annotate('(%s,%s)' % (xy), xy=xy)
```




```
#fill_between
x=[0,1,2,3,4,4,3,3,2,1,1,0]
y1=[5,5,3,5,5,0,0,3,1,3,0,0]
plt.fill_between(x,y1,alpha=0.3)
plt.grid(which='major')
for xy in zip(x,y1):
    plt.annotate('(%s,%s)' % (xy), xy=xy)
```



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**kwargs

Notes

Additional Keyword args passed on to the `PolyCollection`.

kwargs control the `Polygon` properties:

Property	Description
agg_filter	a filter function, which takes a (m, n, 3) float array and a dpi value, and returns a (m, n, 3) array
alpha	float or None
animated	bool
antialiased or antialiaseds	Boolean or sequence of booleans
array	ndarray
clim	a length 2 sequence of floats
clip_box	a Bbox instance
clip_on	bool
clip_path	[(Path, Transform) | Patch | None]
cmap	a colormap or registered colormap name
color	matplotlib color arg or sequence of rgba tuples
contains	a callable function
edgecolor or edgecolors	matplotlib color spec or sequence of specs
facecolor or facecolors	matplotlib color spec or sequence of specs
figure	
gid	
hatch	
label	
linestyle or dashes	
linewidth or linewidth	
norm	
offset_position	
offsets	
path_effects	
picker	
pickradius	float distance in points
rasterized	bool or None
sketch_params	(scale: float, length: float, randomness: float)
snap	bool or None
transform	Transform
url	a url string
urls	List[str] or None
visible	bool
zorder	float

alpha

color

x | y1 | y2

They are Serieses.

```
# fill_between
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
plt.rcParams["figure.figsize"]=[12,8] # (optional)

data=pd.read_csv('CC3.SI.csv',index_col=0,parse_dates=True)
data.drop(data.index[data['Volume']==0],inplace=True)

ma=data['Adj Close'].rolling(15).mean()
mstd=data['Adj Close'].rolling(15).std()

plt.plot(data.index, data['Adj Close'], 'k')
plt.plot(ma.index, ma, 'b')
plt.fill_between(mstd.index, ma-2*mstd, ma+2*mstd,
                 color='b', alpha=0.2)

plt.show()
```

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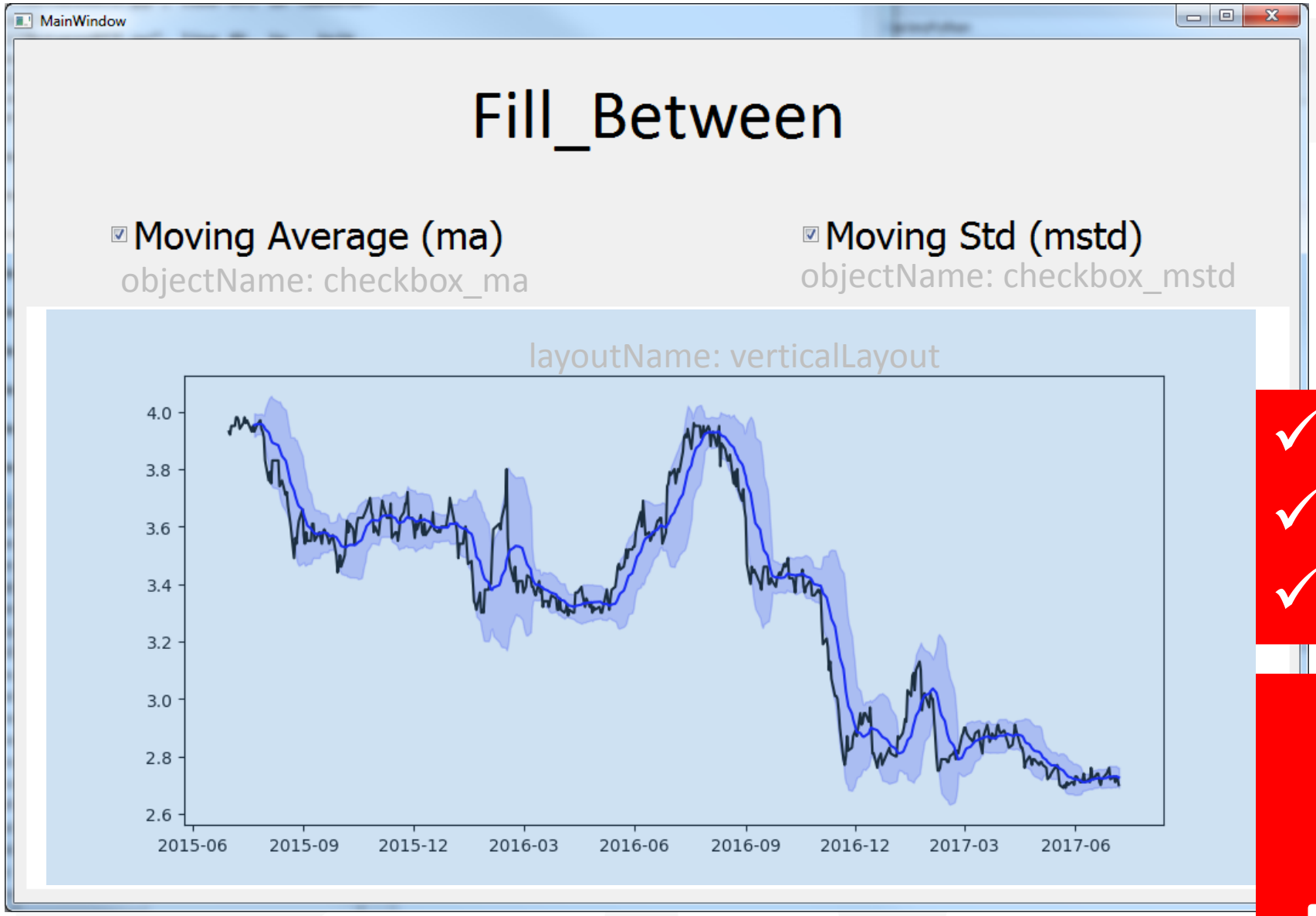

- ✓ 1 label
- ✓ 2 checkbox
- ✓ 1 axes

GUI PyQt5

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058

a .ui file +

```python
import sys
from PyQt5.QtWidgets import QMainWindow, QApplication # more widgets
from PyQt5 import uic
# more imports

qtCreatorFile = "FromQtDesigner.ui"
Ui_MainWindow, QtBaseClass = uic.loadUiType(qtCreatorFile)

class Main(QMainWindow, Ui_MainWindow):
    def __init__(self):
        super().__init__()
        self.setupUi(self)
        # more initialzation

    # more functions/methods

if __name__=='__main__':
    app=QApplication(sys.argv)
    main=Main()
    main.show()
    sys.exit(app.exec_())
```

PyQT5 template.py

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```python
import sys
from PyQt5.QtWidgets import QMainWindow, QApplication
from PyQt5 import uic
# more imports
import pandas as pd
import matplotlib.pyplot as plt
from matplotlib.figure import Figure
from matplotlib.backends.backend_qt5agg \
    import FigureCanvasQTAgg as FigureCanvas

qtCreatorFile = "AppFillBetween.ui"
Ui_MainWindow, QtBaseClass = uic.loadUiType(qtCreatorFile)
```

Template for adding a figure in a GUI.

058

```python
class Ui_MainWindow(object):
    def setupUi(self, MainWindow):
        MainWindow.setObjectName("MainWindow")
        MainWindow.resize(1059, 711)
```

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```
14 class Main(QMainWindow, Ui_MainWindow):
15     def __init__(self):
16         super().__init__()
17         self.setupUi(self)
18
19         # more initialization
20         self.data=pd.read_csv('CC3.SI.csv',index_col=0,parse_dates=True)
21         self.data.drop(self.data.index[self.data['Volume']==0],inplace=True)
22         self.ma=self.data['Close'].rolling(15).mean()
23         self.mstd=self.data['Close'].rolling(15).std()
24
25         self.checkBox_ma.setChecked(True)
26         self.checkBox_mstd.setChecked(True)
27
28         self.fig1 = Figure()
29         self.ax1 = self.fig1.add_subplot(111)
30         self.ax1.plot(self.data.index, self.data['Close'], 'k')
31         self.plot2=self.ax1.plot(self.ma.index, self.ma, 'b')
32         self.plot3=self.ax1.fill_between(self.mstd.index, self.ma-2*self.mstd,
33                                          self.ma+2*self.mstd, color='b', alpha=0.2)
34         self.canvas1 = FigureCanvas(self.fig1)
35         self.verticalLayout.addWidget(self.canvas1)
36         self.canvas1.draw()
37
38         self.checkBox_ma.stateChanged.connect(self.updategraph)
39         self.checkBox_mstd.stateChanged.connect(self.updategraph)
```

Ui_MainWindow.setupUi

self

058

(Dr. Z: The rest is to add an axes in a figure in a canvas widget in the verticalLayout in the QMainWindow.)

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```
40
41      # more functions/methods
42      def updategraph(self):
43          if self.checkBox_ma.isChecked():
44              plt.setp(self.plot2, visible=True)
45          else:
46              plt.setp(self.plot2, visible=False)
47          if self.checkBox_mstd.isChecked():
48              plt.setp(self.plot3, visible=True)
49          else:
50              plt.setp(self.plot3, visible=False)
51          self.canvas1.draw()
52
53  if __name__ == '__main__':
54      app = QApplication(sys.argv)
55      main = Main()
56      main.show()
57      sys.exit(app.exec_())
```

self

058

plt.setp

visible

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https://matplotlib.org/api/finance_api.html#matplotlib.finance.candlestick_ohlc

```
matplotlib.finance.candlestick_ohlc(ax, quotes, width=0.2, colorup='k', colordown='r', alpha=1.0)
```

ax : Axes

an Axes instance to plot to

quotes : sequence of (time, open, high, low, close, ...) sequences

As long as the first 5 elements are these values, the record can be as long as you want (e.g., it may store volume).

time must be in float days format - see date2num

A sequence of sequences.

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In-Class Exercise 35: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

060

```
from matplotlib.finance import candlestick_ohlc
from matplotlib.dates import date2num
r=data.iloc[:15, :]
fig, ax = plt.subplots()
d=date2num(r.index.date)
candlestick_ohlc(ax, zip(d, r.Open, r.High, r.Low, r.Close),
                 width=0.5, colorup='g', colordown='r', alpha=1)
plt.setp(ax.get_xticklabels(), rotation=30)
ax.xaxis_date()
plt.show()
```

```
fig=plt.figure()
ax=plt.axes()
```

(Dr. Z: Can we develop a GUI for this?)

ax

1. Use `.subplots()` to return `ax`, or ...
2. Use `date2num` to convert dates to float days
3. Use `zip` to create the sequence of tuples.

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Challenge: Modify "AppFillBetween.ui" (using Qt Designer) and the code "AppFillBetweenUI.py" to obtain the same GUI as shown in the following two slides.

061

References:

- http://doc.qt.io/qt-5/qfiledialog.html
- https://pythonspot.com/pyqt5-file-dialog/

See sample code

QFileDialog.getOpenFileName

```
fname = QFileDialog.getOpenFileName(self,'Open file',
                                    os.getcwd(),'CSV(*.csv)')
```

```
fname,_ = QFileDialog.getOpenFileName(self,'Open file',
                                      os.getcwd(),'CSV(*.csv)')
```

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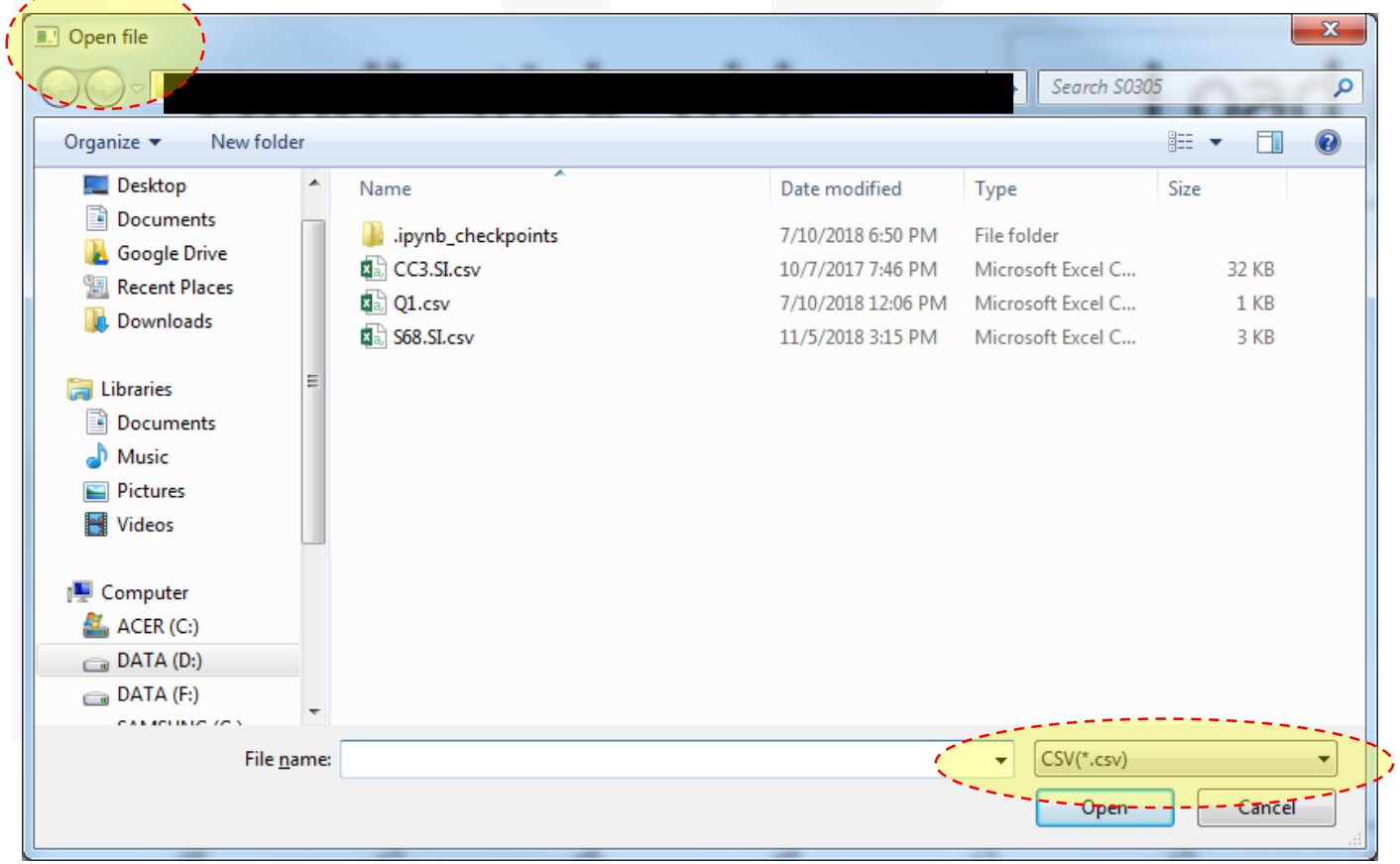
```
fname = QFileDialog.getOpenFileName(self,'Open file',
                                    os.getcwd(),'CSV(*.csv)')
```

get current working directory

```
('foldername/S68.SI.csv', 'CSV(*.csv)')
```



061

How about **print** it?

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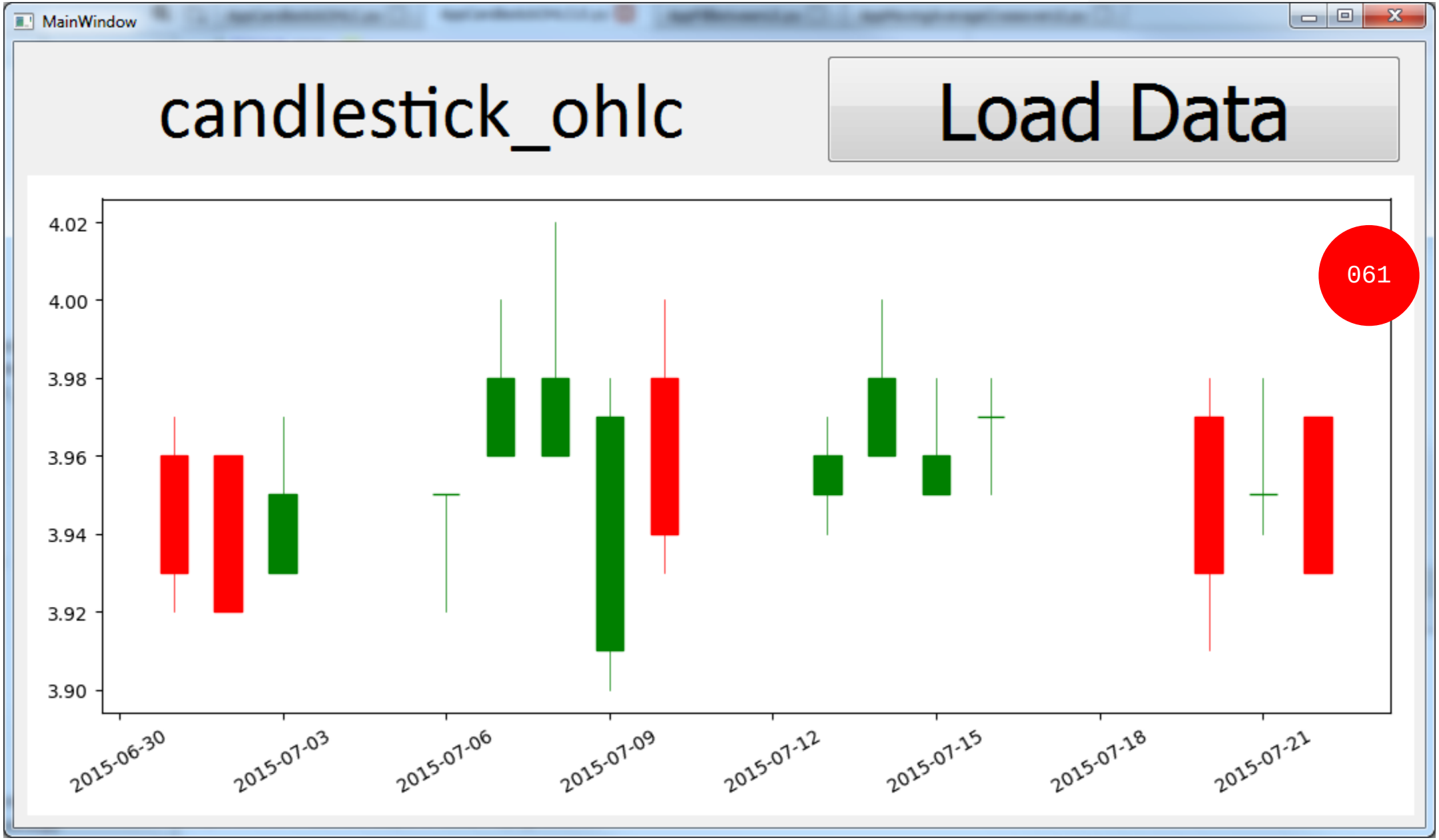

(Clicking on "Load Data" button, followed by choosing another csv file, say **S68.SI.csv**, we obtain another plot.)

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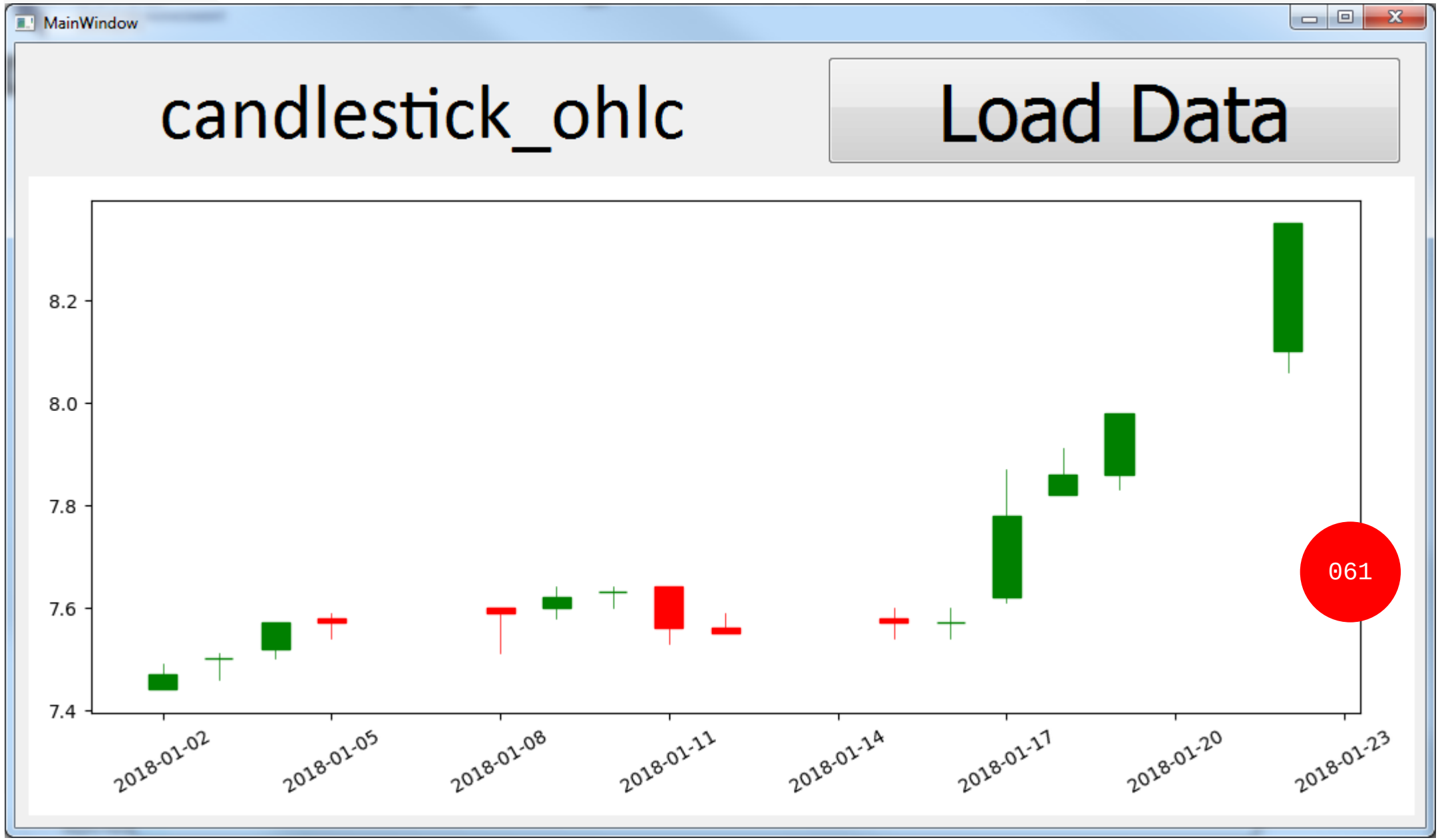

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Next, let's learn some basics of Numpy and Pandas.

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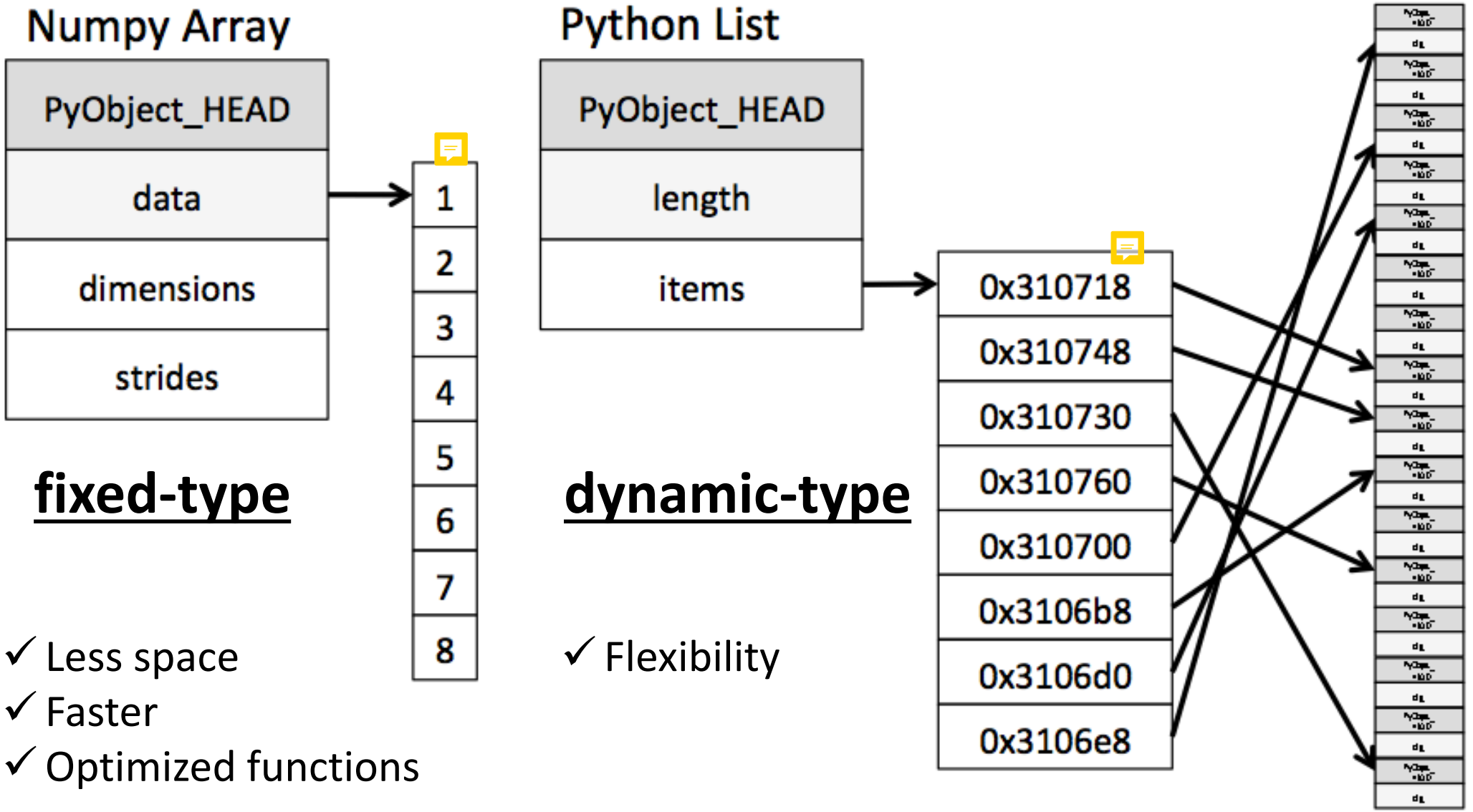
(Source: Python Data Science Handbook)

062



fixed-type

dynamic-type

- ✓ Less space
- ✓ Faster
- ✓ Optimized functions

- ✓ Flexibility

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Learning Outcomes:

ndarrays and DataFrames/Serieses

- ✓ Creation
- ✓ Indexing and Slicing
- ✓ Assignment
- ✓ Some Operations
- ✓ Some Functions

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Python

Numpy

Pandas

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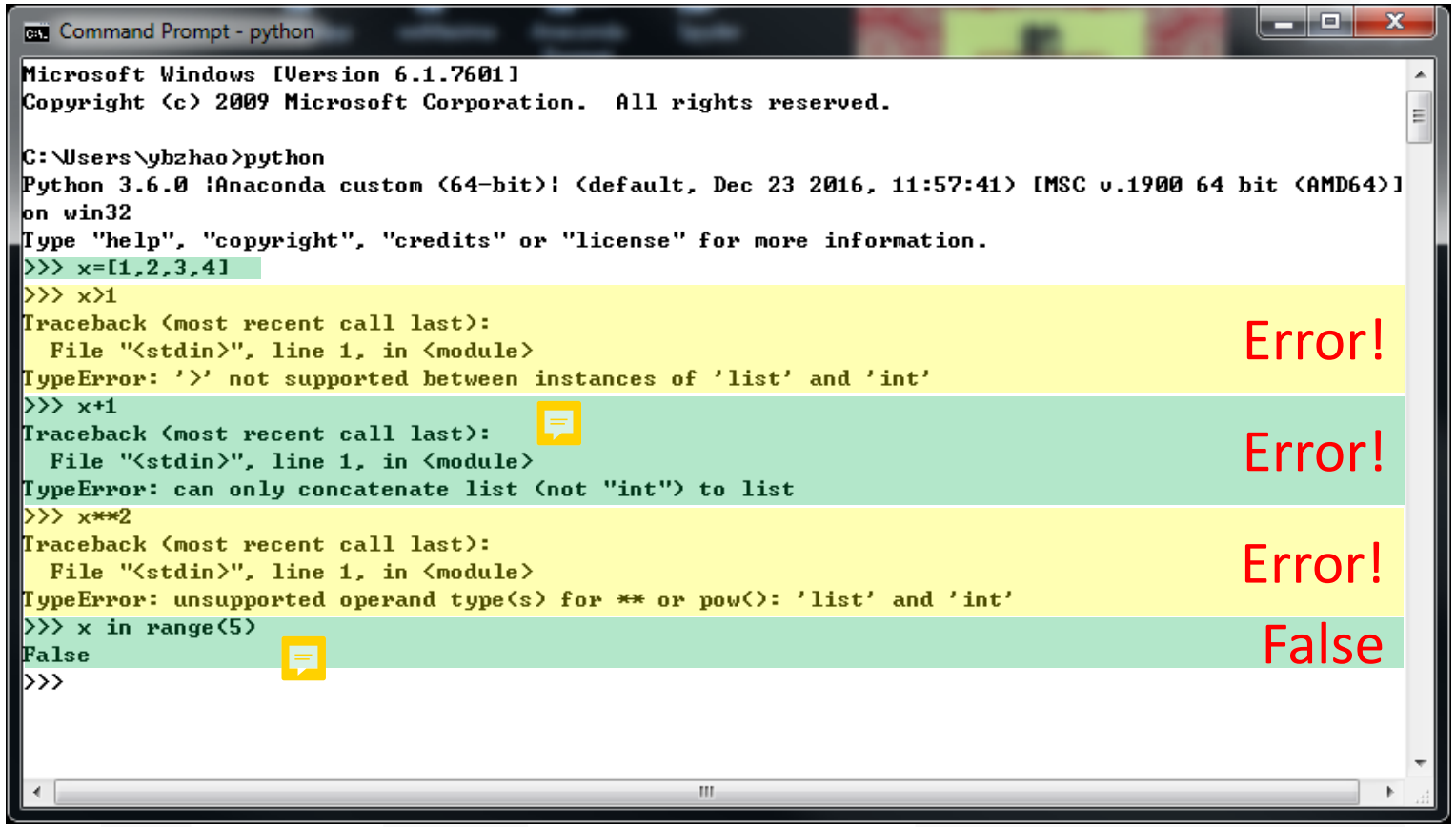

Solution:

- List comprehension

Built-in Functions				
abs()	dict()	help()	min()	setattr()
all()	dir()	hex()	next()	slice()
any()	divmod()	id()	object()	sorted()
ascii()	enumerate()	input()	oct()	staticmethod()
bin()	eval()	int()	open()	str()
bool()	exec()	isinstance()	ord()	sum()
bytearray()	filter()	issubclass()	pow()	super()
bytes()	float()	iter()	print()	tuple()
callable()	format()	len()	property()	type()
chr()	frozenset()	list()	range()	vars()
classmethod()	getattr()	locals()	repr()	zip()
compile()	globals()	map()	reversed()	__import__()
complex()	hasattr()	max()	round()	
delattr()	hash()	memoryview()	set()	

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all(*iterable*)

Return `True` if all elements of the *iterable* are true (or if the iterable is empty). Equivalent to:

```
def all(iterable):
    for element in iterable:
        if not element:
            return False
    return True
```

```
>>> all([1,2,3])
True
>>> all([1,0,3])
False
>>> all([])
True
>>> all([[]])
False
```

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any(*iterable*)

Return `True` if any element of the *iterable* is true. If the iterable is empty, return `False`. Equivalent to:

```
def any(iterable):
    for element in iterable:
        if element:
            return True
    return False
```

```
>>> any([1,2,3])
True
>>> any([1,0,3])
True
>>> any([])
False
>>> any([[]])
False
```

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In-Class Exercise 36: Use list comprehension to solve the following problem.

```
x=[1, 2, 3, 4]
#Q1: Compare x>1 element-by-element

#Q2: Is there any element of x greater than 1?

#Q3: Are all elements of x greater than 1?

#Q4: Compute x+1 element-by-element

#Q5: Compute x**2 element-by-element

#Q6: Test x in range(5) element-by-element

#Q7: Is there any element of x in range(5)

#Q8: Are all elements of x in range(5)
```

[False, True, True, True]	Q1
True	Q2
False	Q3
[2, 3, 4, 5]	Q4
[1, 4, 9, 16]	Q5
[True, True, True, True]	Q6
True	Q7
True	Q8

063 065

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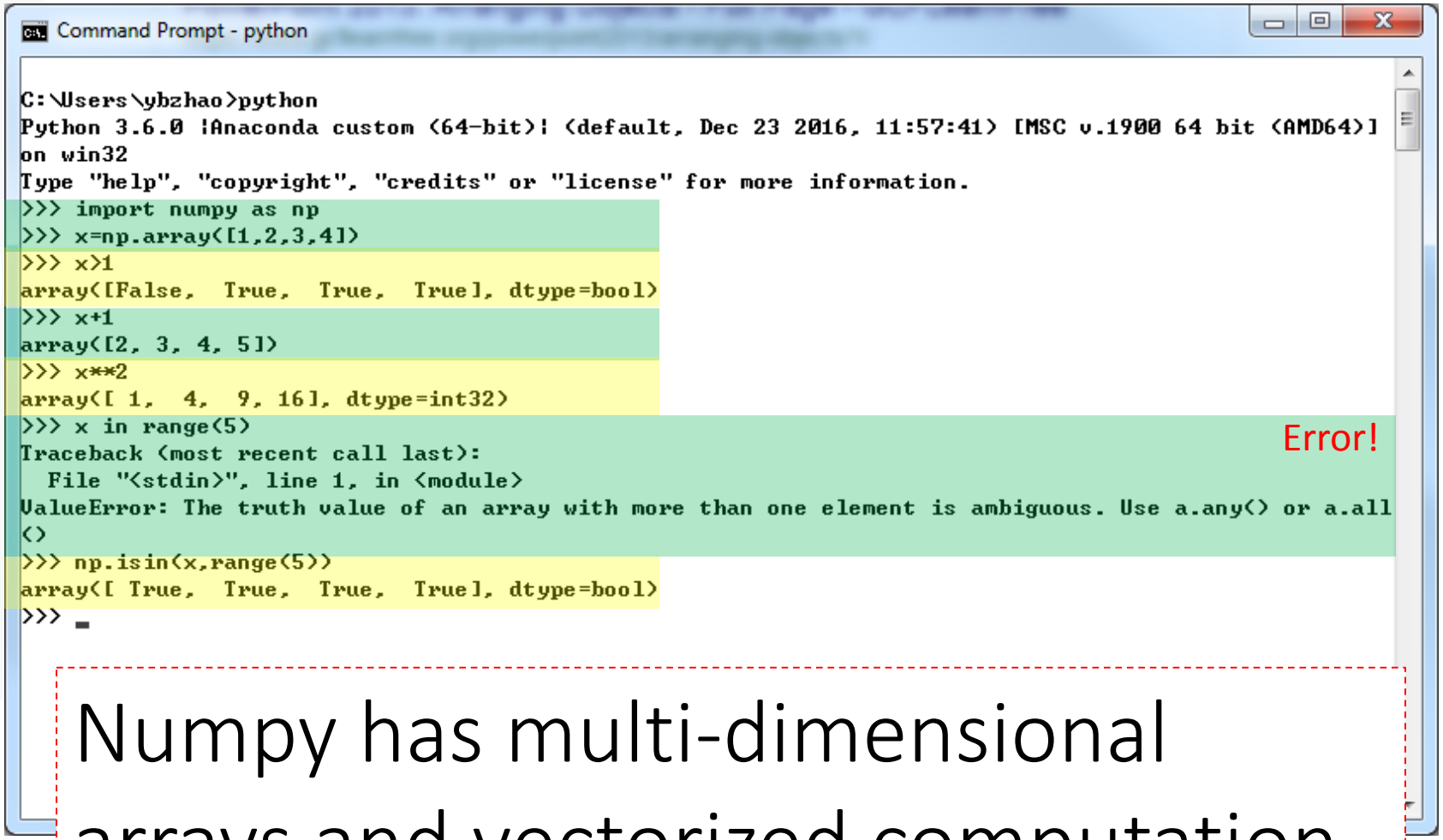
Python

Numpy

Pandas

```
>>> np.isin(x,range(5))
```



Numpy has multi-dimensional arrays and vectorized computation

In-Class Exercise 37: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
import numpy as np
x=np.array([1,2,3,4])
print(type(x))
print(x>1)
print(x+1)
print(x**2)
print(np.isin(x,range(5)))
```

numpy.ndarray

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```
<class 'numpy.ndarray'>
[False  True  True  True]
[2 3 4 5]
[ 1  4  9 16]
[ True  True  True  True]
```

multi-Dimensional
1D, 2D, 3D, …, n-D, …

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SciPy.org Sponsored By ENTHOUGHT https://docs.scipy.org/doc/numpy/reference/generated/numpy.array.html

Scipy.org | Docs | NumPy v1.14 Manual | NumPy Reference | Routines | Array creation routines

numpy.array

numpy.array

numpy.array

numpy.**array**(*object*, *dtype=None*, *copy=True*, *order='K'*, *subok=False*, *ndmin=0*)

Create an array.

Parameters:

object : *array_like*

An array, any object exposing the array interface, an object whose __array__ method returns an array, or any (nested) sequence.

dtype : *data-type, optional*

The desired data-type for the array. If not given, then the type will be determined as the minimum type required to hold the objects in the sequence. This argument can only be used to 'upcast' the array. For downcasting, use the .astype(t) method.

copy : *bool, optional*

If true (default), then the object is copied. Otherwise, a copy will only be made if __array__ returns a copy, if obj is a nested sequence, or if a copy is needed to satisfy any of the other requirements (`dtype`, *order*, etc.).

order : *{'K', 'A', 'C', 'F'}, optional*

Specify the memory layout of the array. If object is not an array, the newly created array will be in C order (row major) unless 'F' is specified, in which case it will be in Fortran order (column major). If object is an array the following holds.

order	no copy	copy=True
'K'	unchanged	F & C order preserved, otherwise most similar order
'A'	unchanged	F order if input is F and not C, otherwise C order
'C'	C order	C order
'F'	F order	F order

When `copy=False` and a copy is made for other reasons, the result is the same as if `copy=True`, with some exceptions for *A*, see the Notes section. The default order is 'K'.

subok : *bool, optional*

If True, then sub-classes will be passed-through, otherwise the returned array will be forced to be a base-class array (default).

ndmin : *int, optional*

Specifies the minimum number of dimensions that the resulting array should have. Ones will be pre-pended to the shape as needed to meet this requirement.

Returns:

out : *ndarray*

An array object satisfying the specified requirements.

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In-Class Exercise 38: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
import numpy as np
x=np.array([[1,2],[3,4]])
print(type(x))
print(x>1)
print(x+1)
print(x**2)
print(np.isin(x,range(5)))
```

1	2
3	4

```
<class 'numpy.ndarray'>
[[False  True]
 [ True  True]]
[[2 3]
 [4 5]]
[[ 1  4]
 [ 9 16]]
[[ True  True]
 [ True  True]]
```

numpy.ndarray

multi-Dimensional
1D, 2D, 3D, …, n-D, …

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Python

Numpy

Pandas

```
>>> import pandas as pd
>>> x=pd.DataFrame([[1,2],[3,4]])
>>> x>1
       0      1
0  False   True
1   True   True
>>> x+1
   0  1
0  2  3
1  4  5
>>> x**2
   0   1
0  1   4
1  9  16
>>> x.isin(range(5))
       0      1
0   True   True
1   True   True
```

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1	2
3	4

DataFrame
(2D only)

Series
(1D only)

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pandas.DataFrame

https://pandas.pydata.org/pandas-docs/stable/generated/pandas.DataFrame.html

class `pandas.DataFrame`(*data=None, index=None, columns=None, dtype=None, copy=False*) [source]

Two-dimensional size-mutable, potentially heterogeneous tabular data structure with labeled axes (rows and columns). Arithmetic operations align on both row and column labels. Can be thought of as a dict-like container for Series objects. The primary pandas data structure

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Parameters:

data : *numpy ndarray (structured or homogeneous), dict, or DataFrame*
Dict can contain Series, arrays, constants, or list-like objects

index : *Index or array-like*
Index to use for resulting frame. Will default to np.arange(n) if no indexing information part of input data and no index provided

columns : *Index or array-like*
Column labels to use for resulting frame. Will default to np.arange(n) if no column labels are provided

dtype : *dtype, default None*
Data type to force. Only a single dtype is allowed. If None, infer

copy : *boolean, default False*
Copy data from inputs. Only affects DataFrame / 2d ndarray input

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In-Class Exercise 39: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
import pandas as pd
x=pd.DataFrame([[1,2],[3,4]], columns=list('ab'))
print(type(x))
print(x>1)
print(x+1)
print(x**2)
print(x.isin(range(5)))
```

```
<class 'pandas.core.frame.DataFrame'>
       a     b
0  False  True
1   True  True
   a  b
0  2  3
1  4  5
   a   b
0  1   4
1  9  16
      a     b
0  True  True
1  True  True
```

1	2
3	4

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```
>>> import numpy as np
>>> x=np.array([1,2,3,4]);x
array([1, 2, 3, 4])
>>> x>1
array([False,  True,  True,  True], dtype=bool)
>>> any(x>1)
True
>>> all(x>1)
False
>>> y=np.array([[1,2],[3,4]]);y
array([[1, 2],
       [3, 4]])
>>> y>1
array([[False,  True],
       [ True,  True]], dtype=bool)
>>> any(y>1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: The truth value of an array with mor
()
>>> all(y>1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: The truth value of an array with mor
()
```

any() and all() work on 1D arrays,

```
>>> np.any(x>1), np.all(x>1)
(True, False)
>>> np.any(y>1), np.all(y>1)
(True, False)
```

but not on 2D arrays.

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numpy.any

numpy. **any** (*a*, *axis=None*, *out=None*, *keepdims=<class 'numpy._globals._NoValue'>*) [source]

Test whether any array element along a given axis evaluates to True.

Returns single boolean unless *axis* is not `None`

Parameters: **a** : *array_like*

Input array or object that can be converted to an array.

axis : *None or int or tuple of ints, optional*

Axis or axes along which a logical OR reduction is performed. The default (*axis = None*) is to perform a logical OR over all the dimensions of the input array. *axis* may be negative, in which case it counts from the last to the first axis.

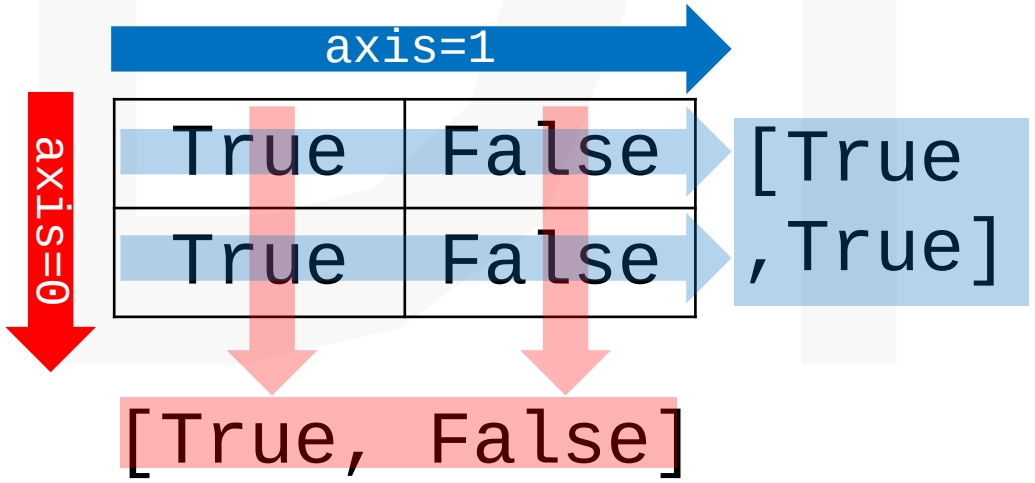
New in version 1.7.0.

If this is a tuple of ints, a reduction is performed on multiple axes, instead of a single axis or all the axes as before.

axis=None

071

072




```
>>> np.any([[True,False],[True,False]])
True
>>> np.any([[True,False],[True,False]], axis=0)
array([ True, False], dtype=bool)
>>> np.any([[True,False],[True,False]], axis=1)
array([ True,  True], dtype=bool)
>>> np.any([[True,False],[True,False]], axis=-1)
array([ True,  True], dtype=bool)
```

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numpy.ndarray.any

ndarray.**any**(*axis=None, out=None, keepdims=False*)

Returns True if any of the elements of *a* evaluate to True.

Refer to `numpy.any` for full documentation.

See also:

`numpy.any` equivalent function

```
>>> import numpy as np
>>> x=[[True,False],[True,False]]
>>> x.any()
Traceback (most recent call last):
  File "<stdin>", line 1, in <modu
AttributeError: 'list' object has
>>> np.array(x).any()
True
```

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```
>>> np.any([[True,False],[True,False]])
True
>>> np.any([[True,False],[True,False]], axis=0)
array([ True, False], dtype=bool)
>>> np.any([[True,False],[True,False]], axis=1)
array([ True,  True], dtype=bool)
>>> np.any([[True,False],[True,False]], axis=-1)
array([ True,  True], dtype=bool)
```

```
>>> x=[[True,False],[True,False]]
>>> #axis=0
... [any([x[i][j] for i in range(2)]) for j in range(2)]
[True, False]
>>> #axis=1
... [any([x[i][j] for j in range(2)]) for i in range(2)]
[True, True]
```

Do Not Test

A 3-level nested list (2-by-2-by-2):

Do Not Test

```
import numpy as np
x=[[[True,False],[True,False]],[[True,True],[False,False]]]
#axis=1
print(np.any(x,axis=1))

print([[any([x[i0][i1][i2] for i1 in range(2)]) for i2 in range(2)] for i0 in range(2)])

#axis=(0,2)
print(np.any(x,axis=(0,2)))

print([any([x[i0][i1][i2] for i2 in range(2) for i0 in range(2)]) for i1 in range(2)])
```

```
[[ True False]
 [ True  True]]
[[True, False], [True, True]]
[ True  True]
[True, True]
```

axis=(0,2)

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Indexing & Slicing

(for Numpy ndarray and Pandas DataFrame/Series)

Q: What is the output? (Indexing vs Slicing)

```
>>> x=[[0,1,2],
...    [3,4,5],
...    [6,7,8]]; x
[[0, 1, 2], [3, 4, 5], [6, 7, 8]]
>>> x[0]
[0, 1, 2]
>>> x[:1]
[[0, 1, 2]]
>>> x[1][1]
4
>>> x[:1][:1]
[[0, 1, 2]]
>>> x[1,1]
Traceback (most recent call last)
  File "<stdin>", line 1, in <mod
TypeError: list indices must be i
>>> x[:1,:1]
Traceback (most recent call last)
  File "<stdin>", line 1, in <mod
TypeError: list indices must be i
```

0	1	2
3	4	5
6	7	8

```
>>> import numpy as np
>>> x=np.arange(9).reshape(3,-1);x
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])
>>> x[0]
array([0, 1, 2])
>>> x[:1]
array([[0, 1, 2]])
>>> x[1][1]
4
>>> x[:1][:1]
array([[0, 1, 2]])
>>> x[1,1]
4
>>> x[:1,:1]
array([[0]])
```

073

074

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075

```
>>> x=[[0,1,2],[3,4,5],[6,7,8]]; x
[[0, 1, 2], [3, 4, 5], [6, 7, 8]]
>>> x[1,1]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: list indices must be integers or slices, not tuple
>>> x[1]
[3, 4, 5]
>>> x[1][[True,False,True]]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: list indices must be integers or slices, not list
>>> x[1][[1,2,0,0]]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: list indices must be integers or slices, not list
```

Error

Error

Error

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In-Class Exercise 40: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

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```
import numpy as np
x=np.arange(0,9).reshape(3,-1)
print(x)
print(x[1])
print(x[1][1], x[1,1])          multidimensional indexing
print(x[0::2,1:])               multidimensional slicing
print(x>4)
x[x>4]=-1                       boolean indexing
print(x)
print(x[1][[1,2,0,0]])          fancying indexing
print(x[1::-1,[1,2,0,0]])       combined indexing
```

```
[[0 1 2]
 [3 4 5]
 [6 7 8]]
[3 4 5]
4 4
[[1 2]
 [7 8]]
[[False False False]
 [False False  True]
 [ True  True  True]]
[[ 0  1  2]
 [ 3  4 -1]
 [-1 -1 -1]]
[ 4 -1  3  3]
[[ 4 -1  3  3]
 [ 1  2  0  0]]
```

Indexing & Slicing (numpy.ndarray)

https://docs.scipy.org/doc/numpy-1.13.0/user/basics.indexing.html

In-Class Exercise 41: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
import numpy as np
x=np.arange(0,9).reshape(3,-1)
print(x[1])
print(x[[1]])
```

077

x[1]

```
import numpy as np
x=np.arange(0,9).reshape(3,-1)
print(x[1])
print(x[[1]])
```

VS

```
[3 4 5]
[[3 4 5]]
```

x[[1]]

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Copy or View? (list)


```
>>> x=[0, 1, 2, 3]; x
[0, 1, 2, 3]
>>> x[:2]=-1; x
Traceback (most recent
  File "<stdin>", line
TypeError: can only as
>>> x[:2]=[-1,-2]; x
[-1, -2, 2, 3]
>>> y=x[:2]; y
[-1, -2]
>>> y[0]=100; y
[100, -2]
>>> x
[-1, -2, 2, 3]
```

➔ x[:2][0]=100

y=x[:2]

y is a copy here.

Q: How to validate this?

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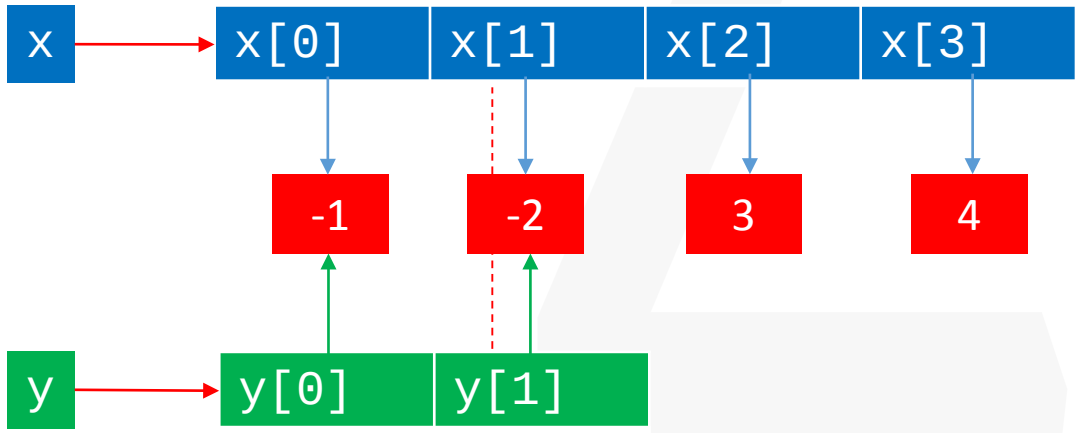
```
>>> x=[0, 1, 2, 3]; x
[0, 1, 2, 3]
>>> x[:2]=-1; x
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: can only assign an iterable
>>> x[:2]=[-1,-2]; x
[-1, -2, 2, 3]
>>> y=x[:2]; y
[-1, -2]
>>> id(x), id(y)
(45133000, 45157448)
>>> id(x[0]), id(y[0])
(1628486032, 1628486032)
>>> id(x[1]), id(y[1])
(1628486000, 1628486000)
```



(for illustration only)

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Copy or View? (1D ndarray)

```
>>> import numpy as np
>>> x=np.arange(4); x
array([0, 1, 2, 3])
>>> x[:2]=-1; x
array([-1, -1,  2,  3])
>>> x[:2]=[-1,-2]; x
array([-1, -2,  2,  3])
>>> y=x[:2]; y
array([-1, -2])
>>> y[0]=100; y
array([100,  -2])
>>> x
array([100,  -2,   2,   3])
```

A NEW, VALID operation.

➔ x[:2][0]=100

y=x[:2]

y is a view.

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```
>>> import numpy as np
>>> x=np.arange(4); x
array([0, 1, 2, 3])
>>> y=x[:2];y
array([0, 1])
>>> z=x[[0,1]];z
array([0, 1])
>>> id(x), id(y), id(z)
(56356656, 39900464, 56401152)
>>> y.base is x, z.base is x
(True, False)
>>> x[0]=100
>>> y,z
(array([100,   1]), array([0, 1]))
```

080

numpy.ndarray is too complicated to use id() to tell us anything.

✓ numpy.ndarray.base

Slicing of ndarray returns a view; fancy indexing returns a copy.

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```
x[:2][0]=100
```

(Dr. Z: This is called ***chained indexing***. It is difficult to tell whether the **assignment** happens to a copy or a view of x. It depends on the implementation of __getitem__ and __setitem__. So, we won't explore further what will happen on it.)

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https://pandas.pydata.org/pandas-docs/stable/indexing.html#indexing-and-selecting-data

DataFrame

- ✓ Selection via `[ ]`
- ✓ Selection by Position (`.iloc`)
- ✓ Selection by Label (`.loc`)
- ✓ Boolean Indexing

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In-Class Exercise 42: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
import numpy as np
import pandas as pd
x=pd.DataFrame(np.arange(16).reshape(4,4))
print(x, type(x))                                    1
print(x[1], type(x[1]))                              2
print(x[[1]], type(x[[1]]))                          3
print(x[:1], type(x[:1]))                            4
print(x[1][1], type(x[1][1]))                        5
x[x>9]=-1
print(x)                                             6
```

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```
    0   1   2   3
0   0   1   2   3
1   4   5   6   7
2   8   9  10  11
3  12  13  14  15 <class 'pandas.core.frame.DataFrame'>
```
1

```
0     1
1     5
2     9
3    13
Name: 1, dtype: int32 <class 'pandas.core.series.Series'>
```
2

```
    1
0   1
1   5
2   9
3  13 <class 'pandas.core.frame.DataFrame'>
```
3

```
   0  1  2  3
0  0  1  2  3 <class 'pandas.core.frame.DataFrame'>
```
4

```
5 <class 'numpy.int32'>
```
5

```
   0  1  2  3
0  0  1  2  3
1  4  5  6  7
2  8  9 -1 -1
3 -1 -1 -1 -1
```
6

DataFrame

Indexing:
column
+
Series

081

Fancy indexing:
column
+
DataFrame

Slicing: row + DataFrame

[ ]

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ndarray VS DataFrame

```
>>> import numpy as np
>>> x=np.arange(9).reshape(3,3); x
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])
>>> x[1,1]
4
```

```
>>> import pandas as pd
>>> import numpy as np
>>> x=pd.DataFrame(np.arange(9).reshape(3,3));x
   0  1  2
0  0  1  2
1  3  4  5
2  6  7  8
>>> x[1,1]
Traceback (most recent call last):
  File "pandas\_libs\index.pyx", line 154, in pa
dex.c:5126)
  File "pandas\_libs\hashtable_class_helper.pxi"
```

(Dr. Z: DataFrames use .loc and .iloc for multidimensional indexing.)

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`.iloc` integer position based

- `.iloc` is primarily integer position based (from `0` to `length-1` of the axis), but may also be used with a boolean array. `.iloc` will raise `IndexError` if a requested indexer is out-of-bounds, except *slice* indexers which allow out-of-bounds indexing. (this conforms with python/numpy *slice* semantics). Allowed inputs are:
  - An integer e.g. `5` — indexing
  - A list or array of integers `[4, 3, 0]` — fancy indexing
  - A slice object with ints `1:7` — slicing
  - A boolean array — Boolean indexing
  - A `callable` function with one argument (the calling Series, DataFrame or Panel) and that returns valid output for indexing (one of the above)

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082

```
df.iloc[1] ⇔ df.iloc[1,:]
```

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In-Class Exercise 43: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
import numpy as np
import pandas as pd
x=pd.DataFrame(np.arange(16).reshape(4,4),
                  index=[2,1,4,3],columns=list('bcad'))
print(x)                                                    1
print(x.iloc[2], type(x.iloc[2]))                           2
print(x.iloc[[2]], type(x.iloc[[2]]))                       3
print(x.iloc[:2], type(x.iloc[:2]))                         4
print(x.iloc[[True,False,False,True]],                      5
      type(x.iloc[[True,False,False,True]]))
print(x.iloc[1,1])                                          6
```

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iloc

082

```
    b   c   a   d
2   0   1   2   3
1   4   5   6   7
4   8   9  10  11
3  12  13  14  15
```

```
b     8
c     9
a    10
d    11
Name: 4, dtype: int32 <class 'pandas.core.series.Series'>
```

```
   b  c   a   d
4  8  9  10  11 <class 'pandas.core.frame.DataFrame'>
```

```
   b  c  a  d
2  0  1  2  3
1  4  5  6  7 <class 'pandas.core.frame.DataFrame'>
```

```
    b   c   a   d
2   0   1   2   3
3  12  13  14  15 <class 'pandas.core.frame.DataFrame'>
```

```
5
```

1

☆ row 2

☆ row 3

☆ row 4

☆ row 5

☆ 6

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.loc

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- `.loc` is primarily label based, but may also be used with a boolean array. `.loc` will raise `KeyError` when the items are not found. Allowed inputs are:
  - A single label, e.g. `5` or `'a'`, (note that `5` is interpreted as a *label* of the index. This use is **not** an integer position along the index)
  - A list or array of labels `['a', 'b', 'c']`
  - A slice object with labels `'a':'f'` (note that contrary to usual python slices, **both** the start and the stop are included, when present in the index! - also see Slicing with labels)
  - A boolean array
  - A `callable` function with one argument (the calling Series, DataFrame or Panel) and that returns valid output for indexing (one of the above)

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In-Class Exercise 44: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
import numpy as np
import pandas as pd
x=pd.DataFrame(np.arange(16).reshape(4,4),
                  index=[2,1,4,3],columns=list('bcad'))
print(x)                                                          1
print(x.loc[2], type(x.loc[2]))                                   2
print(x.loc[[2]], type(x.loc[[2]]))                               3
print(x.loc[:2], type(x.loc[:2]))                                 4
print(x.loc[[True,False,False,True]],
      type(x.loc[[True,False,False,True]]))                       5
print(x.loc[1,'a'])                                               6
```

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```
    b   c   a   d
2   0   1   2   3
1   4   5   6   7
4   8   9  10  11
3  12  13  14  15
```

083

```
b    0
c    1
a    2
d    3
Name: 2, dtype: int32 <class 'pandas.core.series.Series'>
```

```
   b  c  a  d
2  0  1  2  3 <class 'pandas.core.frame.DataFrame'>
```

```
   b  c  a  d
2  0  1  2  3 <class 'pandas.core.frame.DataFrame'>
```

```
    b   c   a   d
2   0   1   2   3
3  12  13  14  15 <class 'pandas.core.frame.DataFrame'>
```

```
6
```

SciPy.org Sponsored By ENTHOUGHT

Scipy.org | Docs | NumPy v1.13 Manual | NumPy Reference | Routines | Array creation routines

numpy.arange

numpy.**arange**([*start*,]*stop*, [*step*,]*dtype=None*)

Return evenly spaced values within a given interval.

Values are generated within the half-open interval `[start, stop)` (in other words, the interval including *start* but excluding *stop*). For integer arguments the function is equivalent to the Python built-in range function, but returns an ndarray rather than a list.

When using a non-integer step, such as 0.1, the results will often not be consistent. It is better to use `linspace` for these cases.

```
>>> import numpy as np
>>> np.arange(1,2,0.2)
array([ 1. ,  1.2,  1.4,  1.6,  1.8])
>>> np.linspace(1,2,6)
array([ 1. ,  1.2,  1.4,  1.6,  1.8,  2. ])
```


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numpy.linspace

`numpy.` **`linspace`** (*start, stop, num=50, endpoint=True, retstep=False, dtype=None*)

Return evenly spaced numbers over a specified interval.

Returns *num* evenly spaced samples, calculated over the interval [*start, stop*].

The endpoint of the interval can optionally be excluded.

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numpy.ndarray.reshape

`ndarray.` **`reshape`** (*shape, order='C'*)

Row-major order

085

Returns an array containing the same data with a new shape.

Refer to `numpy.reshape` for full documentation.

https://en.wikipedia.org/wiki/Row-_and_column-major_order

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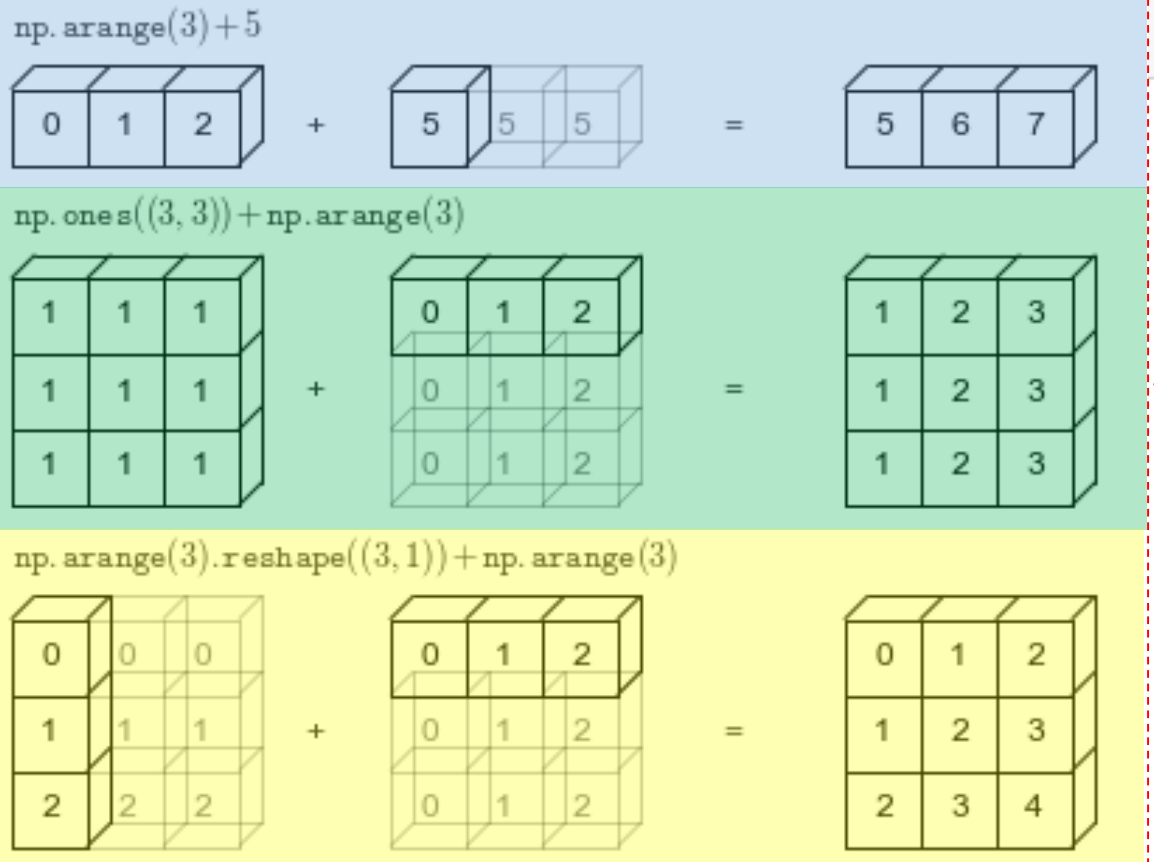
In-Class Exercise 45: Type (or copy and paste) the following lines of code followed by pressing "Shift-Enter"

```
import numpy as np
print(np.arange(3)+5)
print(np.ones((3,3))+np.arange(3))
print(np.arange(3).reshape((3,1))+np.arange(3))
```

https://jakevdp.github.io/PythonDataScienceHandbook/02.05-computation-on-arrays-broadcasting.html

```
import numpy as np
print(np.arange(3)+5)
print(np.ones((3,3))+np.arange(3))
print(np.arange(3).reshape((3,1))+np.arange(3))
```

```
[5 6 7]
[[ 1.  2.  3.]
 [ 1.  2.  3.]
 [ 1.  2.  3.]]
[[0 1 2]
 [1 2 3]
 [2 3 4]]
```



Stretching and Broadcasting (ndarray)

086

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numpy.ones

numpy. **ones** (*shape, dtype=None, order='C'*)

Return a new array of given shape and type, filled with ones.

```
>>> import numpy as np
>>> np.ones((3,3))
array([[ 1.,  1.,  1.],
       [ 1.,  1.,  1.],
       [ 1.,  1.,  1.]])
>>> np.ones(3,3)
Traceback (most recent ca
  File "<stdin>", line 1,
  File "C:\Continuum\Anac
    a = empty(shape, dtyp
TypeError: data type not
```

Default: `float` type

`dtype=int` ⇨ `int` type

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```
>>> import pandas as pd
>>> x=pd.DataFrame([1,2,3]); x
   0
0  1
1  2
2  3
>>> y=pd.DataFrame([[1,2,3]]); y
   0  1  2
0  1  2  3
>>> x.values+y.values
array([[2, 3, 4],
       [3, 4, 5],
       [4, 5, 6]], dtype=int64)
>>> x+y
     0   1   2
0  2.0 NaN NaN
1  NaN NaN NaN
2  NaN NaN NaN
>>> pd.DataFrame(x.values+y.values)
   0  1  2
0  2  3  4
1  3  4  5
2  4  5  6
```

It seems that pandas.DataFrame does not have ndarray's "Stretching and Broadcasting".

So what? ☺

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```
>>> import pandas as pd
>>> x=pd.Series(range(5)); x
0    0
1    1
2    2
3    3
4    4
dtype: int32
>>> x[:3]
0    0
1    1
2    2
dtype: int32
>>> x[2:]
2    2
3    3
4    4
dtype: int32
>>> x[:3]-x[2:]
0    NaN
1    NaN
2    0.0
3    NaN
4    NaN
dtype: float64
```

089

```
>>> x[:3]-x[2:].values
0   -2
1   -2
2   -2
dtype: int32
```

Subtraction of Two Series with different labels.

Algorithm (Binomial Tree):

Given S, K, r, q, t, T, σ and N (1 day=1/365 years)

$$\tau = T - t$$

090

1. $\Delta t = \frac{T-t}{N}, u = e^{\sigma\sqrt{\Delta t}}, d = \frac{1}{u}, p = \frac{e^{(r-q)\Delta t} - d}{u-d}$
2. $f_{N,j} = \max(0, Su^j d^{N-j} - K)$ (Call), $f_{N,j} = \max(0, K - Su^j d^{N-j})$ (Put), for $j = 0, 1, \ldots, N$
3. $f_{i,j} = e^{-r\Delta t}[p \cdot f_{i+1,j+1} + (1-p) \cdot f_{i+1,j}]$ for $i = N-1, N-2, \ldots, 1, 0; j = 0, 1, \ldots, i$
4. Option (call/put) price: $V = f_{0,0}$
5. Option Greeks (*Delta and *Gamma):

$$\Delta = \frac{f_{1,1} - f_{1,0}}{S \cdot u - S \cdot d}, \Gamma = \frac{d(f_{2,2} - f_{2,1}) - u(f_{2,1} - f_{2,0})}{S^2(u-d)^2}$$

(optional)

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For example: $S = 50, K = 50, r = 0.04, q = 0.01, \tau = 183/365, \sigma = 0.4$, and $N = 3$.

1. $\Delta t = \frac{r}{N}, u = e^{\sigma\sqrt{\Delta t}}, d = \frac{1}{u}, p = \frac{e^{(r-q)\Delta t} - d}{u - d}$
2. $(i = 3)$
   - $(j = 0)$ $f_{3,0} = \max(0, Su^0 d^{3-0} - K)$ (Call), $f_{3,0} = \max(0, K - Su^0 d^{3-0})$ (Put)
   - $(j = 1)$ $f_{3,1} = \max(0, Su^1 d^{3-1} - K)$ (Call), $f_{3,1} = \max(0, K - Su^1 d^{3-1})$ (Put)
   - $(j = 2)$ $f_{3,2} = \max(0, Su^2 d^{3-2} - K)$ (Call), $f_{3,2} = \max(0, K - Su^2 d^{3-2})$ (Put)
   - $(j = 3)$ $f_{3,3} = \max(0, Su^3 d^{3-3} - K)$ (Call), $f_{3,3} = \max(0, K - Su^3 d^{3-3})$ (Put)
3.
   - $(i = 2)$
     - $(j = 0)$ $f_{2,0} = e^{-r\Delta t}[p \cdot f_{3,1} + (1-p) \cdot f_{3,0}]$
     - $(j = 1)$ $f_{2,1} = e^{-r\Delta t}[p \cdot f_{3,2} + (1-p) \cdot f_{3,1}]$
     - $(j = 2)$ $f_{2,2} = e^{-r\Delta t}[p \cdot f_{3,3} + (1-p) \cdot f_{3,2}]$
   - $(i = 1)$
     - $(j = 0)$ $f_{1,0} = e^{-r\Delta t}[p \cdot f_{2,1} + (1-p) \cdot f_{2,0}]$
     - $(j = 1)$ $f_{1,1} = e^{-r\Delta t}[p \cdot f_{2,2} + (1-p) \cdot f_{2,1}]$
   - $(i = 0)$
     - $(j = 0)$ $f_{0,0} = e^{-r\Delta t}[p \cdot f_{1,1} + (1-p) \cdot f_{1,0}]$

- $\tau \rightarrow$ `tau`
- $\Delta t \rightarrow$ `deltaT`
- $f_{i,j} \rightarrow$ `f[i][j]`

```
>>> f=[[0.0],
...     [0.0, 0.0],
...     [0.0, 0.0, 0.0],
...     [0.0, 0.0, 0.0, 0.0]]
```

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```
>>> f
[[0.0], [0.0, 0.0], [0.0, 0.0, 0.0], [0.0, 0.0, 0.0, 0.0]]
>>> f[3][0]=1.1
>>> f
[[0.0], [0.0, 0.0], [0.0, 0.0, 0.0], [1.1, 0.0, 0.0, 0.0]]
```

f[0][0]
f[1][0]
f[1][1]
f[2][0]
f[2][1]
f[2][2]
f[3][0]
f[3][1]
f[3][2]
f[3][3]

$f_{i,j} \rightarrow$ f[i][j]

$f_{3,0} = 1.1 \rightarrow$ f[3][0]=1.1

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Three Implementations

1. Nested list with for loop
2. Nested list with list comprehension
3. Numpy ndarray

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Given N, …

$f_{N,j},\ j = 0, 1, \ldots, N$ $N = 3$: $f_{3,0}, f_{3,1}, f_{3,2}, f_{3,3}$

$f_{i,j},\ i = N-1, \ldots, 0;\ j = 0, 1, \ldots, i$ $N = 3$: $f_{2,0}, f_{2,1}, f_{2,2}; f_{1,0}, f_{1,1}; f_{0,0}$

For example, $N = 3$

$f_{0,0}$			
$f_{1,0}$	$f_{1,1}$		
$f_{2,0}$	$f_{2,1}$	$f_{2,2}$	
$f_{3,0}$	$f_{3,1}$	$f_{3,2}$	$f_{3,3}$

$f_{i,j} \rightarrow$ `f[i][j]` list, ndarray

$f_{i,j} \rightarrow$ `f[i,j]` ndarray

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$f_{0,0}$			
$f_{1,0}$	$f_{1,1}$		
$f_{2,0}$	$f_{2,1}$	$f_{2,2}$	
$f_{3,0}$	$f_{3,1}$	$f_{3,2}$	$f_{3,3}$

```
N=3
f=[[0.0 for j in range(i+1)]
        for i in range(N+1)]
```

$$f_{i,j} \rightarrow \texttt{f[i][j]}$$

(list)

```
>>> N=3
>>> f=[[0.0 for j in range(i+1)]
...         for i in range(N+1)]
>>> f
[[0.0], [0.0, 0.0], [0.0, 0.0, 0.0], [0.0, 0.0, 0.0, 0.0]]
```

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$f_{0,0}$			
$f_{1,0}$	$f_{1,1}$		
$f_{2,0}$	$f_{2,1}$	$f_{2,2}$	
$f_{3,0}$	$f_{3,1}$	$f_{3,2}$	$f_{3,3}$

(Numpy ndarray)

$f_{i,j} \rightarrow$ `f[i,j]`

$f_{i,j} \rightarrow$ `f[i][j]`

```
import numpy as np
N=3
f=np.zeros((N+1,N+1))
```

```
>>> import numpy as np
>>> N=3
>>> f=np.zeros((N+1,N+1))
>>> f
array([[ 0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.]])
```

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2. $f_{N,j} = \max\left(0, Su^j d^{N-j} - K\right)$ (Call), $f_{N,j} = \max\left(0, K - Su^j d^{N-j}\right)$ (Put), for $j = 0, 1, \ldots, N$

$$f_{i,j} \rightarrow \texttt{f[i][j]}$$

```
for j in range(N+1):
    fc[N][j]=max(0, S*(u**j)*(d**(N-j))-K)
    fp[N][j]=max(0, K-S*(u**j)*(d**(N-j)))
```

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3. $f_{i,j} = e^{-r\Delta t}[p \cdot f_{i+1,j+1} + (1-p) \cdot f_{i+1,j}]$ for $i = N-1, N-2, \ldots, 1, 0; j = 0, 1, \ldots, i$

$$f_{i,j} \rightarrow \texttt{f[i][j]}$$

```
p1=1-p
ert=math.exp(-r*deltaT)

for i in range(N-1,0-1,-1):
    for j in range(i+1):
        fc[i][j]=ert*(p*fc[i+1][j+1]+p1*fc[i+1][j])
        fp[i][j]=ert*(p*fp[i+1][j+1]+p1*fp[i+1][j])
```

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```
# nested list with for loop
import math
def V_binomial_tree_py(S,K,r,q,tau,sigma,N=100):
    # 1.
    deltaT=tau/N
    u=math.exp(sigma*math.sqrt(deltaT))
    d=1/u
    p=(math.exp((r-q)*deltaT)-d)/(u-d)
    # 2.
    fc=[[0.0 for j in range(i+1)] for i in range(N+1)]
    fp=[[0.0 for j in range(i+1)] for i in range(N+1)]

    for j in range(N+1):
        fc[N][j]=max(0, S*(u**j)*(d**(N-j))-K)
        fp[N][j]=max(0, K-S*(u**j)*(d**(N-j)))
    # 3.
    p1=1-p
    ert=math.exp(-r*deltaT)

    for i in range(N-1,0-1,-1):
        for j in range(i+1):
            fc[i][j]=ert*(p*fc[i+1][j+1]+p1*fc[i+1][j])
            fp[i][j]=ert*(p*fp[i+1][j+1]+p1*fp[i+1][j])
    # 4.
    c=fc[0][0]
    p=fp[0][0]
    return (c, p)

if __name__=='__main__':
    S=50.0; K=50.0; tau=183/365;
    sigma=0.4; r=0.04; q=0.01
    print('Call: {0[0]}, Put: {0[1]}'.format(
          V_binomial_tree_py(S,K,r,q,tau,sigma)))
```

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```
# nested list with list comprehension
import math
def V_binomial_tree_py2(S,K,r,q,tau,sigma,N=100):
    # 1.
    deltaT=tau/N
    u=math.exp(sigma*math.sqrt(deltaT))
    d=1/u
    p=(math.exp((r-q)*deltaT)-d)/(u-d)
    # 2.
    fc=[0]*(N+1)
    fp=[0]*(N+1)

    fc[N]=[max(0, S*(u**j)*(d**(N-j))-K) for j in range(N+1)]
    fp[N]=[max(0, K-S*(u**j)*(d**(N-j))) for j in range(N+1)]

    # 3.
    p1=1-p
    ert=math.exp(-r*deltaT)

    for i in range(N-1,0-1,-1):
        fc[i]=[ert*(p*fc[i+1][j+1]+p1*fc[i+1][j]) for j in range(i+1)]
        fp[i]=[ert*(p*fp[i+1][j+1]+p1*fp[i+1][j]) for j in range(i+1)]

    # 4.
    c=fc[0][0]
    p=fp[0][0]
    return (c, p)

if __name__=='__main__':
    S=50.0; K=50.0; tau=183/365;
    sigma=0.4; r=0.04; q=0.01
    print('Call: {0[0]}, Put: {0[1]}'.format(
          V_binomial_tree_py2(S,K,r,q,tau,sigma)))
```

(using list comprehension)

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2. $f_{N,j} = \max\left(0, Su^j d^{N-j} - K\right)$ (Call), $f_{N,j} = \max\left(0, K - Su^j d^{N-j}\right)$ (Put), for $j = 0, 1, \ldots, N$

(ndarray)

$$f_{i,j} \rightarrow \texttt{f[i,j]}$$

(Dr. Z: Remember ndarrays allow vectorized operations?

```
for j in range(N+1):
    fc[N,j]=max(0, S*(u**j)*(d**(N-j))-K)
    fp[N,j]=max(0, K-S*(u**j)*(d**(N-j)))
```

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```
for j in range(N+1):
    fc[N,j]=max(0, S*(u**j)*(d**(N-j))-K)
    fp[N,j]=max(0, K-S*(u**j)*(d**(N-j)))
```

```
j=np.arange(0,N+1,1);
Ss=S*(u**j)*(d**(N-j))
fc[N,:]=np.maximum(0, Ss-K)
fp[N,:]=np.maximum(0, K-Ss)
```

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numpy.maximum

numpy. **maximum** (*x1, x2, /, out=None, *, where=True, casting='same_kind', order='K', dtype=None, subok=True[, signature, extobj]*) = <*ufunc 'maximum'*>

Element-wise maximum of array elements.

Compare two arrays and returns a new array containing the element-wise maxima. If one of the elements being compared is a NaN, then that element is returned. If both elements are NaNs then the first is returned. The latter distinction is important for complex NaNs, which are defined as at least one of the real or imaginary parts being a NaN. The net effect is that NaNs are propagated.

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```
>>> import numpy as np
>>> np.maximum([2,3,4],[1,5,2])
array([2, 5, 4])
>>> np.maximum(np.eye(2),[0.5,2]) # broadcasting
array([[ 1. ,  2. ],
       [ 0.5,  2. ]])
>>> np.maximum([np.nan, 0, np.nan], [0, np.nan, np.nan])
__main__:1: RuntimeWarning: invalid value encountered in maximum
array([ nan,  nan,  nan])
>>> np.maximum(np.Inf, 1)
inf
```

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3. $f_{i,j} = e^{-r\Delta t}[p \cdot f_{i+1,j+1} + (1-p) \cdot f_{i+1,j}]$ for $i = N-1, N-2, \ldots, 1, 0; j = 0, 1, \ldots, i$

$$f_{i,j} \rightarrow \texttt{f[i,j]}$$

```
p1=1-p
ert=math.exp(-r*deltaT)

for i in range(N-1,0-1,-1):
    for j in range(i+1):
        fc[i,j]=ert*(p*fc[i+1,j+1]+p1*fc[i+1,j])
        fp[i,j]=ert*(p*fp[i+1,j+1]+p1*fp[i+1,j])
```

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```
for i in range(N-1,0-1,-1):
    for j in range(i+1):
        fc[i,j]=ert*(p*fc[i+1,j+1]+p1*fc[i+1,j])
        fp[i,j]=ert*(p*fp[i+1,j+1]+p1*fp[i+1,j])
```

(using vectorized operations)

```
for i in range(N-1,0-1,-1):
    fc[i,0:i+1]=ert*(p*fc[i+1,0+1:i+1+1]+p1*fc[i+1,0:i+1])
    fp[i,0:i+1]=ert*(p*fp[i+1,0+1:i+1+1]+p1*fp[i+1,0:i+1])
```

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```
# Numpy ndarray
import numpy as np


def V_binomial_tree_np(S,K,r,q,tau,sigma,N=100):
    # 1.
    deltaT=tau/N
    u=np.exp(sigma*np.sqrt(deltaT))
    d=1/u
    p=(np.exp((r-q)*deltaT)-d)/(u-d)
    # 2.
    fc=np.zeros((N+1,N+1))
    fp=np.zeros((N+1,N+1))
    j=np.arange(0,N+1,1);
    Ss=S*(u**j)*(d**(N-j))
    fc[N,:]=np.maximum(0, Ss-K)
    fp[N,:]=np.maximum(0, K-Ss)
    # 3.
    p1=1-p
    ert=np.exp(-r*deltaT)
    for i in range(N-1,0-1,-1):
        fc[i,0:i+1]=ert*(p*fc[i+1,0+1:i+1+1]+p1*fc[i+1,0:i+1])
        fp[i,0:i+1]=ert*(p*fp[i+1,0+1:i+1+1]+p1*fp[i+1,0:i+1])
    # 4.
    c=fc[0,0]
    p=fp[0,0]
    return (c, p)

if __name__=='__main__':
    S=50.0; K=50.0; tau=183/365;
    sigma=0.4; r=0.04; q=0.01
    print('Call: {0[0]}, Put: {0[1]}'.format(
                V_binomial_tree_np(S,K,r,q,tau,sigma)))
```

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Numpy

https://docs.scipy.org/doc/numpy/reference/routines.html

- numpy.array
- numpy.arange
- numpy.reshape or numpy.ndarray.reshape
- numpy.isin
- numpy.linspace
- numpy.ones, numpy.zeros, numpy.empty
- **numpy.exp, numpy.sqrt**
- **numpy.mean, numpy.std, numpy.sum, numpy.cumsum**
- numpy.maximum
- numpy.random
- numpy.append, numpy.concatenate
- ...(numpy.linalg)...

Next!

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numpy.random.randn

numpy.random.**randn**(*d0, d1, ..., dn*)

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

If positive, int_like or int-convertible arguments are provided, **randn** generates an array of shape `(d0, d1, ..., dn)`, filled with random floats sampled from a univariate "normal" (Gaussian) distribution of mean 0 and variance 1 (if any of the d_i are floats, they are first converted to integers by truncation). A single float randomly sampled from the distribution is returned if no argument is provided.

This is a convenience function. If you want an interface that takes a tuple as the first argument, use numpy.random.standard_normal instead.

Parameters: d0, d1, ..., dn : *int, optional*

The dimensions of the returned array, should be all positive. If no argument is given a single Python float is returned.

Returns: Z : *ndarray or float*

A `(d0, d1, ..., dn)`-shaped array of floating-point samples from the standard normal distribution, or a single such float if no parameters were supplied.

```
np.random.randn(3,4)
```

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numpy.random.standard_normal

numpy.random.standard_normal(*size=None*)

Draw samples from a standard Normal distribution (mean=0, stdev=1).

Parameters: size : *int or tuple of ints, optional*

Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns: out : *float or ndarray*

Drawn samples.

Examples

```
>>> s = np.random.standard_normal(8000)
>>> s
array([ 0.6888893 ,  0.78096262, -0.89086505, ...,  0.49876311, #random
       -0.38672696, -0.4685006 ])                               #random
>>> s.shape
(8000,)
>>> s = np.random.standard_normal(size=(3, 4, 2))
>>> s.shape
(3, 4, 2)
```

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np.random.standard_normal((3,4))

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numpy.random.random

numpy.random.random(*size=None*)

Return random floats in the half-open interval [0.0, 1.0).

Results are from the "continuous uniform" distribution over the stated interval. To sample $Unif[a, b), b > a$ multiply the output of random_sample by *(b-a)* and add *a*:

```
(b - a) * random_sample() + a
```

Parameters: **size** : *int or tuple of ints, optional*

Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns: **out** : *float or ndarray of floats*

Array of random floats of shape *size* (unless `size=None`, in which case a single float is returned).

```
np.random.random((3,4))
```


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Anaconda Prompt - python

```
Python 3.6.4 |Anaconda custom (64-bit)| (default, Jan 16 2018, 10:22:32) [MSC v.
1900 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> import numpy as np
>>> np.random.randn(3,4)                                          ✓✓✓✓✓
array([[-1.02131365, -1.29791614,  0.55330455,  0.98542153],
       [ 0.16692936,  1.0607157 , -0.1153914 , -0.5761791 ],
       [ 0.58843827, -0.64756756,  0.00655177, -0.08050467]])
>>> np.random.random((3,4))                                       ✓✓✓✓✓
array([[0.72118706, 0.07525318, 0.32270341, 0.77687445],
       [0.13139268, 0.9516377 , 0.65025612, 0.47259156],
       [0.9623561 , 0.01804862, 0.17095629, 0.99188202]])
>>> np.random.randn((3,4))                                        x x x x x
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "mtrand.pyx", line 1420, in mtrand.RandomState.randn
  File "mtrand.pyx", line 1550, in mtrand.RandomState.standard_normal
  File "mtrand.pyx", line 167, in mtrand.cont0_array
TypeError: 'tuple' object cannot be interpreted as an integer
>>> np.random.random(3,4)                                         x x x x x
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "mtrand.pyx", line 819, in mtrand.RandomState.random_sample
TypeError: random_sample() takes at most 1 positional argument (2 given)
>>>
```


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numpy.append

numpy.append(*arr*, *values*, *axis=None*) [source]

Append values to the end of an array.

Parameters:

arr : *array_like*

Values are appended to a copy of this array.

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values : *array_like*

These values are appended to a copy of *arr*. It must be of the correct shape (the same shape as *arr*, excluding *axis*). If *axis* is not specified, *values* can be any shape and will be flattened before use.

axis : *int, optional*

The axis along which *values* are appended. If *axis* is not given, both *arr* and *values* are flattened before use.

Returns:

append : *ndarray*

A copy of *arr* with *values* appended to *axis*. Note that append does not occur in-place: a new array is allocated and filled. If *axis* is None, *out* is a flattened array.

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Anaconda Prompt - python

```
(base) C:\Users\ybzhao>python
Python 3.6.4 |Anaconda custom (64-bit)| (default, Jan 16 2018, 10:22:32) [MSC v.
1900 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> import numpy as np
>>> np.append([1,2,3],[[4,5,6],[7,8,9]])
array([1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> np.append([[1,2,3],[4,5,6]],[[7,8,9]],axis=0)
array([[1, 2, 3],
       [4, 5, 6],
       [7, 8, 9]])
>>> np.append([[1,2,3],[4,5,6]],[[7],[8]],axis=1)
array([[1, 2, 3, 7],
       [4, 5, 6, 8]])
>>> np.append([[1,2,3],[4,5,6]],[7,8,9],axis=0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "C:\Continuum\anaconda3\lib\site-packages\numpy\lib\function_base.py", li
ne 5166, in append
    return concatenate((arr, values), axis=axis)
ValueError: all the input arrays must have same number of dimensions
>>>
```

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numpy.concatenate

numpy.**concatenate**(*(a1, a2, ...), axis=0, out=None*)

Join a sequence of arrays along an existing axis.

Parameters: **a1, a2, ... :** ***sequence of array_like***

The arrays must have the same shape, except in the dimension corresponding to *axis* (the first, by default).

axis : ***int, optional***

The axis along which the arrays will be joined. If axis is None, arrays are flattened before use. Default is 0.

out : ***ndarray, optional***

If provided, the destination to place the result. The shape must be correct, matching that of what concatenate would have returned if no out argument were specified.

Returns: **res :** ***ndarray***

The concatenated array.

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```
np.append([1, 2], [3, 4]) ⇔ np.concatenate(([1,2], [3,4]))
```

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numpy.random.seed

numpy.random.seed(*seed=None*)

Seed the generator.

This method is called when RandomState is initialized. It can be called again to re-seed the generator. For details, see RandomState.

Parameters: seed : *int or 1-d array_like, optional*

Seed for RandomState. Must be convertible to 32 bit unsigned integers.

Seed Number

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```
>>> import numpy as np
>>> np.random.seed(0)
>>> print(np.random.randn(2))
[1.76405235 0.40015721]
>>> print(np.random.randn(2))
[0.97873798 2.2408932 ]
>>> np.random.seed(0)
>>> print(np.random.randn(4))
[1.76405235 0.40015721 0.97873798 2.2408932 ]
```

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(See sample exam paper, Question 6)

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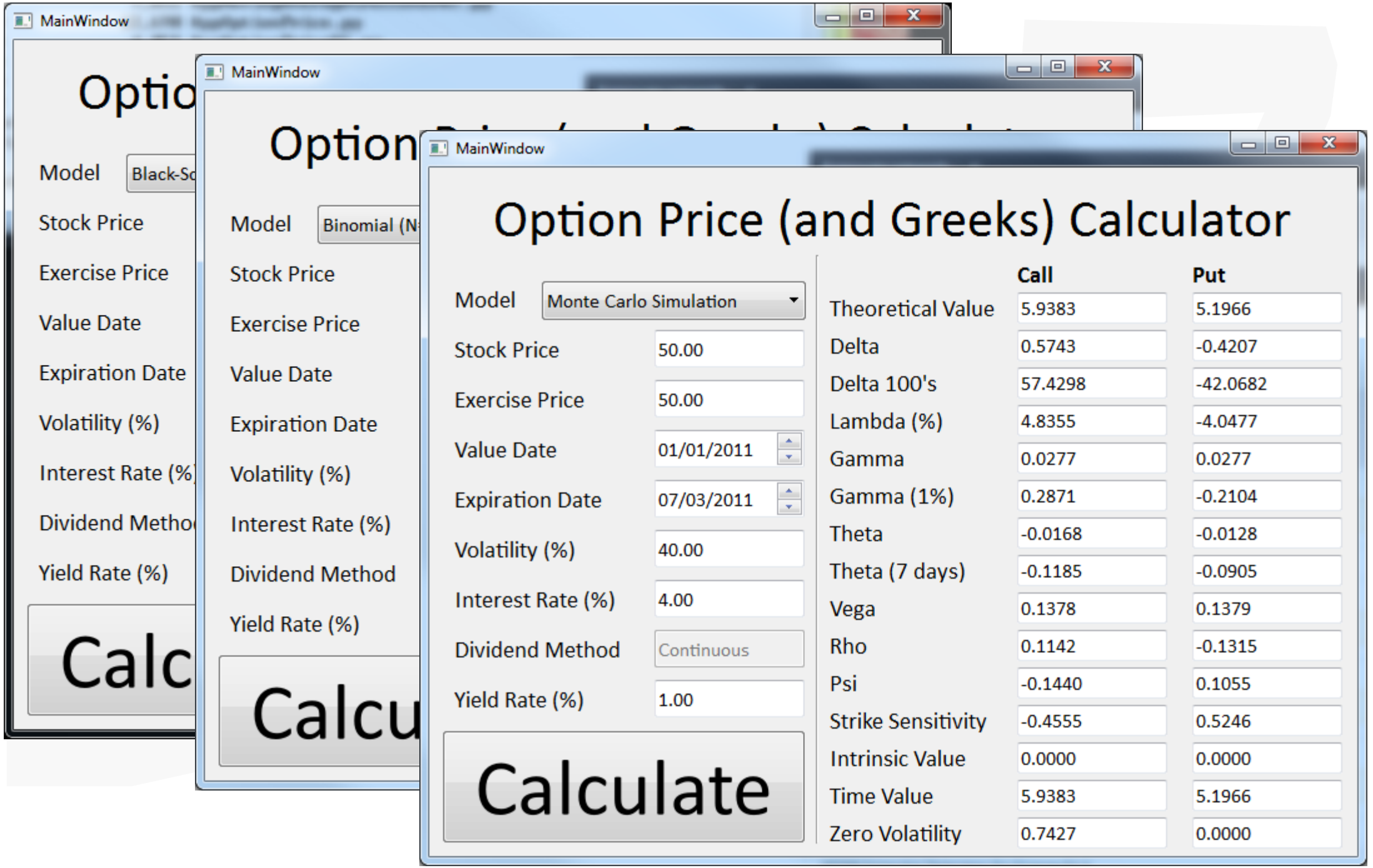

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