

Pandas

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Basics

- Tool for data sets:
 - Analysis
 - Aggregation
 - Cleaning
 - Merging
 - Pivoting

Basics

- Where to get Pandas
 - Install via pip or homebrew
 - Use a distribution like Anaconda
 - Comes with Jupyter (aka iPython) Notebooks which are popular among data scientists

Pandas Overview

- Build on top of NumPy
 - Uses DataFrame (and Series) as fundamental data structure
- Supports
 - attaching labels to data
 - working with missing data
 - grouping
 - pivoting

Pandas Overview

- Usually imported as pd

Pandas Series

- A one-dimensional array
 - Can hold data of any type
 - Axis labels are called index
 - Works a bit like a dictionary

Pandas Series

- Can create using a scalar that is going to be repeated.
 - An index needs to be explicitly provided

```
pd.Series(5, ['a', 'b', 'c'])
```

```
a      5  
b      5  
c      5  
dtype: int64
```

Pandas Series

- Default Index is `np.arange(n)`, i.e. the numbers from 0, ...,
 - Example:

```
import pandas as pd
```

```
lit_it_isl = pd.Series(['elba', 'ischia', 'capri'])
```

- creates a Pandas Series

```
0      elba  
1     ischia  
2     capri  
dtype: object
```


Pandas Series

- dtype is the type of the Series
 - In this case, it is object because the data consists of strings

Pandas Series

- We can create an explicit index

```
labels = ['nice', 'nicer', 'nicest']  
data = ['elba', 'ischia', 'capri']  
lit_it_isl = pd.Series(data = data, index = labels)
```

- When we print out the result, we now see the index

```
      nice      elba  
      nicer     ischia  
      nicest     capri  
dtype: object
```

Pandas Series

- There are a number of data sources
 - Can create using a Python list
 - Can create using a dictionary

```
isl_dic={'nice':'elba', 'nicer':'ischia', 'nicest':'capri'}  
>>> lit_it_isl = pd.Series(isl_dic)
```

- Can create using a numpy array

```
pd.Series(np.random.uniform(0,1,5))  
0      0.644686  
1      0.812248  
2      0.496581  
3      0.876687  
4      0.280538  
dtype: float64
```

Pandas Series

- There is no limit imposed on the objects that can be stored
 - For example, we can store functions

```
pd.Series([random.uniform, print, len, "".join])
0    <bound method Random.uniform of <random.Random...
1                                     <built-in function print>
2                                     <built-in function len>
3    <built-in method join of str object at 0x104c3...
dtype: object
```

Pandas Series

- To retrieve a data value, we give it the index

```
lit_it_isl['nicer']  
'ischia'
```

Pandas Series

- The slice operation works differently

```
ex = pd.Series(['capri', 'ischia', 'elba',  
               'giglia', 'giannutri'],  
              index=list('abcde'))
```

```
a      capri  
b      ischia  
c      elba  
d      giglia  
e      giannutri  
dtype: object
```

Pandas Series

- Both the beginning and the end are included

```
ex['b':'d']  
b      ischia  
c      elba  
d      giglia  
dtype: object
```

Pandas Series

- Slices:
 - Like in NumPy, a slice only creates a **reference**
 - If you change a slice, you change the original
 - Example: Create a series

```
ex = pd.Series(['capri', 'ischia', 'elba', 'gigliola',  
'giannutri'], index=list('abcde'))
```

- Create a slice

```
my_slice = ex['b':'d']
```


Pandas Series

- Slices are references (cont.)

- Change the slice

```
my_slice = ex['b':'d']
```

- The original (as well as the slice) have changed

```
ex
a      capri
b      ischia
c      zanone
d      giglia
e      giannutri
dtype: object
```

Pandas Series

- If an index is not in the series, a KeyError is raised

```
ex['h']  
Traceback (most recent call last):  
...  
  
KeyError: 'h'  
>>>
```

Pandas Series

- As we have seen, we can use indexing to update a value

Pandas Series

- Use `head()` and `tail()` to access beginning and end of a series

```
df = pd.Series(['bonn', 'koeln', 'duesseldorf',  
               'essen', 'aachen', 'dortmund'])  
>>> df.head(2)  
0      bonn  
1      koeln  
dtype: object  
>>> df.tail(2)  
4      aachen  
5      dortmund  
dtype: object
```

Pandas Series

- In addition to explicit indexing with the `[]` operator
 - Can use subsets referring explicit indices (offsets)
 - with the `.loc` operator
 - with the `.iloc`

Pandas Series

- Example:
 - Define a series based on the Olympic ice-hockey tournament 2018

```
icehockey2018 = pd.Series({'russia': 1, 'germany': 2,  
'canada': 3, 'czech': 4, 'sweden': 5})
```

```
>>> icehockey2018
```

```
russia      1  
germany     2  
canada      3  
czech       4  
sweden      5  
dtype: int64
```

Pandas Series

- Example
 - Using `.loc` with a list of labels

```
icehockey2018.loc[['russia', 'sweden']]  
russia      1  
sweden      5  
dtype: int64
```

Pandas Series

- Example
 - Accessing a sub-series with `iloc` by numerical index

```
icehockey2018.iloc[1:3]
```

```
germany      2  
canada       3  
dtype: int64
```


Pandas Series

- Example
 - Using a series of integer indices with `.iloc`

```
icehockey2018.iloc[[1, 2, 3, 4]]
```

```
germany      2  
canada       3  
czech        4  
sweden       5  
dtype: int64
```

Pandas Series

- Just as for numpy arrays, we can use operations between series
- These are dependent on labels

Pandas Series

- Example: Olympic Ice-hockey results

```
icehockey2018 = pd.Series({'russia': 1, 'germany': 2,  
'canada': 3, 'czech': 4, 'sweden':5})
```

```
>>> icehockey2018
```

```
russia      1  
germany     2  
canada      3  
czech       4  
sweden      5  
dtype: int64
```

Pandas Series

```
icehockey2014= pd.Series({'canada':1, 'sweden':2,  
'finland':3, 'usa': 4, 'czech':5})
```

Pandas Series

- Calculate the average, and we get lot's of Not a Number (NaN)

```
(icehockey2018+icehockey2014) / 2
```

```
canada      2.0  
czech       NaN  
finland     NaN  
germany     NaN  
russia      3.0  
sweden      3.5  
usa         NaN  
dtype: float64
```

Pandas Dataframe

- A two-dimensional table

```
example = pd.DataFrame(np.random.randn(5, 4),  
                        ['a', 'b', 'c', 'd', 'e'], ['w', 'x', 'y', 'z'])
```

```
>>> example
```

	w	x	y	z
a	0.968015	-0.292712	-0.456712	0.478160
b	-0.182741	0.801120	1.466134	0.883498
c	0.497248	-0.170697	-0.487031	3.018604
d	0.948902	-0.878197	0.796428	-0.479922
e	-1.420614	0.200272	1.111076	-0.283730

Pandas Dataframe

- Access to data uses the bracket [] operation
 - Example (continued):

```
example['w']
```

```
a    0.968015
```

```
b   -0.182741
```

```
c    0.497248
```

```
d    0.948902
```

```
e   -1.420614
```

```
Name: w, dtype: float64
```

Pandas Dataframe

- Example (continued)

```
example[['w', 'z']]
```

	w	z
a	0.968015	0.478160
b	-0.182741	0.883498
c	0.497248	3.018604
d	0.948902	-0.479922
e	-1.420614	-0.283730

Pandas Dataframe

- The rows are given by an "index"
- Columns can be added

```
example['summa'] = example['w'] + example['x'] +  
                    example['y'] + example['z']
```

	w	x	y	z	summa
a	0.968015	-0.292712	-0.456712	0.478160	0.696751
b	-0.182741	0.801120	1.466134	0.883498	2.968011
c	0.497248	-0.170697	-0.487031	3.018604	2.858124
d	0.948902	-0.878197	0.796428	-0.479922	0.387211
e	-1.420614	0.200272	1.111076	-0.283730	-0.392997

Pandas Dataframe

- Columns can also be deleted
 - Use drop
 - drop has a parameter axis
 - Axis 0: drop an index
 - Axis 1: drop a column

Pandas Dataframe

- Example:
 - Drop the first column with label 'w'

```
example.drop('w', axis=1)
```

	x	y	z	summa
a	-0.292712	-0.456712	0.478160	0.696751
b	0.801120	1.466134	0.883498	2.968011
c	-0.170697	-0.487031	3.018604	2.858124
d	-0.878197	0.796428	-0.479922	0.387211
e	0.200272	1.111076	-0.283730	-0.392997

Pandas Dataframe

- Example (continued)
 - But this does not change the original dataframe

example

	w	x	y	z	summa
a	0.968015	-0.292712	-0.456712	0.478160	0.696751
b	-0.182741	0.801120	1.466134	0.883498	2.968011
c	0.497248	-0.170697	-0.487031	3.018604	2.858124
d	0.948902	-0.878197	0.796428	-0.479922	0.387211
e	-1.420614	0.200272	1.111076	-0.283730	-0.392997

Pandas Dataframe

- To make the change to the original, need to specify that the inplace parameter is True
 - Otherwise, we are just making a copy
 - This is really a bit of a headache
 - Need to lookup manual to figure out whether an operation makes a copy or changes the original

Pandas Dataframe

- Example: With inplace being True, we change the dataframe itself

```
example.drop('w', axis=1, inplace=True)
```

```
example
```

	x	y	z	summa
a	-0.292712	-0.456712	0.478160	0.696751
b	0.801120	1.466134	0.883498	2.968011
c	-0.170697	-0.487031	3.018604	2.858124
d	-0.878197	0.796428	-0.479922	0.387211
e	0.200272	1.111076	-0.283730	-0.392997

Pandas Dataframe Selftest

- Drop a row from an example dataframe

Pandas Dataframe

Self-test Solution

- Just use `axis = 0`

```
example.drop('e', axis=0, inplace = True)
```

	x	y	z	summa
a	-0.292712	-0.456712	0.478160	0.696751
b	0.801120	1.466134	0.883498	2.968011
c	-0.170697	-0.487031	3.018604	2.858124
d	-0.878197	0.796428	-0.479922	0.387211

Pandas Dataframe

- How to select rows
 - Use the .loc operation

```
example.loc[['a', 'c']]
```

	x	y	z	summa
a	-0.292712	-0.456712	0.478160	0.696751
c	-0.170697	-0.487031	3.018604	2.858124

- Use the .iloc operation

Pandas Dataframe

- Just as for numpy arrays, can use multi-indices

```
example.loc[['a', 'c'], ['x', 'y']]
```

```
          x          y  
a -0.292712 -0.456712  
c -0.170697 -0.487031
```

Pandas Dataframe

- Just as in numpy, we can create boolean selections

```
boolex = example > 1
```

```
      x      y      z  summa
a  False False False  False
b  False  True False   True
c  False False  True   True
d  False False False  False
```

Pandas Dataframe

- And use the boolean selection to select values from the frame
- Behavior differs from numpy

```
example[boolex]
```

	x	y	z	summa
a	NaN	NaN	NaN	NaN
b	NaN	1.466134	NaN	2.968011
c	NaN	NaN	3.018604	2.858124
d	NaN	NaN	NaN	NaN

Pandas Dataframe

- Or do so in a single step

```
example[example>1]
```

	x	y	z	summa
a	NaN	NaN	NaN	NaN
b	NaN	1.466134	NaN	2.968011
c	NaN	NaN	3.018604	2.858124
d	NaN	NaN	NaN	NaN

- Notice that the numbers not fitting are NaNs

Pandas Dataframe

- A more typical selection uses a column
- Example: The example dataframe

	x	y	z	summa
a	-0.292712	-0.456712	0.478160	0.696751
b	0.801120	1.466134	0.883498	2.968011
c	-0.170697	-0.487031	3.018604	2.858124
d	-0.878197	0.796428	-0.479922	0.387211

- Select the rows where the 'z' value is positive:

```
example[example['z']>0]
```

	x	y	z	summa
a	-0.292712	-0.456712	0.478160	0.696751
b	0.801120	1.466134	0.883498	2.968011
c	-0.170697	-0.487031	3.018604	2.858124

Pandas Dataframe

- Compound Conditions
 - We can combine conditions for selection
 - Unlike classical Python, we **cannot** use and / or
 - Need to use single ampersand or vertical bar & | for and, or

Pandas Dataframe

- Example:
 - Create a random frame

```
example = pd.DataFrame(np.random.randn(4, 3),  
                        ['a', 'b', 'c', 'd'], ['x', 'y', 'z'])
```

```
print(example)
```

```
      x      y      z  
a  1.411543  2.160431 -1.891248  
b -1.062715 -0.831573  0.440250  
c -1.157673 -0.963104  1.817167  
d -0.162145  0.140711 -0.016717
```


Pandas Dataframe

- Select the rows where 'x' is negative and 'z' is positive

	x	y	z
a	1.411543	2.160431	-1.891248
b	-1.062715	-0.831573	0.440250
c	-1.157673	-0.963104	1.817167
d	-0.162145	0.140711	-0.016717

- These are rows b and c

Pandas Dataframe

- Use the ampersand
 - Parentheses are necessary

```
new_frame = example[(example['x']<0) & (example['z']>0)]  
print(new_frame)
```

```
      x      y      z  
b -1.062715 -0.831573  0.440250  
c -1.157673 -0.963104  1.817167
```

Pandas Dataframe

- We can make our own Boolean conditions
 - We do so by using the dataframe .apply method that applies a function along an axis of the data frame
 - axis=0: index
 - Applies function to each column
 - default
 - axis=1: columns
 - Applies function to each row

Pandas Dataframe

- Example:
 - Find all entries that have US somewhere in the 'company_name' of a dataframe df

```
return df[df[company_name].apply(  
    lambda x: 'US' in x)]
```

- Here the function returns a Boolean value

Pandas Dataframe

- We can change the index
 - Example: Import the following .csv file

```
First Name, Last Name, Position, Year
Salmon, Chase, CJUS, 1865
Salmon, Chase, CJUS, 1866
Salmon, Chase, CJUS, 1867
Salmon, Chase, CJUS, 1868
Salmon, Chase, CJUS, 1869
Ulysses, Grant, PotUS, 1869
Ulysses, Grant, GUSA, 1866
Ulysses, Grant, GUSA, 1867
Ulysses, Grant, GUSA, 1868
Andrew, Johnson, PotUS, 1865
Andrew, Johnson, PotUS, 1866
Andrew, Johnson, PotUS, 1867
Andrew, Johnson, PotUS, 1868
Andrew, Johnson, PotUS, 1869
William, Sherman, GUSA, 1869
```

Pandas Dataframe

- Import using `read_csv`

```
ex = pd.read_csv('example.csv')
```

	First Name	Last Name	Position	Year
0	Salmon	Chase	CJUS	1865
1	Salmon	Chase	CJUS	1866
2	Salmon	Chase	CJUS	1867

Pandas Dataframe

- Create a new column
 - Needs to have the same number of elements as there are data rows:

```
ex['entry']=['a','b','c','d','e','f','g','h','i',  
            'j','k','l','m','n','o']
```

	First Name	Last Name	Position	Year	entry
0	Salmon	Chase	CJUS	1865	a
1	Salmon	Chase	CJUS	1866	b
2	Salmon	Chase	CJUS	1867	c
3	Salmon	Chase	CJUS	1868	d

Pandas Dataframe

- Now set the index to this new column

```
ex.set_index('entry')
```

```
entry
```

	First Name	Last Name	Position	Year
a	Salmon	Chase	CJUS	1865
b	Salmon	Chase	CJUS	1866
c	Salmon	Chase	CJUS	1867
d	Salmon	Chase	CJUS	1868

- add parameter `inplace = True` if these changes are intended to be permanent

Example:
Salaries in San Francisco

Example

- Use Salaries.csv with salary data from municipal employees in San Francisco
- San Francisco is one of the most expensive cities in the country

Example

- Look at the raw file first:

```
def get_head():  
    with open('Salaries.csv') as infile:  
        line_nr = 0  
        for line in infile:  
            print(line)  
            line_nr+=1  
            if line_nr > 5:  
                break
```

Example

- Result: Column header

```
Id,EmployeeName,JobTitle,BasePay,OvertimePay,OtherPay,Benefits>TotalPay>TotalPayBenefits,Year,Notes,Agency,Status
```

```
1,NATHANIEL FORD,GENERAL MANAGER-METROPOLITAN TRANSIT  
AUTHORITY,167411.18,0.0,400184.25,,567595.43,567595.43,2011,,San Francisco,
```

```
2,GARY JIMENEZ,CAPTAIN III (POLICE  
DEPARTMENT),155966.02,245131.88,137811.38,,538909.28,538909.28,2011,,San Francisco,
```

```
3,ALBERT PARDINI,CAPTAIN III (POLICE  
DEPARTMENT),212739.13,106088.18,16452.6,,335279.91,335279.91,2011,,San Francisco,
```

```
4,CHRISTOPHER CHONG,WIRE ROPE CABLE MAINTENANCE  
MECHANIC,77916.0,56120.71,198306.9,,332343.61,332343.61,2011,,San Francisco,
```

```
5,PATRICK GARDNER,"DEPUTY CHIEF OF DEPARTMENT,(FIRE  
DEPARTMENT)",134401.6,9737.0,182234.59,,326373.19,326373.19,2011,,San Francisco,
```

Example

- Pandas has functions to read csv files

```
sal = pd.read_csv('Salaries.csv', low_memory = False)
```

- Remove the limit on columns to be displayed

```
pd.set_option('display.max_columns', None)
```

- Read first line of data

```
>>> sal.iloc[[0], [0, 1, 2, 3, 4, 5]]
```

```
   Id  EmployeeName  JobTitle \
0   1  NATHANIEL FORD  GENERAL MANAGER-METROPOLITAN
TRANSIT AUTHORITY
```

```
   BasePay  OvertimePay  OtherPay
0  167411.18           0.0  400184.25
```

Example

- Sometimes, we will need converters in order to read data
 - Let's write a converter that converts to float or NaN

```
def my_converter(x):  
    try:  
        converted_value = float(x)  
    except ValueError:  
        converted_value = np.NaN  
    return converted_value
```


Example

- Now we got the salary database as a Pandas datasheet

```
sal = get_data()
```


Example

- Who is getting paid a lot?

```
def high_paid():  
    sal = get_data()  
    return sal[sal['BasePay']>300000]  
[['EmployeeName', 'BasePay', 'TotalPayBenefits',  
'JobTitle', 'Year']]
```

Example

- What is the mean salary?

```
>>>     sal = get_data()
>>>     return sal['TotalPay'].mean()
74768.32197169267
```

Example

- Who is getting paid the most?
 - For this we need to look up the argmin function and find it is deprecated.
 - The new function is `idxmax()`
 - We first find the index of the person with the biggest 'TotalPay'
 - And then use `iloc` to print it out

```
sal.iloc[sal['TotalPay'].idxmax()]
```

Example

- And who is getting paid least?

```
sal.iloc[sal['TotalPay'].idxmin()]
```

Id	148654
EmployeeName	Joe Lopez
JobTitle	Counselor, Log Cabin Ranch
BasePay	0
OvertimePay	0
OtherPay	-618.13
Benefits	0
TotalPay	-618.13
TotalPayBenefits	-618.13
Year	2014
Notes	NaN
Agency	San Francisco
Status	NaN

Example

- And who is getting paid least?

```
>>> sal.iloc[sal['BasePay'].idxmin()]
Id          72833
EmployeeName  Irwin Sidharta
JobTitle      Junior Clerk
BasePay      -166.01
OvertimePay   249.02
OtherPay       0
Benefits      6.56
TotalPay      83.01
TotalPayBenefits  89.57
Year          2012
Notes         NaN
Agency       San Francisco
Status        NaN
Name: 72832, dtype: object
```

Example

- Find all captains.
 - This is a boolean condition, which we can implement easiest by applying a function on the 'JobTitle' column

```
>>> sal[sal['JobTitle'].apply(lambda x: 'captain' in x.lower())]
['BasePay']
1          155966.02
2          212739.13
11         99722.00
17         140546.87
22         140546.88
...
116604     73355.21
120867     7660.00
122361      0.00
126588     68491.89
132232     61039.43
Name: BasePay, Length: 552, dtype: float64
```

Example

- And this is how much they make on average

```
>>> sal[sal['JobTitle'].apply(lambda x: 'captain' in
x.lower())]['BasePay'].mean()
152090.02520871142
```

Aggregation

- For analysis, need to aggregate information
 - Typical aggregation functions:
 - mean, standard deviation, max, min and other descriptive statistics

Aggregation

- Typical:
 - Split a data frame
 - Using a label or list of labels
 - Using a mapping / function
 - Done by the groupby method
 - Which returns a qu
 - Combine the results in each split using an aggregation function

Aggregation

- Example:
 - Download the file '30_Auto_theft.csv'
 - Load it into a data frame

```
import pandas as pd
import numpy as np
```

```
def get_data():
    return pd.read_csv('30_Auto_theft.csv')
```

Aggregation

- Example (continued)
 - This creates a group-by object
 - Can aggregate on the group-by object

```
auto = get_data()  
auto.groupby('Area_Name').mean()  
      [['Auto_Theft_Stolen']]
```

- Returns the mean for each 'Area_Name'

Combining Data Frames

- Can combine through
 - Concatenation
 - Merging
 - Joining

Repetition

- Pandas Series:
 - A one-dimensional array with an index
 - Can use the default index or create the index yourself

```
>>> import pandas as pd
>>> obj = pd.Series([4, 3, 8, 7])
>>> obj
0      4
1      3
2      8
3      7
dtype: int64
```

Repetition

- The values of the Pandas series are in property values.
- The index in property index

```
>>> obj.values
array([4, 3, 8, 7])
>>> obj.index
RangeIndex(start=0, stop=4, step=1)
```

Repetition

- Creating a series with explicit index

```
>>> obj = pd.Series([4,3,8,7], index = ['green',  
    'red', 'blue', 'yellow'])  
>>> obj  
green      4  
red        3  
blue       8  
yellow     7  
dtype: int64
```

Repetition

- Access to elements
 - `obj['green']`
 - Like NumPy, can use conditions

```
>>> obj[obj > 5]
blue      8
yellow    7
dtype: int64
```


Repetition

- Can treat a pandas series as a dictionary
- Vice versa, can use a dictionary to create a pandas series

```
>>> pd.Series(dicti)
Ahmedabad      5
Mumbai         18
Delhi          16
Kolkatta       14
Chennai        9
Bangalore      9
Hyderabad      8
Pune           5
dtype: int64
```

Repetition

- In this case, the series has the key:value pairs in the same order as they are in the dictionary
- We can control this by giving the indices explicitly

```
>>> popu = pd.Series(dicti, index =  
['Mumbai', 'Delhi', 'Kolkatta', 'Surat'])  
>>> popu  
Mumbai      18.0  
Delhi       16.0  
Kolkatta    14.0  
Surat       NaN
```

- Surat is not in the dictionary, therefore the NaN

Repetition

- We can check for null values with `pd.isnull`
 - Provided we imported pandas as `pd`

```
>>> pd.isnull (popu)
Mumbai      False
Delhi       False
Kolkatta    False
Surat       True
```

Repetition

- DataFrames are rectangular tables
 - Often created from a dictionary of arrays of equal size

```
populationdict = {  
'city': ['Kolkata', 'Kolkata', 'Kolkata', 'Mumbai',  
'Mumbai', 'Mumbai', 'Chennai', 'Chennai',  
'Chennai'],  
'years': [1901, 1951, 2001, 1901, 1951, 2001, 1901,  
1951, 2001],  
'population': [1.5, 4.7, 13.3, 1.0, 3.2, 16.4,  
.6, 1.5, 6.7]}
```

Repetition

- Without a specific index, all rows get a default index.

```
>>> frame = pd.DataFrame(populationdict)
```

```
>>> frame
```

	city	years	population
0	Kolkata	1901	1.5
1	Kolkata	1951	4.7
2	Kolkata	2001	13.3
3	Mumbai	1901	1.0
4	Mumbai	1951	3.2
5	Mumbai	2001	16.4
6	Chennai	1901	0.6
7	Chennai	1951	1.5
8	Chennai	2001	6.7

Repetition

- Can use either dictionary-like notation or the name of the columns in order to select a series

```
>>> frame['population']    >>> frame.population
0      1.5
1      4.7
2     13.3
3      1.0
4      3.2
5     16.4
6      0.6
7      1.5
8      6.7
```

Repetition

- We can add a column through assignment

```
>>> frame['debt'] = 0.0
```

```
>>> frame
```

	city	years	population	debt
0	Kolkata	1901	1.5	0.0
1	Kolkata	1951	4.7	0.0
2	Kolkata	2001	13.3	0.0
3	Mumbai	1901	1.0	0.0
4	Mumbai	1951	3.2	0.0
5	Mumbai	2001	16.4	0.0
6	Chennai	1901	0.6	0.0
7	Chennai	1951	1.5	0.0
8	Chennai	2001	6.7	0.0

Repetition

- We can change the index by simply assigning an array

```
>>> frame.index = ['a1', 'a2', 'a3', 'b1', 'b2', 'b3',  
'c1', 'c2', 'c3']
```

```
>>> frame
```

	city	years	population	debt
a1	Kolkata	1901	1.5	0.0
a2	Kolkata	1951	4.7	0.0
a3	Kolkata	2001	13.3	0.0
b1	Mumbai	1901	1.0	0.0
b2	Mumbai	1951	3.2	0.0
b3	Mumbai	2001	16.4	0.0
c1	Chennai	1901	0.6	0.0
c2	Chennai	1951	1.5	0.0
c3	Chennai	2001	6.7	0.0

Repetition

- Dataframes and Series work together
 - Can assign a series to a dataframe column
 - Holes are filled with NaN

```
frame.debt = pd.Series({'a1':0.0, 'a2':10.0, 'a3': 140.0, 'b1':  
0, 'b2': 12, 'c1': 0})
```

```
>>> frame
```

	city	years	population	debt
a1	Kolkata	1901	1.5	0.0
a2	Kolkata	1951	4.7	10.0
a3	Kolkata	2001	13.3	140.0
b1	Mumbai	1901	1.0	0.0
b2	Mumbai	1951	3.2	12.0
b3	Mumbai	2001	16.4	NaN
c1	Chennai	1901	0.6	0.0
c2	Chennai	1951	1.5	NaN
c3	Chennai	2001	6.7	NaN

Repetition

- We can also use a a nested dict of dicts
 - outer dictionary keys are columns
 - inner dictionary keys are rows

```
>>> population={'Kolkata':{1901: 1.5, 1951: 4.7, 2001: 13.3},
                'Mumbai':{1901:1.0, 1951: 3.2, 2001:16.4},
                'Chennai':{1901: 0.6, 1951: 1.5, 2001: 6.7}}
```

```
>>> popframe = pd.DataFrame(population)
```

```
>>> popframe
```

	Kolkata	Mumbai	Chennai
1901	1.5	1.0	0.6
1951	4.7	3.2	1.5
2001	13.3	16.4	6.7

Repetition

- Just like numpy, we can transpose
 - (switch rows and columns)

```
>>> popframe.T
          1901    1951    2001
Kolkata    1.5     4.7    13.3
Mumbai     1.0     3.2    16.4
Chennai    0.6     1.5     6.7
```

Repetition

- Index objects
 - Hold the name of the axis labels and other metadata
 - ```
>>> popframe.index
Int64Index([1901, 1951, 2001], dtype='int64')
```
  - Indices are immutable
  - Can also contain multiple values

# Reindex

- Reindex: Create a new object with the data *conformed* to the new index
  - Create a series

```
>>> allIndia = pd.Series([238, 316, 1071,
1380], index=[1901, 1951, 2001, 2020])
>>> allIndia
1901 238
1951 316
2001 1071
2020 1380
dtype: int64
```

# Reindex

- Now re-index

- 

```
>>> allIndia2 = allIndia.reindex([2020, 2001,
1976, 1951, 1926, 1901])
```

```
>>> allIndia2
```

```
2020 1380.0
```

```
2001 1071.0
```

```
1976 NaN
```

```
1951 316.0
```

```
1926 NaN
```

```
1901 238.0
```

```
dtype: float64
```

# Reindex

- This is particularly important for time series
  - We want to replace missing values using some interpolation
    - One possibility: forward fill: ffill
    - Or set a fillvalue

```
>>> allIndia2 = allIndia.reindex([1901, 1926, 1951, 1976, 2001, 2020],
method = 'ffill')
>>> allIndia2
1901 238
1926 238
1951 316
1976 316
2001 1071
2020 1380
dtype: int64
```

# Reindex

- Use interpolate to fill in missing values in a dataframe

```
>>> allIndia2 =
allIndia.reindex([1901, 1926, 1951,
1976, 2001, 2020])
>>> allIndia2.interpolate()
1901 238.0
1926 277.0
1951 316.0
1976 693.5
2001 1071.0
2020 1380.0
dtype: float64
```



# Dropping

- Remove rows with drop
  - Can remove columns if we use `axis=1` or `axis = 'columns'`

```
>>> allIndia2 = allIndia2.drop([1926, 1976])
>>> allIndia2
1901 238.0
1951 316.0
2001 1071.0
2020 1380.0
dtype: float64
```

# Indexing, Selection, Filtering

- Use bracket notation to find elements
- Can use slicing
  - But endpoints are included (in contrast to Python)

# Indexing, Selection, Filtering

- Access methods are `loc` (using names) and `iloc` (using integer indices)

```
>>> popframe
 Kolkata Mumbai Chennai
1901 1.5 1.0 0.6
1951 4.7 3.2 1.5
2001 13.3 16.4 6.7
```

```
>>> popframe.iloc[1]
Kolkata 4.7
Mumbai 3.2
Chennai 1.5
Name: 1951, dtype: float64
```

# Indexing, Selection, Filtering

- Access methods are `loc` (using names) and `iloc` (using integer indices)

```
>>> popframe
 Kolkata Mumbai Chennai
1901 1.5 1.0 0.6
1951 4.7 3.2 1.5
2001 13.3 16.4 6.7
```

```
popframe.loc[1901:1951]
 Kolkata Mumbai Chennai
1901 1.5 1.0 0.6
1951 4.7 3.2 1.5
```

# Indexing, Selection, Filtering

- Access methods are `loc` (using names) and `iloc` (using integer indices)
- Can get columns

```
>>> popframe
 Kolkata Mumbai Chennai
1901 1.5 1.0 0.6
1951 4.7 3.2 1.5
2001 13.3 16.4 6.7
```

```
popframe.loc[:, 'Chennai']
1901 0.6
1951 1.5
2001 6.7
Name: Chennai, dtype: float64
```

# Indexing, Selection, Filtering

- `df[val]` Select single column or sequence from dataframe
- `df.loc[val]` Select row(s)
- `df.loc[:,val]` Select column(s)
- `df.iloc[where]` Select row by position
- `df.iloc[:,where]` Select row by position
- `df.iloc[rwhere, cwhere]` Select row and column by position
- `df.at[label1, label2]` Select single scalar value

# Operations

- General principle:
  - Only operate on values with the same labels
  - Other values are filled with NaN

# Operations

- Example:
  - Create two dataframes with different dimensions

```
>>> df1 = pd.DataFrame(np.arange(12).reshape((3,4)), columns = list('abcd'))
>>> df2 = pd.DataFrame(np.arange(20).reshape((4,5)), columns =
list('abcde'))
```

```
>>> df1
```

|   | a | b | c  | d  |
|---|---|---|----|----|
| 0 | 0 | 1 | 2  | 3  |
| 1 | 4 | 5 | 6  | 7  |
| 2 | 8 | 9 | 10 | 11 |

```
>>> df2
```

|   | a  | b  | c  | d  | e  |
|---|----|----|----|----|----|
| 0 | 0  | 1  | 2  | 3  | 4  |
| 1 | 5  | 6  | 7  | 8  | 9  |
| 2 | 10 | 11 | 12 | 13 | 14 |
| 3 | 15 | 16 | 17 | 18 | 19 |



# Operations

- Example: Missing values lead to NaN

```
>>> df1 + df2
 a b c d e
0 0.0 2.0 4.0 6.0 NaN
1 9.0 11.0 13.0 15.0 NaN
2 18.0 20.0 22.0 24.0 NaN
3 NaN NaN NaN NaN NaN
```

# Operations

- We can avoid the NaN by giving a fill value in the add method

```
>>> df2.add(df1, fill_value = 2.5)
 a b c d e
0 0.0 2.0 4.0 6.0 6.5
1 9.0 11.0 13.0 15.0 11.5
2 18.0 20.0 22.0 24.0 16.5
3 17.5 18.5 19.5 20.5 21.5
```

# Operations

- Numpy allows operations between arrays of different dimensions
- Pandas similarly allows operations between Series and Dataframes
  - Using the same broadcasting rules
    - By default on the columns

```
df2.add(pd.Series([1.1, 2.2, 3.3], index=list('abc')))
```

|   | a    | b    | c    | d   | e   |
|---|------|------|------|-----|-----|
| 0 | 1.1  | 3.2  | 5.3  | NaN | NaN |
| 1 | 6.1  | 8.2  | 10.3 | NaN | NaN |
| 2 | 11.1 | 13.2 | 15.3 | NaN | NaN |
| 3 | 16.1 | 18.2 | 20.3 | NaN | NaN |

# ufuncs

- Can apply functions to all elements in a frame
  - Example: create a frame

```
>>> frame = pd.DataFrame(np.random.randn(4,3),
columns=['b','c','d'], index = ['Ar', 'Ca',
'Wi', 'Mi'])
```

```
>>> frame
```

|    | b         | c         | d        |
|----|-----------|-----------|----------|
| Ar | -0.112323 | 0.522181  | 1.238267 |
| Ca | 2.157295  | 0.004614  | 0.183871 |
| Wi | -0.154632 | 1.233146  | 0.098956 |
| Mi | 1.491147  | -0.036329 | 0.788408 |

# ufuncs

- Apply `np.abs` to the elements in the frame
- This **does not** change the frame unless we specify explicitly

```
>>> np.abs(frame)
 b c d
Ar 0.112323 0.522181 1.238267
Ca 2.157295 0.004614 0.183871
Wi 0.154632 1.233146 0.098956
Mi 1.491147 0.036329 0.788408
```

# Example

- Get Google stock price data in google.csv
  - Comma separated
  - Need to write converters for date and volume

```
Date,Open,High,Low,Close,Volume
1/3/2012,325.25,332.83,324.97,663.59,"7,380,500"
1/4/2012,331.27,333.87,329.08,666.45,"5,749,400"
1/5/2012,329.83,330.75,326.89,657.21,"6,590,300"
1/6/2012,328.34,328.77,323.68,648.24,"5,405,900"
1/9/2012,322.04,322.29,309.46,620.76,"11,688,800"
```

# Example

- First column has a date, but in standard form
- Volume has a comma in it
- Easiest to write custom converter

```
def convert_volume(x):
 temp=[]
 for letter in x:
 if letter in '0123456789':
 temp.append(letter)
 x = ''.join(temp)
 try:
 return int(x)
 except ValueError:
 return np.NaN
```

# Example

- 'Close' also needs a converter because of a bad value

```
def my_converter(x):
 try:
 return float(x)
 except ValueError:
 return np.NaN
```



# Example

- Now we can get the google data

```
my_df = pd.read_csv('google.csv',
 parse_dates=[0],
 index_col=0,
 converters={
 'Close': my_converter,
 'Volume': convert_volume}
)
```

# Example

- To make sure it works, we print out the info on the data frame

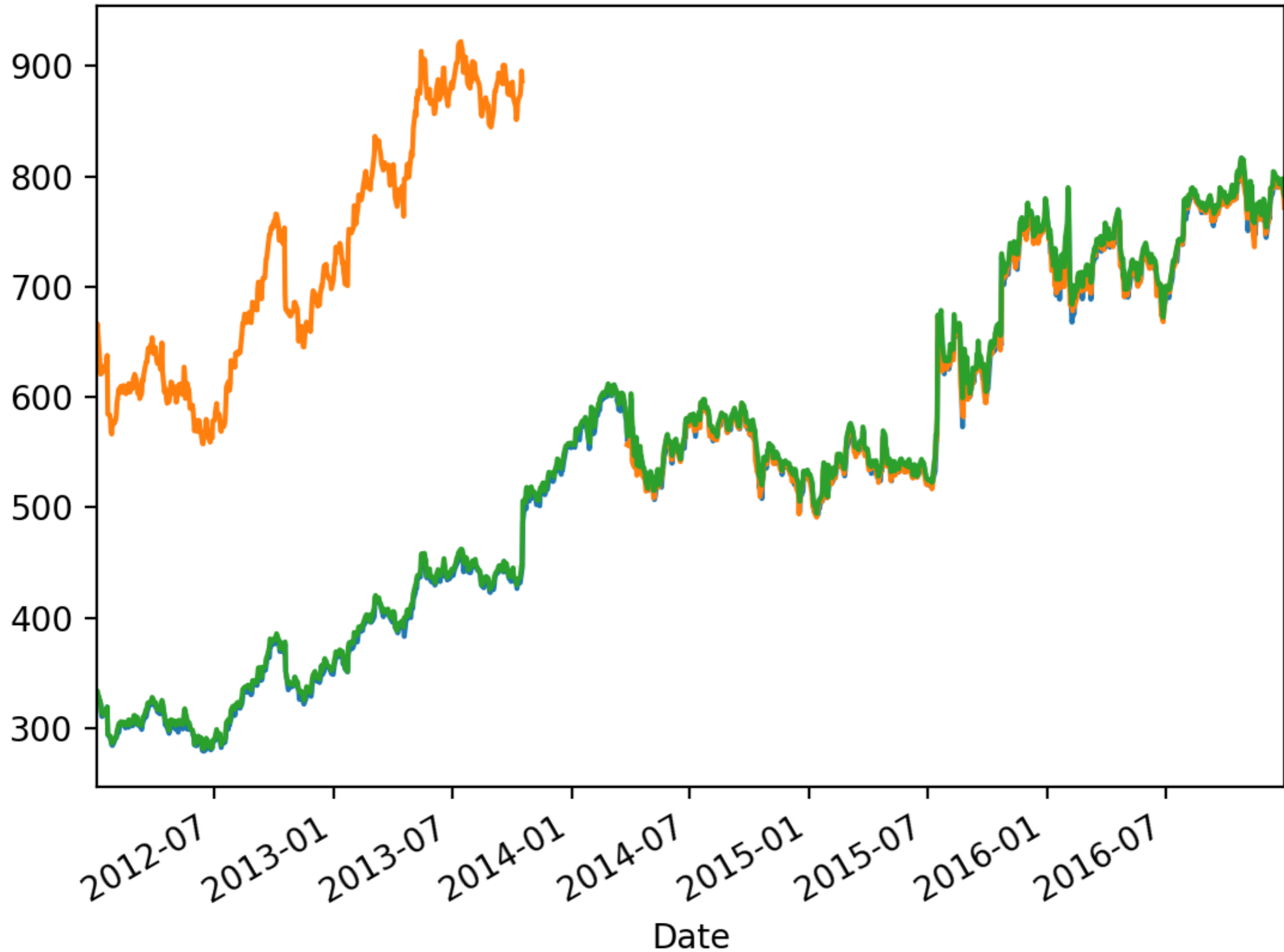
```
>>> google.info()
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 1258 entries, 2012-01-03 to 2016-12-30
Data columns (total 5 columns):
Open 1258 non-null float64
High 1258 non-null float64
Low 1258 non-null float64
Close 1149 non-null float64
Volume 1258 non-null int64
dtypes: float64(4), int64(1)
memory usage: 59.0 KB
```

# Example

- Pandas allows direct plotting

```
>>> google.Open.plot()
<matplotlib.axes._subplots.AxesSubplot object at
0x7faeeb4c3ee0>
>>> google.Close.plot()
<matplotlib.axes._subplots.AxesSubplot object at
0x7faeeb4c3ee0>
>>> google.High.plot()
<matplotlib.axes._subplots.AxesSubplot object at
0x7faeeb4c3ee0>
>>> plt.show
<function show at 0x7faeeb476f70>
>>> plt.show()
```

# Example



# Example

- We can also get the data from Apple

```
>>> apple = pd.read_csv('AAPL.csv', parse_dates=[0],
index_col=0)
>>> apple.info()
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 9848 entries, 1980-12-12 to 2020-01-02
Data columns (total 6 columns):
Open 9847 non-null float64
High 9847 non-null float64
Low 9847 non-null float64
Close 9847 non-null float64
Adj Close 9847 non-null float64
Volume 9847 non-null float64
dtypes: float64(6)
memory usage: 538.6 KB
```

# Example

- We now rename the Close columns

```
>>> google.rename(columns={'Close': 'GOOG'},
 inplace = True)
>>> apple.rename(columns={'Close': 'AAPL'},
 inplace = True)
```

# Example

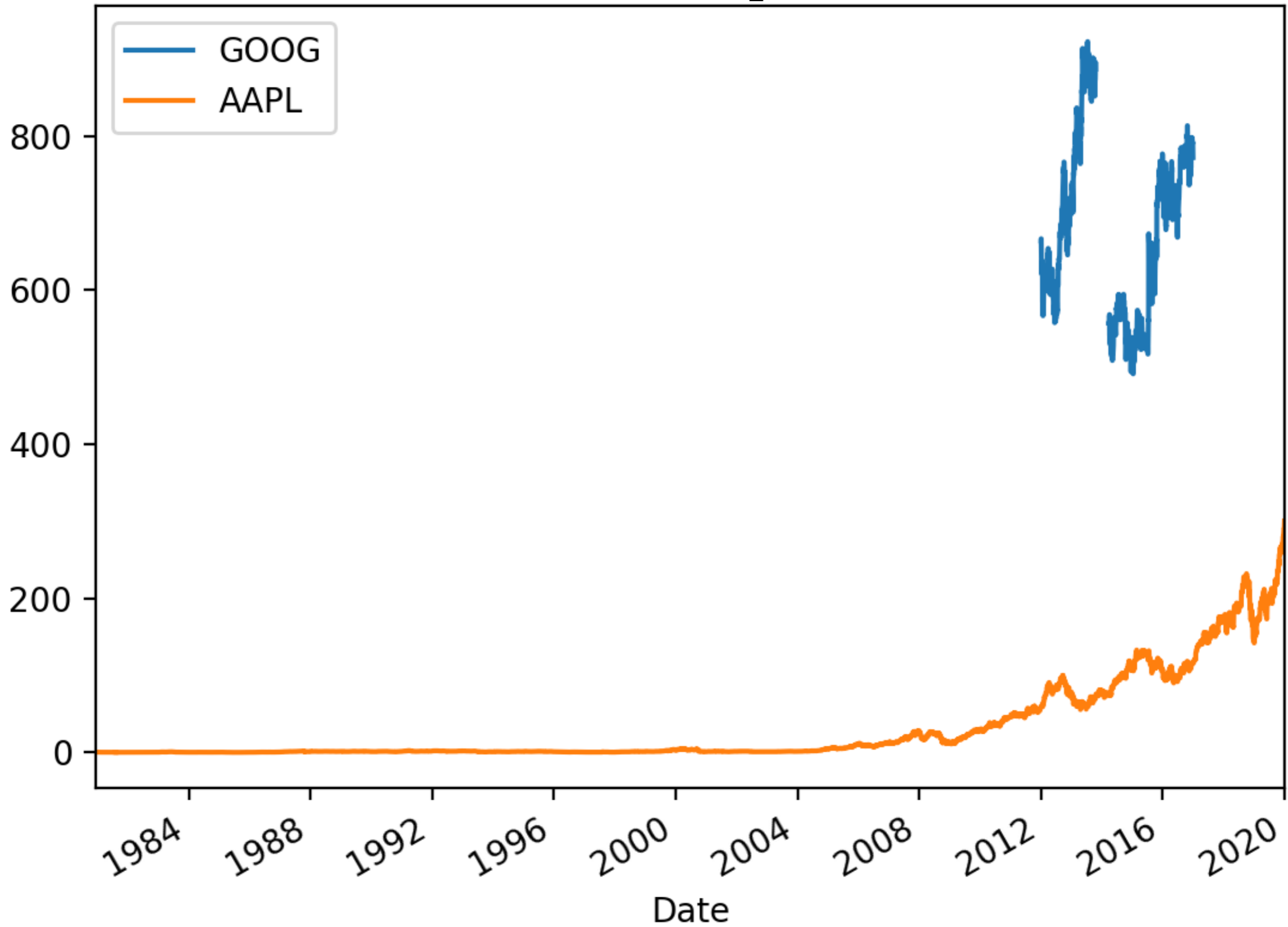
- Now we concatenate parts of the two data frames
  - `axis = 1` means we want to concatenate columns

```
>>> my_df = pd.concat([google['GOOG'], apple['AAPL']],
axis = 1)
>>> my_df.info()
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 9848 entries, 1980-12-12 to 2020-01-02
Data columns (total 2 columns):
GOOG 1149 non-null float64
AAPL 9847 non-null float64
dtypes: float64(2)
memory usage: 230.8 KB
```

# Example

- Let's see what we got:
  - ```
>>> my_df.plot()  
<matplotlib.axes._subplots.AxesSubplot object at  
0x7fd35892b7f0>  
>>> plt.show()
```


Example



Example

- That does not tell us too much (other than that Google had a stock split, as did Apple)
- First, we drop rows with NaN

```
>>> my_df.dropna(inplace = True)
```

```
>>> my_df.head()
```

	GOOG	AAPL
Date		
2012-01-03	663.59	58.747143
2012-01-04	666.45	59.062859
2012-01-05	657.21	59.718571
2012-01-06	648.24	60.342857
2012-01-09	620.76	60.247143

Example

- Now we normalize by setting the beginning value to 100

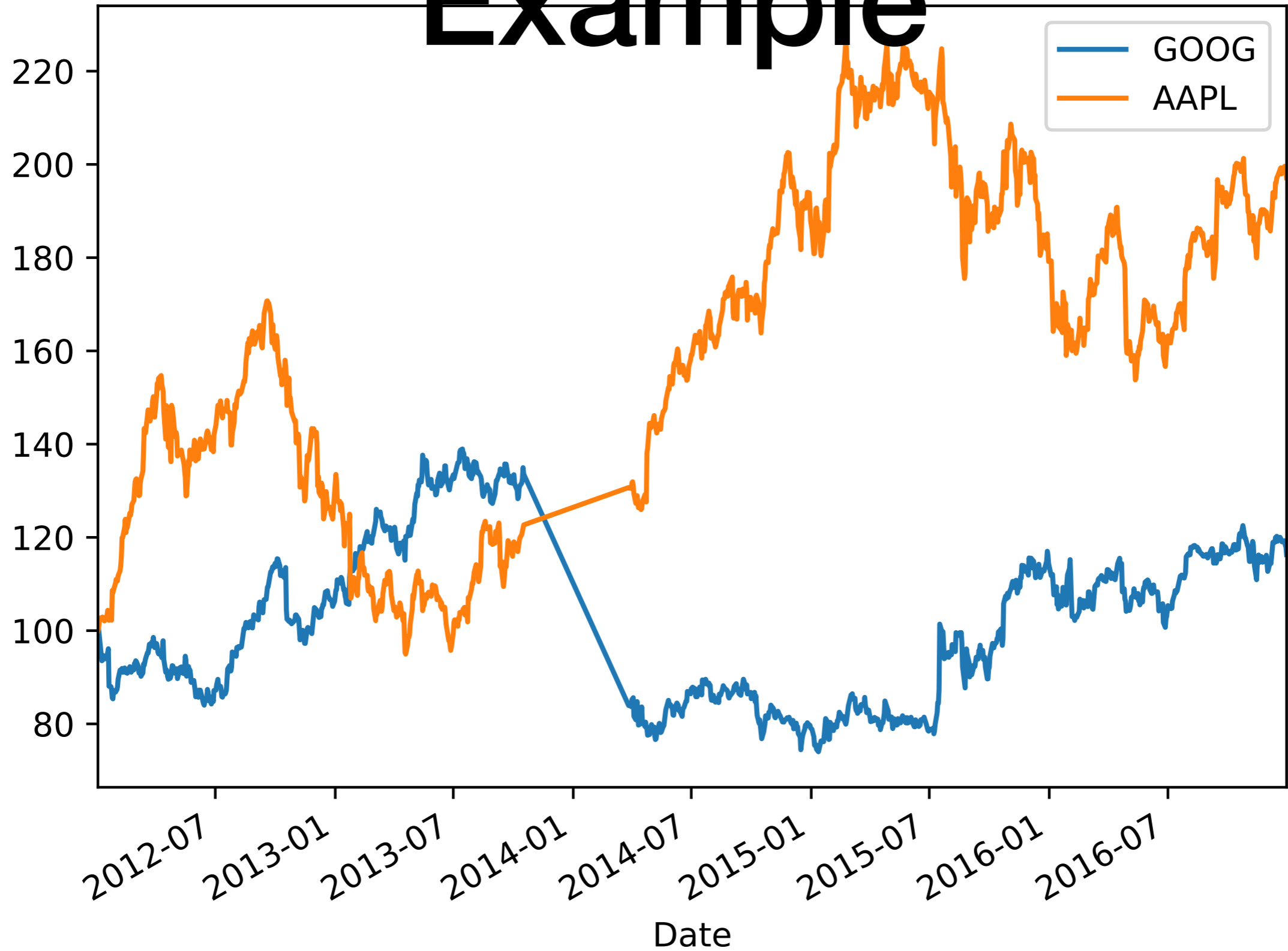
```
>>> normalized = my_df/my_df.iloc[0]*100  
>>> normalized.head()
```

	GOOG	AAPL
Date		
2012-01-03	100.000000	100.000000
2012-01-04	100.430989	100.537415
2012-01-05	99.038563	101.653575
2012-01-06	97.686825	102.716241
2012-01-09	93.545713	102.553316

Example

```
>>> normalized.plot()  
<matplotlib.axes._subplots.AxesSubplot object at  
0x7fd352b00460>  
>>> plt.show()
```

Example



Example

Example