Pandas

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Pandas

- Overview
  - Pandas is built on top of Numpy and Scipy
    - What you learned about Numpy is still directly applicable
  - Automatizes many actions for data science typical tasks

Basics

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

Basics

- Where to get Pandas
  - Install via pip3
  - 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 one 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

- We create series from a list-like object
- 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_dict)
```

  - 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', 'giglia',
'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
  - The work horse of Pandas
  - Looks like a relational database table
    - Columns can have different types
    - There usually is an index

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

```
example.iloc[[0,2]]          #rows


example.iloc[:,[1,2,3]]      #cols
```

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')
```

```
      First Name  Last Name  Position   Year
entry
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

- Then adorn read_csv with converters for each column that has strings in them

```
def get_data():
    return pd.read_csv('Salaries.csv',
                       converters = {'BasePay': my_converter,
                            'OvertimePay': my_converter,
                            'OtherPay': my_converter,
                            'Benefits': my_converter,
                            'TotalPay': my_converter,
                            'TotalPayBenefits': my_converter,
                            'Status' : my_converter}
                       )
```

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                0       1.5
1       4.7                1       4.7
2      13.3                2      13.3
3       1.0                3       1.0
4       3.2                4       3.2
5      16.4                5      16.4
6       0.6                6       0.6
7       1.5                7       1.5
8       6.7                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 column 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

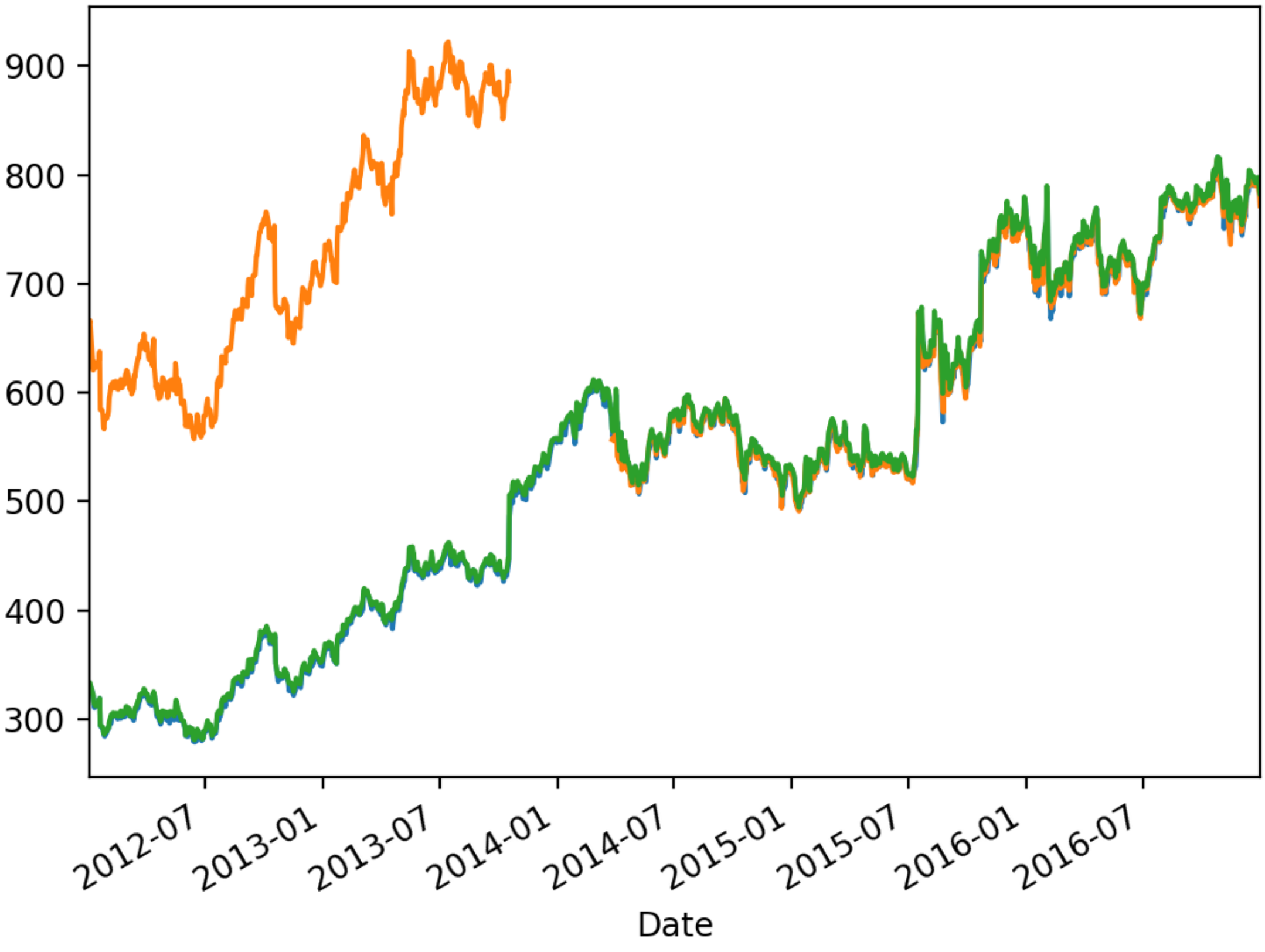
```
>>> google.info()
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 1258 entries, 2012-01-03 to 2016-12-30
Data columns (total 5 columns):
Open      1258 non-null float64
High      1258 non-null float64
Low       1258 non-null float64
Close     1149 non-null float64
Volume    1258 non-null int64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


900
800
700
600
500
400
300
2012-07
2013-01
2013-07
2014-01
2014-07
2015-01
2015-07
2016-01
2016-07
Date

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

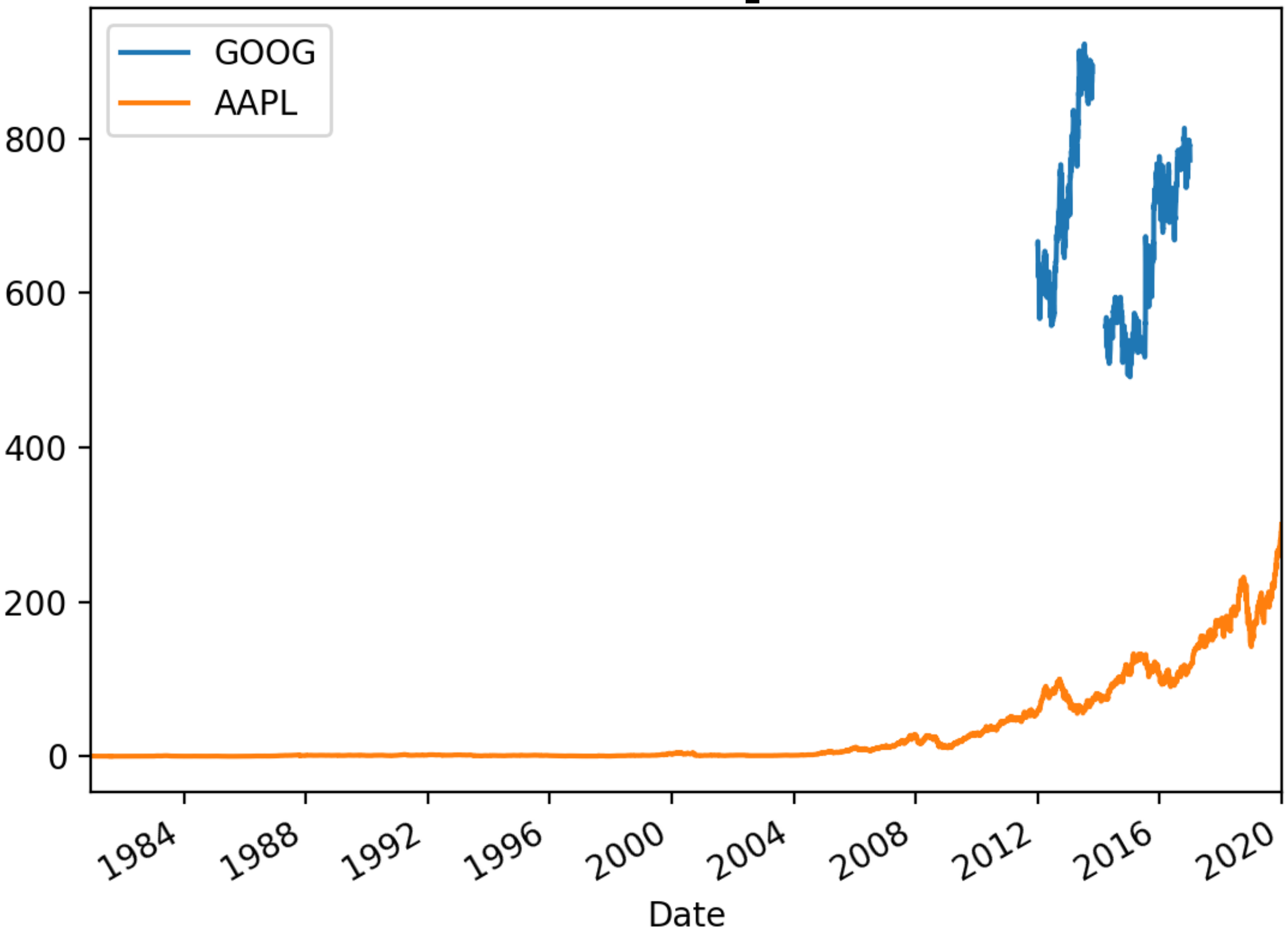
- Now we concatenate parts of the two data frames
  - axis = 1 means we want to concatenate columns

```
>>> 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


GOOG
AAPL
800
600
400
200
0
1984
1988
1992
1996
2000
2004
2008
2012
2016
2020
Date

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

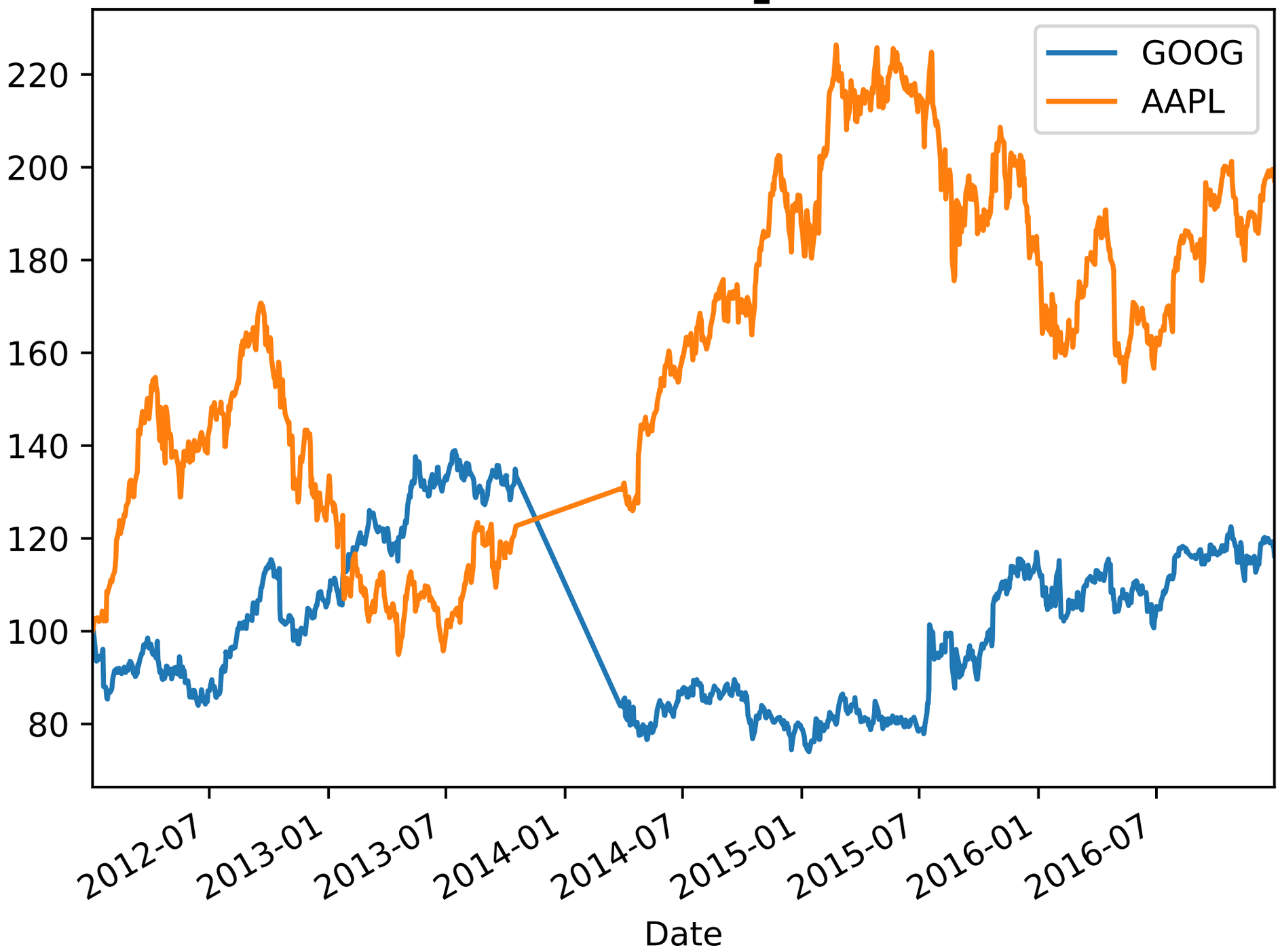
```
>>> normalized = my_df/my_df.iloc[0]*100
>>> normalized.head()
```

Date	GOOG	AAPL
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


GOOG
AAPL
220
200
180
160
140
120
100
80
2012-07
2013-01
2013-07
2014-01
2014-07
2015-01
2015-07
2016-01
2016-07
Date