Python - Data Analysis Essentials

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Course Outline for Today

1. Organization
2. An Introduction to IPython and Jupyter
3. Important Basics of the Python Programming Language
4. Storing and Operating on Data with NumPy
5. Using Pandas to Get More out of Data
6. Exercises

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Using Pandas to Get More out of Data

Learning Objectives

- You know:
  - What a `Series` and `DataFrame` is
  - How to construct a `Series` and `DataFrame` from scratch
  - How to import data using NumPy and/or Pandas
  - How to aggregate, transform, and filter data using Pandas

Pandas

- Pandas is a newer package built on top of NumPy
  - Pandas documentation: https://pandas.pydata.org/pandas-docs/stable/
- NumPy is very useful for numerical computing tasks
- Pandas allows more flexibility: Attaching labels to data, working with missing data, etc.

JUPYTER NB

```
In  [1]: import pandas as pd
         pd.__version__

Out [1]: '0.23.4'
```

- *Note*: We are going to use the `pd` alias for the `pandas` module in all the code samples on the following slides

The Pandas Objects

- Pandas objects are enhanced versions of NumPy arrays: The rows and columns are identified with labels rather than simple integer indices
- `Series` object: A one-dimensional array of indexed data
- `DataFrame` object: A two-dimensional array with both flexible row indices and flexible column names

The Pandas Series Object

- A Pandas Series object is a one-dimensional array of indexed data
  - NumPy array: has an *implicitly* defined integer index
  - A Series object uses by default integer indices:

JUPYTER NB

```
In  [1]: data1 = pd.Series([100,200,300])
```

- A Series object can have an *explicitly* defined index associated with the values:

JUPYTER NB

```
In  [2]: data2 = pd.Series([100,200,300], index=["a","b","c"])
```

- We can access the index labels by using the index attribute:

JUPYTER NB

```
In  [2]: d2ind = data2.index
```

The Pandas `Series` Object

- A Python dictionary maps arbitrary keys to a set of arbitrary values
- A `Series` object maps *typed* keys to a set of *typed* values
  - "Typed" means we know the type of the indices and elements beforehand, making Pandas Series objects much more efficient than Python dictionaries for certain operations

- We can construct a `Series` object directly from a Python dictionary:

JUPYTER NB

```
In  [1]: data_dict = pd.Series({"c":123,"a":30,"b":100})
```

  - *Note*: The index for the `Series` is drawn from the sorted keys

{Live Coding}

The Pandas `DataFrame` Object

- A `DataFrame` object is an analog of a two-dimensional array both with flexible row indices and flexible column names
  - Both the rows and columns have a generalized index for accessing the data
  - The row indices can be accessed by using the `index` attribute
  - The column indices can be accessed by using the `columns` attribute

Constructing DataFrame Objects

- You can think of a DataFrame as a sequence of aligned Series objects, meaning that each column of a DataFrame is a Series

JUPYTER NB

```
In  [1]: df = pd.DataFrame({"col1":series1, "col2":series2, …})
```

Constructing DataFrame Objects

- There are multiple ways to construct a DataFrame object
  - From a single Series object:

```
In  [1]: pd.DataFrame(population, columns=["population"])                JUPYTER NB
```

  - From a list of dictionaries:

```
In  [2]: pd.DataFrame([{'a': 1, 'b': 2}, {'b': 3, 'c': 4}])              JUPYTER NB
```

  - From a dictionary of Series objects:

```
In  [3]: pd.DataFrame({'population': population, 'area': area})          JUPYTER NB
```

  - From a two-dimensional NumPy array:

```
In  [4]: pd.DataFrame(np.random.rand(3, 2),                              JUPYTER NB
                      columns=['foo', 'bar'],
                      index=['a', 'b', 'c'])
```

{Live Coding}

Data Selection in `Series`

- `Series` as a dictionary:
  - Select elements by key, e.g. `data['a']`
  - Modify the `Series` object with familiar syntax, e.g. `data['e'] = 100`
  - Check if a key exists by using the in operator
  - Access all the keys by using the `keys()` method
  - Access all the values by using the `items()` method

Data Selection in `Series`

- `Series` as one-dimensional array:
  - Select elements by the implicit integer index, e.g. `data[0]`
  - Select elements by the explicit index, e.g. `data['a']`
  - Select slices (by using an implicit integer index or an explicit index)
    - *Important*: Slicing with an explicit index (e.g., `data['a':'c']`) will *include* the final index in the slice, while slicing with an implicit index (e.g., `data[0:3]`) will exclude the final index from the slice
  - Use masking operations, e.g., `data[data < 3]`

Data Selection in `DataFrame`

- `DataFrame` as a dictionary of related `Series` objects:
  - Select Series by the column name, e.g. `df['area']`
  - Modify the `DataFrame` object with familiar syntax, e.g. `df['c3'] = df['c2']/ df['c1']`

Data Selection in `DataFrame`

- `DataFrame` as two-dimensional array:
  - Access the underlying NumPy data array by using the `values` attribute
    - `df.values[0]` will select the first row
  - Use the `iloc` indexer to index, slice, and modify the data by using the *implicit* integer index
  - Use the `loc` indexer to index, slice, and modify the data by using the *explicit* index

Ufuncs and Pandas

- Pandas is designed to work with Numpy, thus any NumPy ufunc will work on Pandas `Series` and `DataFrame` objects
- *Index preservation*: Indices are preserved when a new Pandas object will come out after applying ufuncs
- *Index alignment*: Pandas will align indices in the process of performing an operation
  - Missing data is marked with `NaN` ("Not a Number")
  - We can specify on how to fill value for any elements that might be missing by using the optional keyword fill_value: `A.add(B, fill_value=0)`
  - We can also use the `dropna()` method to drop missing values
- *Note*: Any of the ufuncs discussed for NumPy can be used in a similar manner with Pandas objects

Ufuncs: Operations Between `DataFrame` and `Series`

- Operations between a `DataFrame` and a `Series` are similar to operations between a two-dimensional and one-dimensional NumPy array (e.g., compute the difference of a two-dimensional array and one of its rows)

Reading (and Writing) Data with Pandas

File Types

- We will work with *plaintext files* only in this session*;* these contain only basic text characters and do not include font, size, or colour information
  - *Binary files* are all other file types, such as PDFs, images, executable programs etc.

The Current Working Directory

- Every program that runs on your computer has a *current working directory*
  - It's the directory from where the program is executed / run
  - *Folder* is the more modern name for a directory
- The *root directory* is the top-most directory and is addressed by `/`
  - A directory `mydir1` in the root directory can be addressed by `/mydir1`
  - A directory `mydir2` within the `mydir1` directory can be address by `/mydir/mydir2`, and so on

Absolute and Relative Paths

- An *absolute path* begins always with the root folder, e.g. `/my/path/...`
- A *relative path* is always relative to the program's current working directory
  - If a program's current working directory is `/myprogram` and the directory contains a folder `files` with a file `test.txt`, then the relative path to that file is just `files/test.txt`
  - The absolute path to `test.txt` would be `/myprogram/files/test.txt` (note the root folder `/`)

Reading Data with Pandas

- Pandas provides the `pandas.read_csv()` function to load data from a CSV file (or a file that uses a different delimiter than a comma)
  - The path you specify doesn't have to be on your hard disk; you can also provide the URL to file to read it directly into a Pandas object
  - We can set the optional argument `error_bad_lines` to `False` so that bad lines in the file get omitted and do not cause an error
  - Checkout the documentation to learn more about the optional arguments: https://pandas.pydata.org/pandas-docs/stable/generated/pandas.read_csv.html

Some Interesting Data Sources

- Federal Statistical Office: https://www.bfs.admin.ch/bfs/en/home/statistics/catalogues-databases/data.html
- OpenData: https://opendata.swiss/en/
- United Nations: http://data.un.org/
- World Health Organization: http://apps.who.int/gho/data/node.home
- World Bank: https://data.worldbank.org/
- Kaggle: https://www.kaggle.com/datasets
- Cern: http://opendata.cern.ch/
- Nasa: https://data.nasa.gov/
- FiveThirtyEight: https://github.com/fivethirtyeight/data

Exporting `DataFrame` Objects to a File

- We can use the `pandas.DataFrame.to_csv()` method to export a `DataFrame` to a CSV file https://pandas.pydata.org/pandas-docs/stable/generated/pandas.DataFrame.to_csv.html
- Overview of all the `DataFrame` methods to import and export data: https://pandas.pydata.org/pandas-docs/stable/api.html#id12

Aggregating and Grouping Data in Pandas

Simple Aggregation in Pandas

- As with one-dimensional NumPy array, for a Pandas `Series` the aggregates return a single value
- For a `DataFrame`, the aggregates return by default results within each column
- Pandas Series and `DataFrame`s include all of the common NumPy aggregates
  - In addition, there is a convenience method `describe()` that computes several common aggregates for each column and returns the result

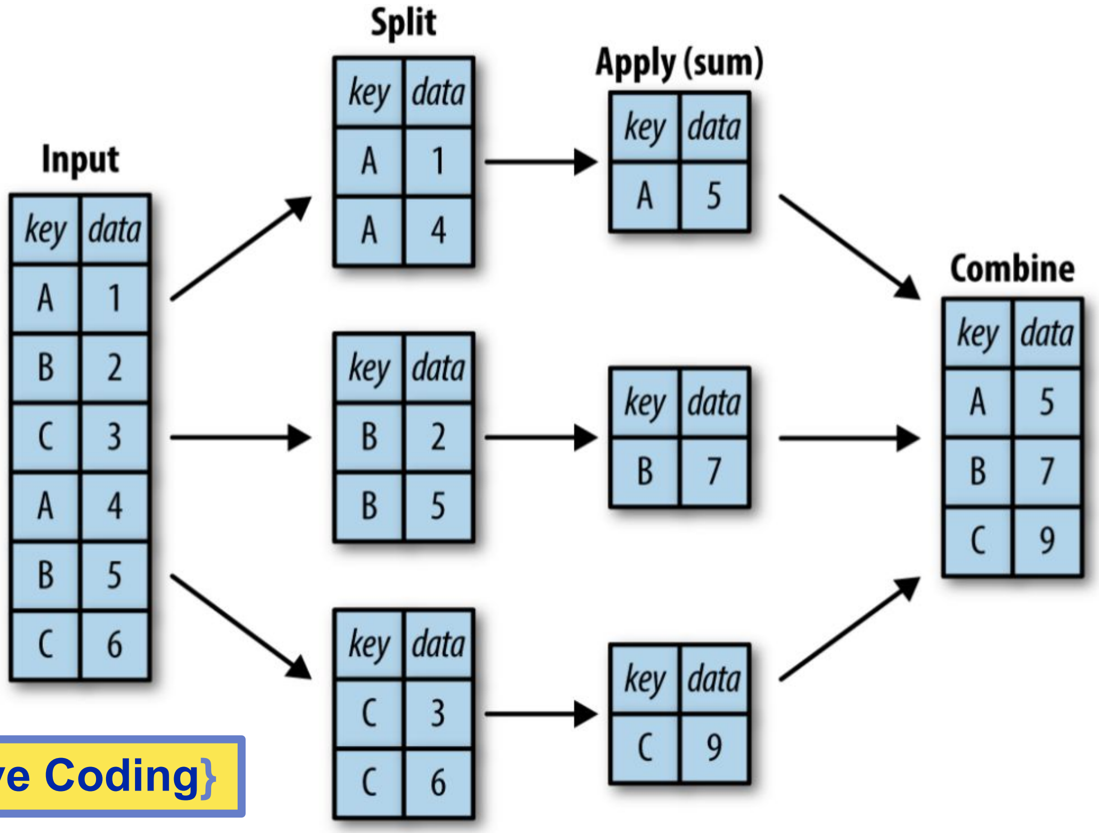
Split, Apply, Combine

- *Split*: Break up and group a `DataFrame` depending on the value of the specified key
- *Apply*: Apply some function, usually an aggregate, transformation, or filtering, within the individual groups
- *Combine*: Merge the results of these operations into an output array

Source: Python Data Science Handbook

Split, Apply, Combine

- Pictured on the right you see an example where in the apply step we use a summation aggregation:
- The **groupBy()** method of **DataFrames** can compute the most basic split-apply-combine operation



Input

key	data
A	1
B	2
C	3
A	4
B	5
C	6

Split

key	data
A	1
A	4

key	data
B	2
B	5

key	data
C	3
C	6

Apply (sum)

key	data
A	5

key	data
B	7

key	data
C	9

Combine

key	data
A	5
B	7
C	9

Lets check out the **groupBy()** method **{Live Coding}**

Source: Python Data Science Handbook

The `GroupBy` Object

- The `groupBy()` method returns a `DataFrameGroupBy`: It's a special view of the `DataFrame`
  - Helps get information about the groups, but does no actual computation until the aggregation is applied ("lazy evaluation", i.e. evaluate only when needed)
  - Apply an aggregate to this `DataFrameGroupBy` object: This will perform the appropriate apply/combine steps to produce the desired result
    - You can apply any Pandas or NumPy aggregation function
  - Other important operations made available by a `GroupBy` are *filter*, *transform*, and *apply*

Column Indexing and Iterating Over Groups

- The `GroupBy` object supports *column indexing* in the same way as the `DataFrame`, and returns a modified `GroupBy` object
- The `GroupBy` object also supports direct iteration over the groups, returning each group as a `Series` or `DataFrame`

Aggregate, Filter, Transform, and Apply

- *Aggregate*: The `aggregate()` method can compute multiple aggregates at once
- *Filter*: The `filter()` method allows you to drop data based on group properties
  - *Note*: `filter()` takes as an argument a *function* that returns a Boolean value specifying whether the group passes the filtering
- *Transformation*: While aggregation must return a reduced version of the data, `transform()` can return some transformed version of the full data to recombine (meaning that we still have the same number of entries before and after the transformation)
- *Apply*: The `apply()` method lets you apply an arbitrary function to the group results. The function should take a `DataFrame`, and return either a Pandas object or a scalar

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Addendum: Working with Files in Python

Opening Files with the open() Function

- Open a file with the `open()` function by providing a string path indicating the file you want to open
  - The path can be an *absolute* or a *relative* path

CODE

```
file = open("/path/to/my/file.txt")
```

  - Typed like this, `open()` will open the file in the *read mode*, meaning we only can read data from the file

- `open()` returns a `File` object, which represents a file on your computer (it's simply another type of value in Python, much like lists and dictionaries)
  - We can now call methods on the `File` object to read its content for example

Reading the Contents of Files

- We can use the `File` object's `read()` method to read the entire contents of a file as a string value
- Lets assume we have a plaintext file located at `/path/to/file.txt` with `Well, hello there!` as its content. Then:

CODE

```
file = open("/path/to/file.txt")

print(file.read())
```

INTERP.

OUTPUT

```
Content of the file
```

Reading the Contents of Files

- Alternatively, we can use the `File` object's `readlines()` method to get a list of string values from the file, one string for each line of text
- Lets assume we have a plaintext file located at `/path/to/newFile.txt` with the following content:

```
First line
Second line
Third line
```

CODE

```
file = open("/path/to/newFile.txt")

print(file.readlines())
```

INTERP.

OUTPUT

```
['First line\n', 'Second line\n',
        'Third line\n']
```

Writing to Files

- We met the *read mode* in the previous slides
- There exist two more modes: the *write mode* and the *append mode*
  - *Write mode* will overwrite the existing file and start from scratch (so watch out!)
    - We pass `"w"` as the second argument to the `open()` function to open the file in write mode
  - *Append mode* will append text to the end of the existing file
    - We pass `"a"` as the second argument to the `open()` function to open the file in append mode

Writing to Files

- If the filename to `open()` does not exist, both write and append mode will create a new, blank file
- After reading or writing a file, call the `close()` method before opening a file again
- Once we have a file opened in one of the writing modes, we can use the `File` object's `write()` method and pass it a string argument to write it into the file
  - The `write()` method will then return the number of bytes written to the file

Reader Objects

- We need to create a `Reader` object to read data from a CSV file with the `csv` module
- The `Reader` object lets you iterate over lines in the CSV file

Reader Objects

CODE

```
import csv

file = open("example.csv")
exReader = csv.reader(file)
data = list(exReader)
print(data)
```

INTERPRETER

OUTPUT

```
[['4/5/2015 13:34', 'Apples', '73'],
['4/5/2015 3:41', 'Cherries', '85'],
['4/6/2015 12:46', 'Pears', '14'],
['4/8/2015 8:59', 'Oranges', '52']]
```

Reading Data from Reader Objects in a `for` Loop

- For large files it is disadvantageous to load the entire file into memory at once
- We are going to use the `Reader` object in a `for` loop to iterate over each row of the CSV file, without having to load the entire file into memory
  - *Note*: The `Reader` object can be looped over only once. You must create the `Reader` object anew if you want to reread the CSV file

Reading Data from Reader Objects in a for Loop

CODE

```
import csv

file = open("example.csv")
exReader = csv.reader(file)
for row in exReader:
  print(str(exReader.line_num) + ": " + str(row))
```

INTERPRETER

OUTPUT

```
1: ['4/5/2015 13:34', 'Apples', '73']
2: ['4/5/2015 3:41', 'Cherries', '85']
3: ['4/6/2015 12:46', 'Pears', '14']
4: ['4/8/2015 8:59', 'Oranges', '52']
```

Writer Objects

- We can use a `Writer` object to write data to a CSV file
- We can pass a list to the `writerow()` method with the data
  - Each value in the list is placed in its own cell in the output CSV file

CODE

```
import csv

file = open("output.csv", "w", newline="")

exWriter = csv.writer(file)
exWriter.writerow(["12/10/2017 14:45", "Fries", "9.5"])
exWriter.writerow(["11/09/2018 10:16", "Bread", "1.2"])

file.close()
```

output.csv

```
12/10/2017 14:45,Fries,9.5
11/09/2018 10:16,Bread,1.2
```

The `delimiter` and `lineterminator` Keyword Arguments

- If you want to separate cells with a tab character instead of a comma and you want the rows to be double-spaced, we can use the `delimiter` and `lineterminator` keyword arguments with the `reader()` and `writer()` methods
    - The *delimiter* is the character that appears between cells on a row
        - By default the delimiter is a comma `,`
    - The *line terminator* is the character that comes at the end of a row
        - By default the line terminator is a newline

```
import csv

file = open("example.csv")
exReader = csv.reader(file, delimiter="\t", lineterminator="\n\n")
```

Please Save Your Progress

Feedback

- After this course you will receive an email by the course direction asking for feedback about this course
- I would be more than happy to receive as much feedback as possible, since I'd love to further improve the course material and/or my teaching skills where needed
- Constructive criticism and positive comments are both very welcome
  - It's good to know where one can improve, for example by updating the course material or polishing the teaching skills in general
  - It's also good to know which parts of the course and/or which teaching skills helped you the most during the course

Questions

- If you have any questions, information, or more about any topic of today's course, feel free to write me at bubanja.kaju@gmail.com

References

- Course content:
  - Al Sweigart, "Automate the Boring Stuff with Python"
    https://automatetheboringstuff.com/
  - Jake VanderPlas, "Python Data Science Handbook"
    https://jakevdp.github.io/PythonDataScienceHandbook/