# Python for Data Science

***Objectives***

This chapter provides a quick overview of:

- Python modules and high-power features
- NumPy library
- pandas library
- SciPy library
- scikit-learn library
- Jupyter notebooks
- Anaconda distribution

## 1.1 In-Class Discussion

- Are you using or have you used Python in the past, and if so, what do you like / dislike in the language?
  - If you know Python, are there any insights you would like to share with the class?

## 1.2 Importing Modules

| Command | Comments |
|---|---|
| **from lib import x**<br>**from lib import x as y** | Importing a single object from a module(lib) allows direct referencing of the object, e.g **x() or y()**<br>Introduces potential variable name collision with other module imports |
| **from lib import *** | Not clean -- potential variable name clobbering |
| **import lib as alias** | You import the whole module giving it an *alias;* use the '.' dot prefix to access objects in it:<br>**alias.x()**<br><br>*That's the preferred way to import modules* |

## 1.3 Listing Methods in a Module

- Use the *dir()* function:

```
dir(module_alias), e.g. dir(np)
or
dir('module_name'), e.g. dir('sys')
```

# 1.4 Creating Your Own Modules

- Create a Python file, e.g.

```
# my_utils.py
def foo(a, b):
    return a + b
```

- Create a directory with the following structure:

```
├── my_library          # directory
│  ├── __init__.py      # empty file, without it, Python will
not allow import from a directory
│  ├── my_utils.py             # your module (def …)
```

- If *my_library* is in the current working directory of an interpreter, we can import *my_utils* in the following way:

```
from my_library import my_utils
my_utils.foo(4, 2)
```

- When you import a module, its code gets automatically scanned and executed by Python
- To create a controlled (entry) execution point when the module is to be run as an application, add the following (highlighted below) code:

```
def foo(a, b):
    return a + b
if __name__ == "__main__":
# Application entry point is here
```

## 1.5 Random Numbers

- Python comes with a pseudo-random (deterministic) number generator

```
import random    # can alias the import
random.random()     # [0, 1)
random.randint(x,y)   #  integer numbers in range [x,y]
```

- **Note**: NumPy offers additional functionality on top of this generator

### Notes:

Python uses the Mersenne Twister as the pseudo-random number generator. It produces 53-bit precision floats and has a generation cycle of 2**19937-1 (the cycle is 6002 digits long). The underlying implementation in C, which is both fast and threadsafe.

## 1.6 Zipping Lists

- The *zip*() function allows you to iterate over two or more lists passed to it as parameters, for example:

```
a = [1,2,3,4,5]
b = [10,20,30,40,50]
[str(x) + ':' + str(y) for x, y in zip(a,b)]

Output:
['1:10', '2:20', '3:30', '4:40', '5:50']
```

## 1.7 List Comprehension

- Comprehensions are constructs that allow sequences (e.g. lists) to be built from other sequences
  - Python 2 introduced list comprehensions and Python 3 extended this functionality to work with dictionaries and sets

```
y = 10
[ i**2 + y for i in range (1, 20) if (i % 2 == 0) ]

Output:
[14, 26, 46, 74, 110, 154, 206, 266, 334]
```

## 1.8 Python Data Science Centric Libraries

- NumPy
- SciPy
- pandas
- scikit-learn
- Matplotlib

## 1.9 NumPy

- Efficient numerical computing is not Python's strong point
- **NumPy** library (http://www.numpy.org/), first released in 2006, addresses Python's shortcomings in this area
  - The project was a successful attempt to bring together a variety of projects in the space and unify the community around a single array package
  - NumPy is part of SciPy
  - It is open-source software
  - Modeled after Matlab
- At core of NumPy is its n-dimensional array called "ndarray" that may be shaped as an array or a matrix
- NumPy also offers developers a large collection of functions to work on the ndarray structure
- The ndarray structure replaces Python's list object

## 1.10 NumPy Arrays

```
import numpy as np

# Simple arrays:
a1 = np.array ([1,2,3,4,5])
a2 = np.arange(5)

# A matrix structure
m = np.array ([[1,2,3,4], [5,6,7,8]])
m.shape
```

```
Output: (2, 4)
```

## 1.11 Select NumPy Operations

- Support for vectorization (no-loop ops, uses very fast C code):

```
10 * np.arange(5) + np.arange(5)
```

```
Output:
array([ 0, 11, 22, 33, 44])
```

```
np.cos( np.pi * np.array([0,1,2,3]))
```

```
Output:
array([ 1., -1.,  1., -1.])
```

- Filtering:

```
a = np.array ([1,2,3,4,5])
a [a % 2 == 0]
```

```
Output:
```

```
array([2, 4])
```

- Reshaping:

```
m = np.array ([1,2,3,4,5,6,7,8]).reshape(4,2)
```

```
Output: a 4x2 matrix
```

## 1.12 SciPy

- SciPy (https://scipy.org/) is a Python-based ecosystem of open-source software for mathematics, science, and engineering:
  - statistics
  - linear algebra
  - optimization
  - signal processing (FFT)
  - Note: For the complete list of modules, visit http://scipy.github.io/devdocs/py-modindex.html
- SciPy is built upon the foundational infrastructure of NumPy

### Notes:

The SciPy module includes the following sub-packages:

```
constants: physical constants and conversion factors (since version 0.7.0[5])
cluster: hierarchical clustering, vector quantization, K-means
fftpack: Discrete Fourier Transform algorithms
integrate: numerical integration routines
interpolate: interpolation tools
io: data input and output
lib: Python wrappers to external libraries
linalg: linear algebra routines
misc: miscellaneous utilities (e.g. image reading/writing)
ndimage: various functions for multi-dimensional image processing
optimize: optimization algorithms including linear programming
```

```
signal: signal processing tools
sparse: sparse matrix and related algorithms
spatial: KD-trees, nearest neighbors, distance functions
special: special functions
stats: statistical functions
weave: tool for writing C/C++ code as Python multiline strings
```

## 1.13 pandas

- **pandas** (https://pandas.pydata.org/) is an open source library that provides high-performance, memory-efficient, easy-to-use data structures, as well as support for data manipulation and analysis for Python
- The core data structure is the DataFrame object with integrated indexing similar to a relational table, Excel spreadsheet, and similar tabular data set containers
  - The major influence was R's DataFrame object
- Through dataframes, pandas offers compact and efficient interfaces for reading and writing data between its data structures and files stored in different formats: CSV, Microsoft Excel, SQL databases, and the fast HDF5 format
- Dataframes offer integrated handling of missing data points and other mechanisms for repairing data sets
- Supported operations include: data set reshaping, grouping, aggregation, pivoting, joining, and similar operations

## 1.14 Examples of Using pandas' DataFrame

```
import pandas as pd
# you build the data as a matrix (array of arrays)
df = pd.DataFrame(data, columns = ["Sales", "Location"])
df.Location
df['Location']
df.iloc[-1, :]
df.Sales.sort_values(ascending=False)
```

## 1.15 Scikit-learn

- **scikit-learn** (http://scikit-learn.org/) is a Python module for machine learning built on top of SciPy
- Supports algorithms in these areas:
  - Classification
  - Clustering
  - Data preprocessing (feature extraction and transformation)
  - Dimensionality reduction (deals with data multicollinearity and variance reduction)
  - Model selection (comparing, validating, and improving model accuracy)
  - Regression

## 1.16 Matplotlib

- **Matplotlib** (https://matplotlib.org/) is a Python library for graphing and visualization
- Depends on NumPy
- With Matplotlib you can generate plots, histograms, bar charts,scatter plots, etc., with just a few lines of code
- Matplotlib's main focus is 2D plotting; 3D plotting is possible with the *mplot3d* package

## 1.17 Python Dev Tools and REPLs

- In addition to the standard Python REPL, Python development is supported through these developer systems:
  - IPython
  - Jupyter with Python kernel (runtime)
  - Visual Studio Code Python plug-in

## 1.18 IPython

- **IPython** (Interactive Python) is a command shell that, in addition to Python, supports other computing languages as well
- Originally released in 2001
- Offers code introspection with name auto-completion (on Tab) and command history
- Supports in-line plotting
- In addition to the primary single-user development on a user machine, it can

also manage parallel computing clusters using asynchronous status callbacks and/or MPI

- In 2014, the original author, Fernando Pérez, announced a spin-off project from IPython called Project Jupyter with IPython acting as Jupyter's kernel (runtime)

## 1.19 Jupyter

- Jupyter is a browser-based Python REPL serviced by an embedded web server
  - This Jupyter architecture allows for [secure] remote access
- Depends on IPython and allows you to use multiple versions of Python (providing their runtimes are installed)
- Supports other languages as well:
  - Julia, R, Haskell, and Ruby
- Central to Jupyter development model is *notebook* that allows you enter, execute, and mark up code (for comments)
  - Notebook files are physical files with extension *.ipynb* automatically saved in your working directory
  - You can have multiple Python notebook sessions running concurrently, each receiving its own Python interpreter sandbox
- You start Jupyter by running this command:

```
jupyter notebook
```

**Notes:**

The name Jupyter is an indirect acronym of the three core languages it was designed for: JUlia, PYThon, and R.

## 1.20 Jupyter Operation Modes

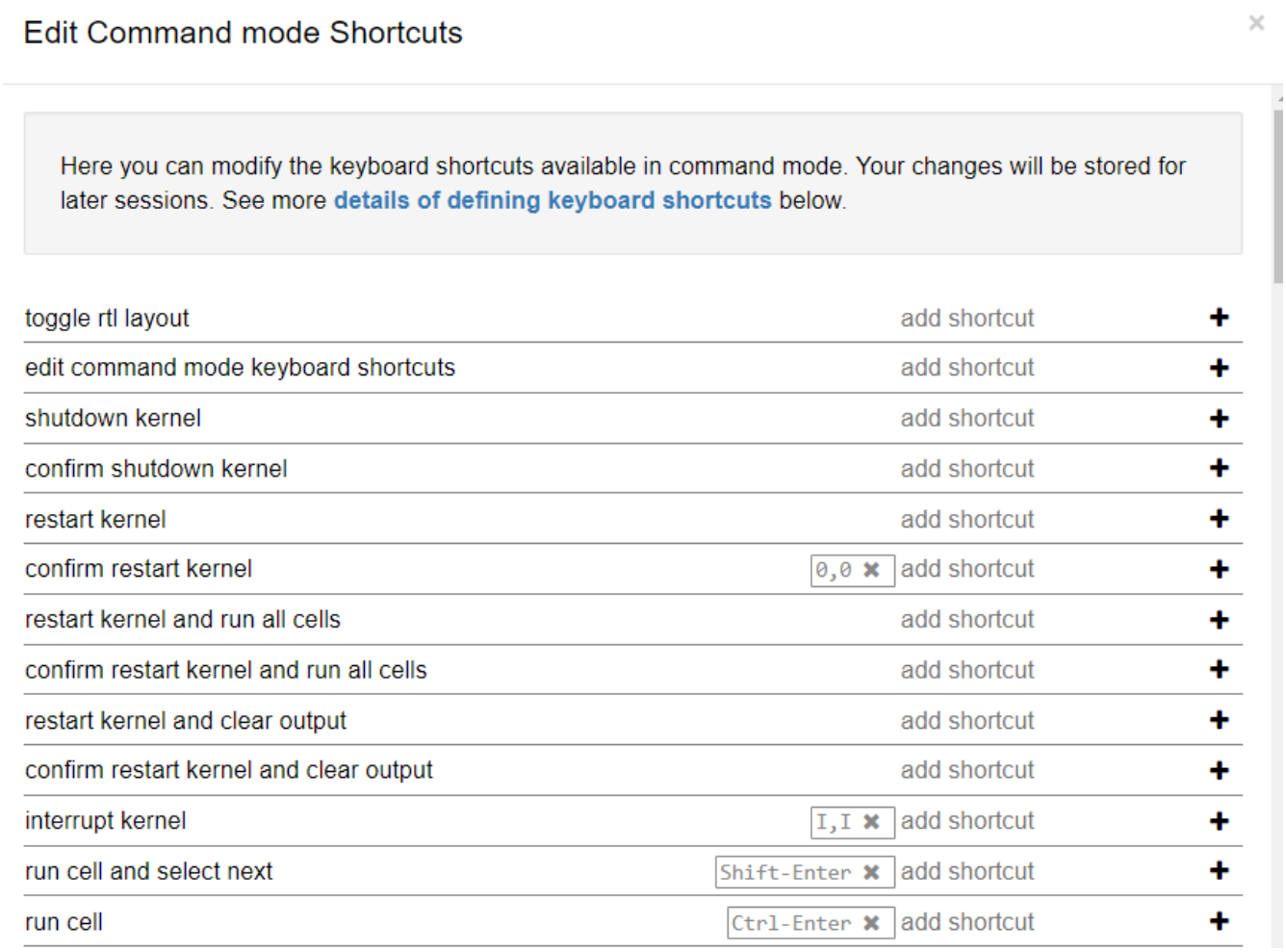
- Developers use a Jupyter notebook in two modes:
  - Command mode (CM)
    - Visually indicated by a blue left-hand border line of the current cell
  - Edit mode (EM)
    - Visually indicated by a green left-hand border line of the current cell
- When you start a notebook, it opens in EM, ready to accept your commands
- To switch to CM, press **Esc**
- To switch back to EM, click your mouse in a cell or press **Enter**

## 1.21 Jupyter Common Commands

- Basic edit mode (EM) commands:
  - **Shift+Enter -** run code in the current cell and add a new cell below for the next command
  - **Ctrl+Enter** - run code in the current cell and switch to CM:
- Basic command mode (CM) commands:
  - **a** - add a cell below the current cell
  - **b** - add a cell above the current cell
  - **c** - copy a cell (**Ctrl-v** to paste it)
  - **d** - delete the current cell
- If you need to re-execute commands in your notebook (*All, All Above, or All Below*) use the **Cell** menu option in the menu bar
- Review Jupyter's help (the **Help** menu option) to learn about available command shortcuts

## Notes:

You can preview and edit the command shortcuts by navigating to **Help > Edit Keyboard Shortcuts** using the menu bar. Unfortunately, for now, Jupyter does not support macros / scripting.



# 1.22 Anaconda

- Anaconda is a distribution of Python along with its frequently used packages (NumPy, SciPy, pandas, scikit-learn, etc.)
- Comes with its package manager called **conda** that helps you list, update and otherwise manage packages
- Anaconda also includes Jupyter

## Notes:

The **conda** package manager supports the following commands:

```
clean        Remove unused packages and caches.
config       Modify configuration values in .condarc. This is modeled
             after the git config command. Writes to the user .condarc
             file (C:\Users\Mikhail\.condarc) by default.
create       Create a new conda environment from a list of specified
             packages.
help         Displays a list of available conda commands and their help
             strings.
info         Display information about current conda install.
install      Installs a list of packages into a specified conda
             environment.
list         List linked packages in a conda environment.
package      Low-level conda package utility. (EXPERIMENTAL)
remove       Remove a list of packages from a specified conda environment.
uninstall    Alias for conda remove. See conda remove --help.
search       Search for packages and display associated information. The
             input is a MatchSpec, a query language for conda packages.
             See examples below.
update       Updates conda packages to the latest compatible version. This
             command accepts a list of package names and updates them to
             the latest versions that are compatible with all other
             packages in the environment. Conda attempts to install the
             newest versions of the requested packages. To accomplish
             this, it may update some packages that are already installed,
             or install additional packages. To prevent existing packages
             from updating, use the --no-update-deps option. This may
             force conda to install older versions of the requested
             packages, and it does not prevent additional dependency
             packages from being installed. If you wish to skip dependency
```

```
                checking altogether, use the '--force' option. This may
                result in an environment with incompatible packages, so this
                option must be used with great caution.
  upgrade       Alias for conda update. See conda update --help.
```

## 1.23 Summary

- In this chapter, we discussed the following topics:
  - Python module import considerations, zip and list comprehension commands
  - NumPy
  - pandas
  - SciPy
  - IPython
  - Jupyter notebooks
  - Anaconda Python distribution