Data Analysis with Python, Numpy and Pandas

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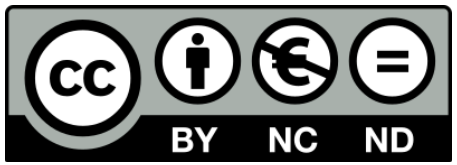

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Anaconda

Anaconda is a single package installing Python and a huge set of modules and tools

- *IPython* : improved REPL command line interface
- *numpy* : efficient number and multi-dimensionnal arrays computation
- *pandas* : data indexing, querying and aggregation
- Both provide objects with similar interfaces (*iteration protocol*, method names) to built-in Python or array module objects
- Interface nicely with CSV files, SQL databases, even Excel files
- *scipy* : numerical analysis, linear algebra, statistics
- *scikit-learn* : classification, clustering, regression
- *matplotlib*, *seaborn* : data visualization, imaging

Note that all these package may also be installed *independantly* from Anaconda by *pip*.

Anaconda

Graphical User Interface

- *anaconda-navigator* gives access to most graphical tools
- *Jupyter* : notebook oriented Web interfaces
- *Spyder* : Integrated Development Environment
- PyCharm can also interfaces itself with Anaconda

More packages (set of modules) can be installed by `conda` command.

Notebooks

- You can share notebooks IPython files saved by Jupyter
- Many are available on the Internet

Numpy

Efficient numerical and array types

```
>>> import numpy as np
>>> np.array( [ [1,2,3] , [4,5,6] ] )
array([[1, 2, 3],
       [4, 5, 6]])
>>> t = np.array( [ [1, 2, 3] , [4, 5, 6] ] )
>>> type(t[0][1])
<class 'numpy.int64'>
>>> t = np.array( [ [1, 2, 3] , [4, 5.0, 6] ] )
>>> type(t[0][1])
<class 'numpy.float64'>
```

Mathematical functions

```
>>> np.exp(t)
array([[  2.71828183,   7.3890561 ,  20.08553692],
       [ 54.59815003, 148.4131591 , 403.42879349]])
```

Arrays in numpy

Arrays creation

- Can be generated from sequences, constant or random values, ranges, files
- Can be reshaped, iterated through, flattened
- Items can be addressed by single or multiple index, slices

Examples

```
>>> v = np.array([1,2,3])
>>> v.dtype # dtype('int64')
>>> v.shape # (3,)
>>> t = np.array([ [1,2,3], [4,5,6.0] ])
>>> t.dtype # dtype('float64')
>>> t.shape # (2, 3)
```

Array creation functions

Constant and special arrays

```
>>> np.zeros((2,2))
>>> np.ones((3,4))
>>> np.full((3,3), 42)
>>> np.eye(3) # identity matrix
>>> np.random.random(2,2)
>>> np.random.randn(4) # Normal std distribution
```

From files or Web ressources

```
>>> np.genfromtxt('myfile.csv', delimiter=';')
```

Functions and operators

Use function from numpy (not math!) or operators

```
>>> np.log(t)
>>> t * 42 # overloaded by numpy
>>> t + 2*t
```

Operations on arrays

- Functions acting on elements
- Linear algebra : `np.linalg`
- Compound functions (sum, mean, average, ...)

```
>>> np.sum(t)
21.0
>>> np.sum(t, axis=0)
array([5., 7., 9.])
>>> np.sum(t, axis=1)
array([ 6., 15.])
```

Other Numpy features, Scipy, Matplotlib

Submodules of Numpy

- numpy.linalg for linear algebra
- polynomial, random, fft (Fourier transformation),
- ...

Scipy is a useful complement of numpy

- Provides more statistical functions
- Combinatorics

Matplotlib is the base module to produce graphs

Can be displayed directly by Jupyter

```
%matplotlib inline
import numpy as np
from matplotlib import pyplot
pyplot.hist(np.random.random(100),
            range = (0, 1),
            bins = 100, color = 'blue',
            edgecolor = 'black')
pyplot.show()
```

- Can produce histogram, pie charts, curves, points, ...
- Documentation provides complete examples of all types

Pandas series

Build on top of Numpy

- Dictionary-like indexing
- Both sequence-like and dictionary-like objects

```
>>> data = pd.Series([42.42, 3.14, 1.0],
                     index=['price','size','weight'])
>>> data['price']
42.42
>>> data
price     42.42
size       3.14
weight     1.00
>>> data['size'] == data[1]
True
```

Pandas series

Database-like object

```
>>> data.where( (lambda x: x > 2) )
price     42.42
size       3.14
weight      NaN
dtype: float64
```

Filtering out NaNs

```
>>> data.where( (lambda x: x > 2) ).dropna()
price    42.42
size      3.14
dtype: float64
```

Pandas dataframes

Both are build on top of np.arrays

- Series are general sequence and dictionary-like one dimensional objects
- Dataframes are general sequence and dictionary-like two-dimensional objects

```
>>> prices = pd.Series( { 'spam':12.5, 'egg':4.3 } )
>>> qty    = pd.Series( { 'spam':4, 'egg':12 } )
>>> stock  = pd.DataFrame( { 'price': prices,
                             'qty': qty } )
>>> stock
      price  qty
spam   12.5    4
egg     4.3   12
```

Dataframe manipulation

You can add columns like you add dictionary entries

```
>>> stock['value'] = stock['price'] * stock['qty']
>>> stock
      price  qty  value
spam   12.5    4   50.0
egg     4.3   12   51.6
```

And aggregates values

```
>>> stock.sum()
price     16.8
qty       16.0
value    101.6
```

Data filtering

```
>>> stock[stock.price > 5]
      price  qty  value
spam   12.5    4   50.0
```

How can it works??

- Isn't `stock.price > 5` supposed to be a boolean?
- No it isn't! Not at all!

```
>>> stock.price > 5
spam     True
egg     False
Name: price, dtype: bool
>>> type(stock.price > 5)
<class 'pandas.core.series.Series'>
```

Pandas *massively* overloads comparison operators.

Pandas data sources

Dataframes can be build from

- Local files
- Remote data accessible through http(s) urls
- Remote well known public ressources
- Remote ressources requiring an access key

`pandas_datareader` module allows to directly access public (or not) data sources such as Eurostat, the World Bank, OECD, etc.

`yfinance` module to access Yahoo finance, etc.

Application to nuclear physics

Download data from CERN

```
dataurl = 'http://opendata.cern.ch/record/700/files/
 MuRun2010B.csv'
import pandas as pd
data = pd.read_csv(dataurl)
data
```

Fix an incorrect column name!

```
data['px1'] = data['px1 '] # Sanitizing field name...
del(data['px1 ']) # we could have used rename
```

Nuclear Physics

Compute total momentum on all spatial directions

For particules beams 1 and 2...

```
data['vector sum px'] = data['px1'] + data['px2']
data['vector sum py'] = data['py1'] + data['py2']
data['vector sum pz'] = data['pz1'] + data['pz2']
```

Resultant momentum...

```
data['resultant momentum sum'] = \
  (data['vector sum px']**2 + \
   data['vector sum py']**2 + \
   data['vector sum pz']**2)**(0.5)
```

Nuclear Physics

Compute relativistic invariant mass

```
data['invariant mass'] = ((data['E1']+data['E2'])**2 \
     - data['resultant momentum sum'] ** 2)**(0.5)

min(data['invariant mass']), \
max(data['invariant mass'])

(1.958119099640791, 109.97712963856803)
```

Nuclear Physics

Display result

```
%matplotlib inline
from matplotlib import pyplot
pyplot.hist(data['invariant mass'],
            range = ( min(data['invariant mass']),
                      max(data['invariant mass'])),
            bins = 100, color = 'orange',
            edgecolor = 'red')
pyplot.show()
```

Add `log=True`, notice the peak at 91Gev. We've discovered the Z boson!
Reference: //opendata.cern.ch/record/72/files/3_DiMuonHistogramExcelInstructions.pdf

Database-like operation in Pandas

Similar to SQL

- `[field1, field2 ...]` for field selection
- Slices (numbers, dates)
- `loc` and `iloc` method to filter lines and colums
- operators for where-like conditions
- grouby and join methods
- specific methods for Series of data: `isin`, `pd.to_numeric`
- .type.method (ex: `str.split`)

A query mini-language

```
df.query("(name=='john') or (country=='UK')")
df.query('col1.str.contains("spam")')
names = ['john', 'terry']
df.query('name in @names')
```

Numpy, Pandas, Matplotlib, and data science ressources

- Python Data Science : book and Jupyter notebooks
  https://jakevdp.github.io/PythonDataScienceHandbook/
- Scipy/Numpy Introduction
  https://sites.engineering.ucsb.edu/~shell/che210d/numpy.pdf
- Scikit tutorial
  https://scikit-learn.org/stable/tutorial/index.html
- Matplotlib Pyplot tutorial
  https://matplotlib.org/tutorials/introductory/pyplot.html
- Quantitative Economics with Python
  https://python.quantecon.org/intro.html