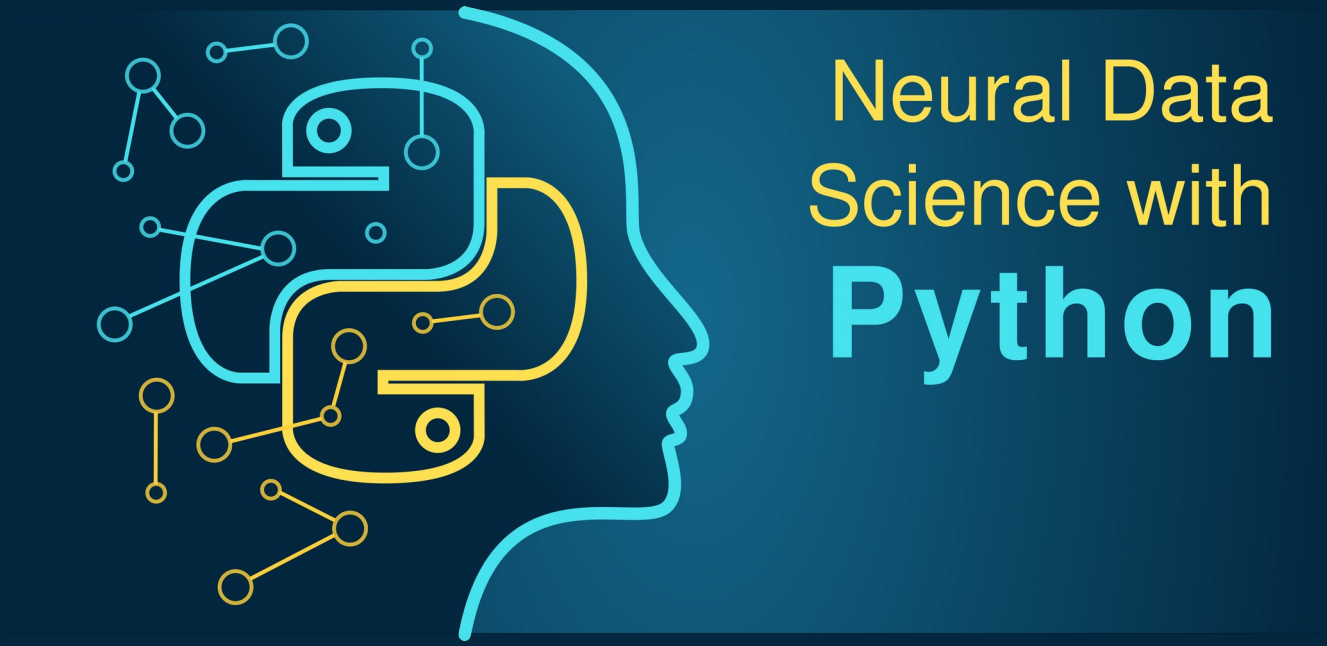


L1 : Introduction to Python : first steps

Michael Graupner

SPPIN – Saint-Pères Institute for the Neurosciences

Université Paris Cité, CNRS

How do YOU deal with data ?

I give you a 2d array of numbers : measurements and time points (*N=1000*).

time	0.1	0.2	0.3	0.4	0.5	0.6	...	99.8	99.9	100.0
measurment	3.2	4.3	3.8	4.5	3.7	5.1	...	8.3	8.1	9.0

- I would like to know the mean and the standard deviation of the measurements.

- I would like to see the data displayed, i.e., plotted as measurement vs time.

→ **How would you do that today ?**

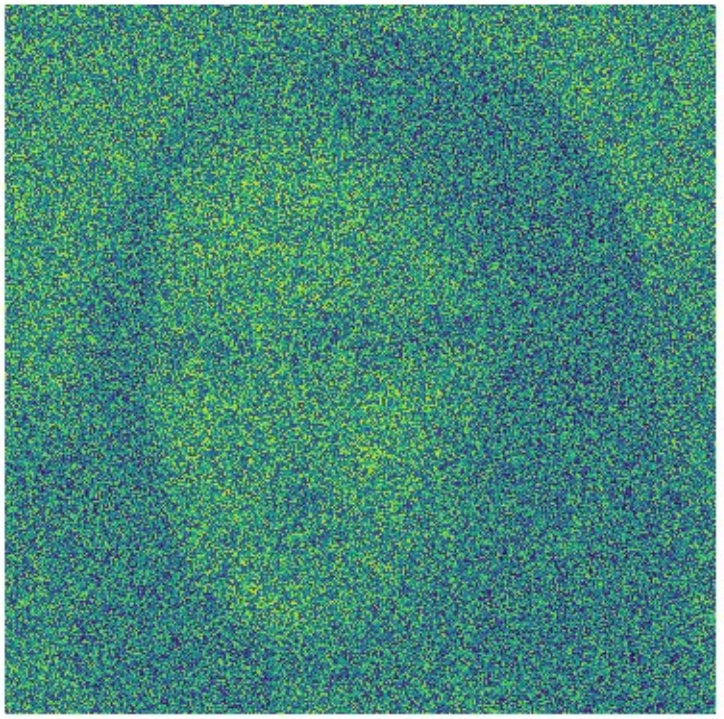
942	509	688	1093	703	416	664	762	664	822	457	400	614	648	243	218	852	459	524	660
158	503	226	1016	322	632	168	419	1015	772	893	774	765	237	161	575	351	244	806	584
692	817	305	168	139	693	507	1121	868	181	943	310	622	345	391	609	1060	1058	1002	401
1050	826	399	1002	1031	140	310	750	394	924	321	425	524	225	428	633	439	686	587	413
787	1103	1012	157	839	632	917	256	677	631	419	1014	239	398	951	223	1042	637	577	843
781	512	994	343	1084	941	343	632	234	518	850	1021	367	310	726	773	672	493	914	506
516	240	575	790	159	657	983	587	933	170	1010	1106	601	868	872	337	1032	533	452	963
464	902	456	976	943	279	797	1008	341	679	585	1011	569	584	775	740	505	497	690	944
179	295	928	549	593	850	375	1068	343	436	535	171	931	557	382	1083	781	536	902	781
1119	648	590	617	221	622	149	978	487	154	763	1088	942	941	1032	411	642	912	199	958
443	150	619	614	747	452	415	502	240	767	160	1066	907	978	1043	382	240	563	939	904
278	684	1080	582	291	580	1100	701	957	287	650	453	573	730	714	412	311	407	1048	275
813	520	997	277	308	1069	1082	235	230	1031	972	658	1033	805	869	344	228	586	144	665
1027	540	1067	293	851	269	274	435	1069	869	941	208	163	1079	887	974	265	733	223	1009
610	546	628	732	218	184	827	412	942	492	624	348	950	676	471	1114	515	355	821	264
621	328	734	905	340	875	1056	1102	1038	130	338	918	945	174	931	1005	884	1054	158	767
511	209	1108	378	1064	478	203	739	868	615	541	641	697	571	920	430	908	299	666	638
728	151	217	404	481	884	231	705	301	908	295	1091	865	169	806	757	1098	913	1082	942
221	715	474	329	560	738	1044	672	531	412	224	284	1127	198	602	464	393	385	293	608
778	1045	1005	689	328	718	395	202	656	1040	489	756	459	582	1010	951	442	731	540	1023

...

⋮

```
 942  509  688 1093  703  416  664  762  664  822  457  400  614  648  243  218  852  459  524  660
 158  503  226 1016  322  632  168  419 1015  772  893  774  765  237  161  575  351  244  806  584
 692  817  305  168  139  693  507 1121  868  181  943  310  622  345  391  609 1060 1058 1002  401
1050  826  399 1002 1031  140  310  750  394  924  321  425
 787 1103 1012  157  839  632  917  256  677  631  419 1014
 781  512  994  343 1084  941  343  632  234  518  850 1021
 516  240  575  790  159  657  983  587  933  170 1010 1106
 464  902  456  976  943  279  797 1008  341  679  585 1011
 179  295  928  549  593  850  375 1068  343  436  535  171
1119  648  590  617  221  622  149  978  487  154  763 1088
 443  150  619  614  747  452  415  502  240  767  160 1066
 278  684 1080  582  291  580 1100  701  957  287  650  453
 813  520  997  277  308 1069 1082  235  230 1031  972  658
1027  540 1067  293  851  269  274  435 1069  869  941  208
 610  546  628  732  218  184  827  412  942  492  624  348
 621  328  734  905  340  875 1056 1102 1038  130  338  918
 511  209 1108  378 1064  478  203  739  868  615  541  641
 728  151  217  404  481  884  231  705  301  908  295 1091
 221  715  474  329  560  738 1044  672  531  412  224  284
 778 1045 1005  689  328  718  395  202  656 1040  489  756
```

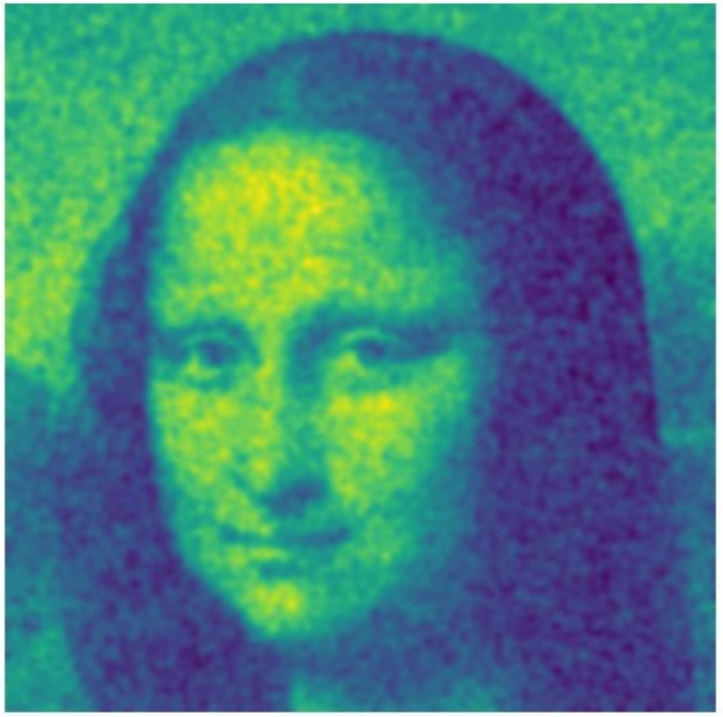
⋮



2D plot

```
 942  509  688 1093  703  416  664  762  664  822  457  400  614  648  243  218  852  459  524  660
 158  503  226 1016  322  632  168  419 1015  772  893  774  765  237  161  575  351  244  806  584
 692  817  305  168  139  693  507 1121  868  181  943  310  622  345  391  609 1060 1058 1002  401
1050  826  399 1002 1031  140  310  750  394  924  321  425
 787 1103 1012  157  839  632  917  256  677  631  419 1014
 781  512  994  343 1084  941  343  632  234  518  850 1021
 516  240  575  790  159  657  983  587  933  170 1010 1106
 464  902  456  976  943  279  797 1008  341  679  585 1011
 179  295  928  549  593  850  375 1068  343  436  535  171
1119  648  590  617  221  622  149  978  487  154  763 1088
 443  150  619  614  747  452  415  502  240  767  160 1066
 278  684 1080  582  291  580 1100  701  957  287  650  453
 813  520  997  277  308 1069 1082  235  230 1031  972  658
1027  540 1067  293  851  269  274  435 1069  869  941  208
 610  546  628  732  218  184  827  412  942  492  624  348
 621  328  734  905  340  875 1056 1102 1038  130  338  918
 511  209 1108  378 1064  478  203  739  868  615  541  641
 728  151  217  404  481  884  231  705  301  908  295 1091
 221  715  474  329  560  738 1044  672  531  412  224  284
 778 1045 1005  689  328  718  395  202  656 1040  489  756
```

⋮



smoothing + 2D plot

Python code for the above operations

Python code

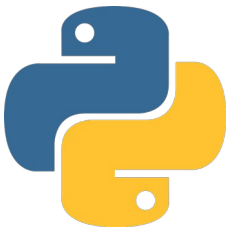
```
img = plt.imread('image-noise.tif')

imgNew = gaussian_filter(img, sigma=10)

ax.imshow(imgNew)
```

→ read image

→ apply Gaussian filter

→ plot/display image

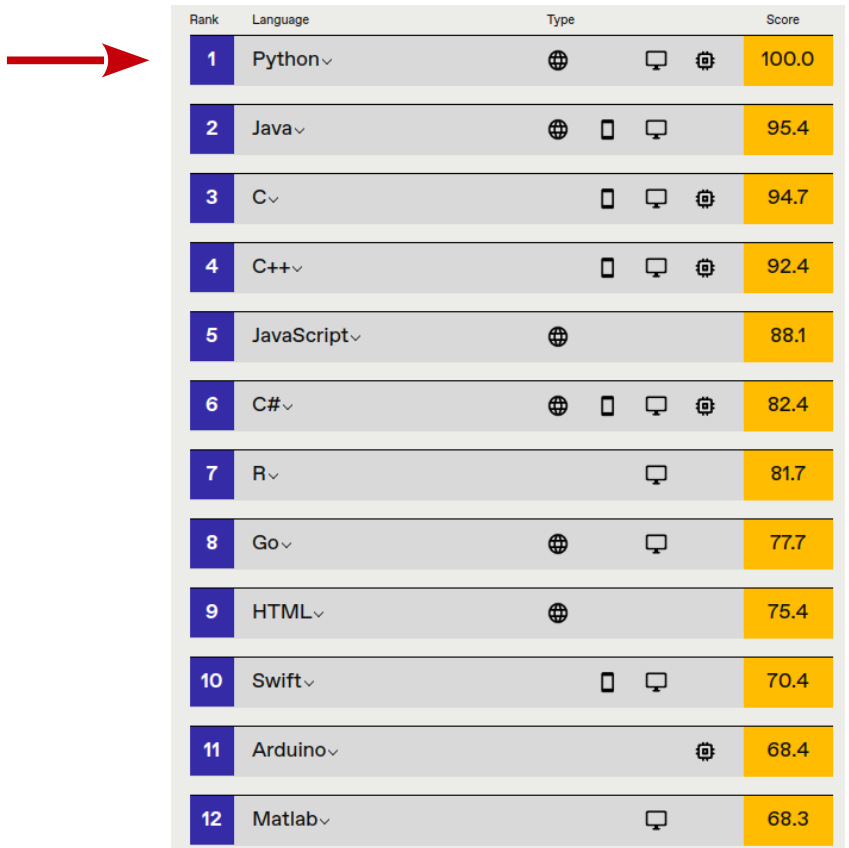
What is Python ?



- modern programming language (since 1991)
- interpreted language (no compilation necessary)
- emphasis is put on the readability of the code
- concepts can be expressed in less lines compared to C/C++ or Java
- extensive libraries available
- build-in visualization

Python - modern programming language

Most popular programming languages in 2021



Rank	Language	Type	Score
1	Python		100.0
2	Java		95.4
3	C		94.7
4	C++		92.4
5	JavaScript		88.1
6	C#		82.4
7	R		81.7
8	Go		77.7
9	HTML		75.4
10	Swift		70.4
11	Arduino		68.4
12	Matlab		68.3

[Source : IEEE Spectrum]

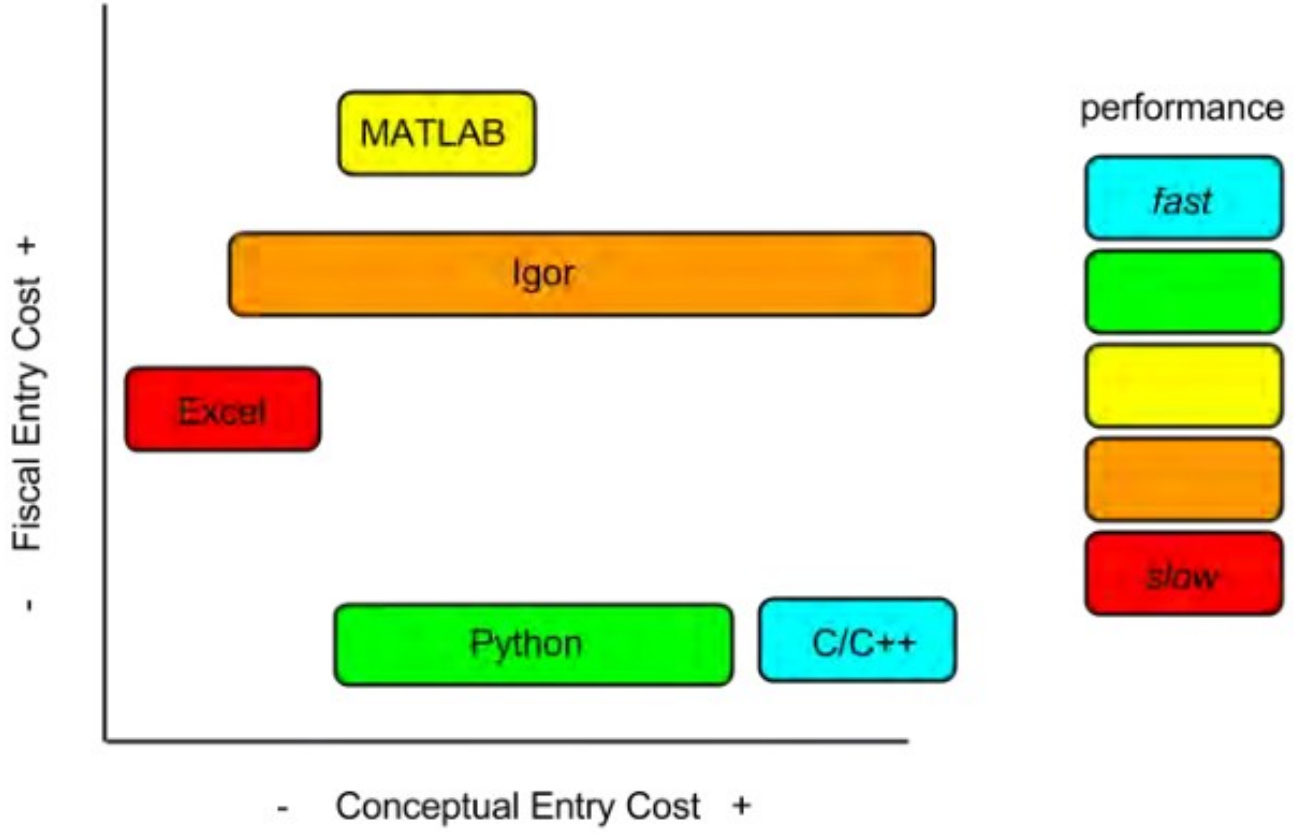
Clear and readable syntax → easy to learn

In [1]:

```
1  # import modules
2  import numpy as np
3
4  # function declaration
5  def update_values(x):
6      return x+1
7
8  x = 1
9  if x>0:
10     print('Hello World!')
11     x = update_values(x)
12
13 print(x)
```

```
Hello World!
2
```

Python - free and easy to learn



Extensive standard and third-party libraries

- **wxPython :** graphical toolbox library for GUI development
- **SymPy :** library for symbolic mathematics : can do algebraic evaluations, differentiation, expansions, complex numbers, etc.
- **Pygame :** library for 2D game development
- **Twisted :** major tool for development of network applications
- **OpenCV :** library for extensive computer vision applications

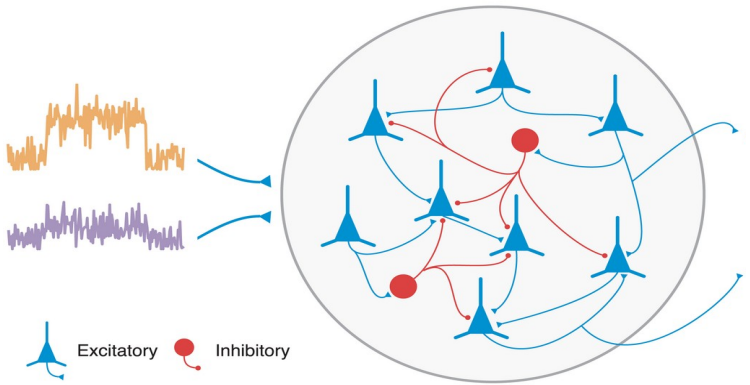
Python modules for Neuroscience applications

- simulators and simulator interfaces
- data collection and analysis
- sharing, re-use, storage and databasing of data and models
- stimulus generation
- parameter search and optimization
- visualization
- machine learning : GPU-based computing

Python in Neuroscience : network simulator

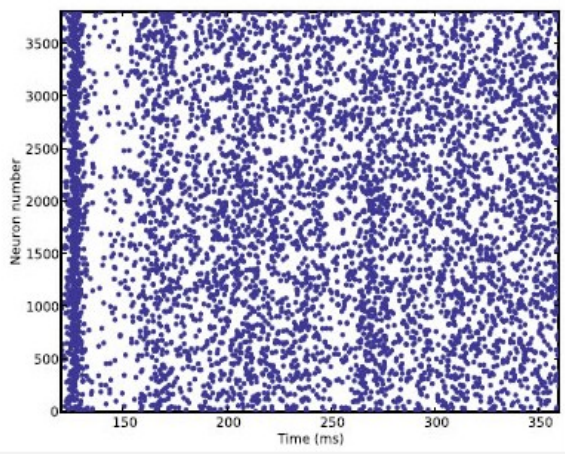
BRIAN

spiking neural network simulator



randomly connected, recurrent network of excitatory and inhibitory neurons

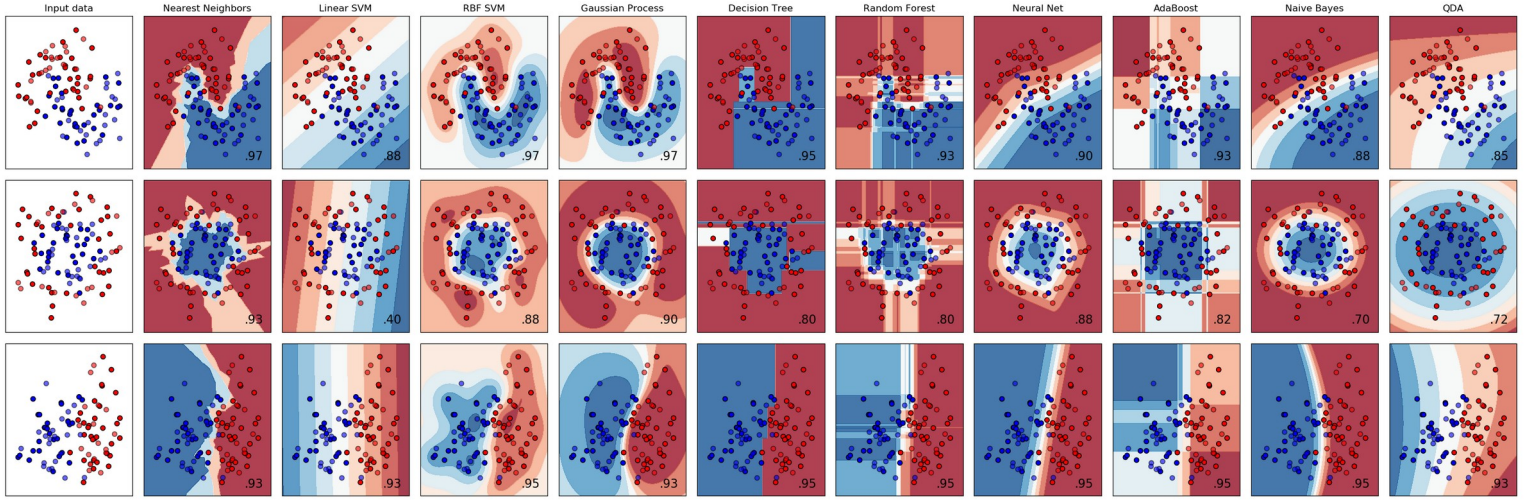
```
from brian import *
eqs = '''
dv/dt = (ge+gi-(v+49*mV))/(20*ms) : volt
dge/dt = -ge/(5*ms) : volt
dgi/dt = -gi/(10*ms) : volt
'''
P = NeuronGroup(4000, eqs, threshold=-50*mV, reset=-60*mV)
P.v = -60*mV+10*mV*rand(len(P))
Pe = P.subgroup(3200)
Pi = P.subgroup(800)
Ce = Connection(Pe, P, 'ge', weight=1.62*mV, sparseness=0.02)
Ci = Connection(Pi, P, 'gi', weight=-9*mV, sparseness=0.02)
M = SpikeMonitor(P)
run(1*second)
raster_plot(M)
show()
```



Python in Neuroscience : machine learning

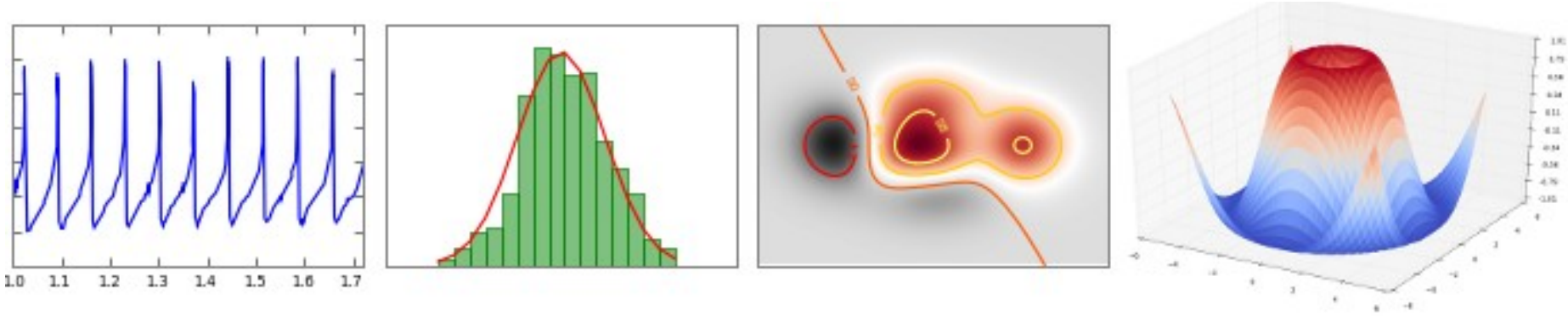
Machine Learning in Python. Simple and efficient tools for data mining and data analysis

e.g. classification using several classifiers



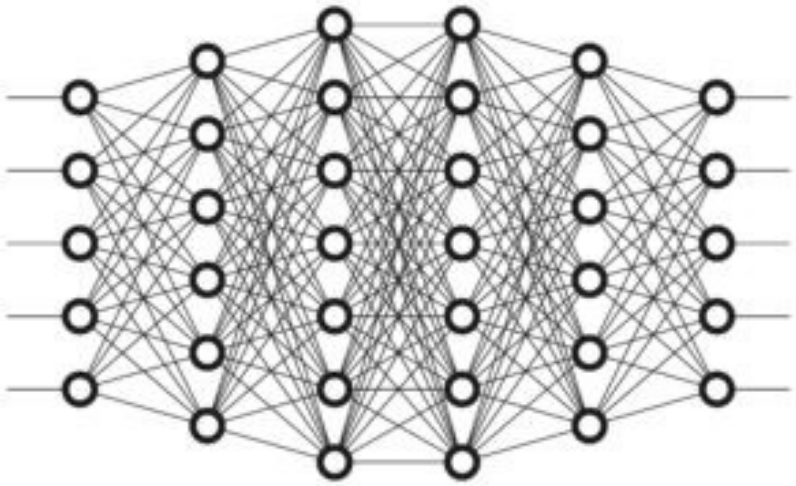
Python in Neuroscience : visualization

e.g. matplotlib library



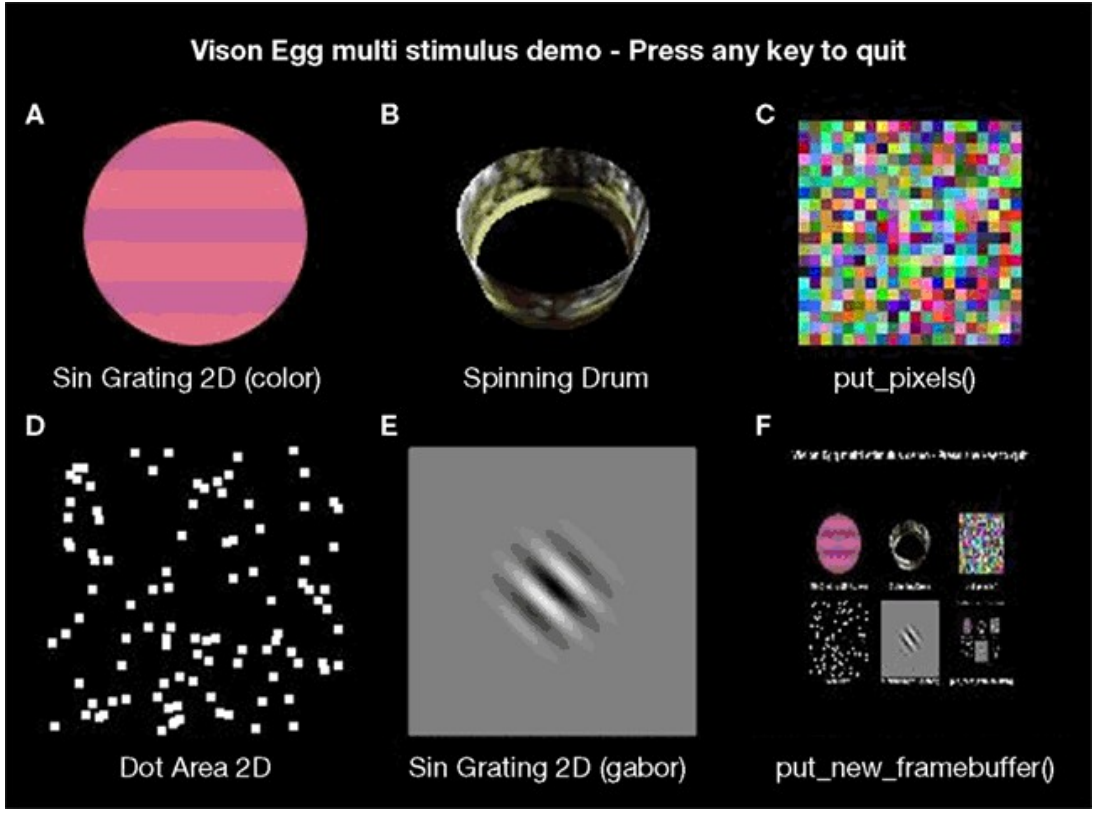
Python in Neuroscience : deep learning/networks

simulate multi-layer networks for deep-learning applications



Python in Neuroscience : stimulus generation

e.g. Vision EGG, or PsychoPy



Getting started : Python installation

- Windows, Mac OS X, Linux (distributions for package handling)
  - **Anaconda** from Continuum Analaytics : https://www.continuum.io/downloads
  - Enthought Python : https://www.enthought.com/
  - Python(x,y) : http://python-xy.github.io/
- Debian + Ubuntu Linux

```
$ apt-get install python-numpy python-scipy python-matplotlib \
 ipython
```

- Mac OS X : Install Fink, then

```
$ fink install scipy-core-py25 scipy-py25 matplotlib-py25 ipython-py25
```

- Note that “$” symbolizes command line prompt, it is not part of the command

Getting started : interpreter and IDEs

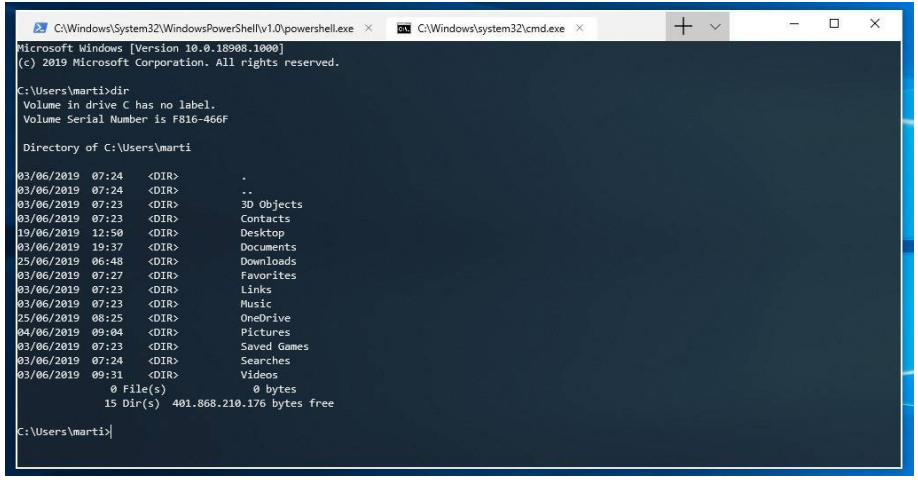
- **ipython**
  - command line interpreter : interactive shell for enhanced introspection, code highlighting and tab completion
- **Jupyter Notebook**
  - command line interpreter in the browser
  - combines code execution, rich text, and visualizations
- **Spyder** (IDE): Scientific PYthon Development EnviRonment
- **PyCharm** (IDE): code development environment

IDE ... Integrated Development Environment

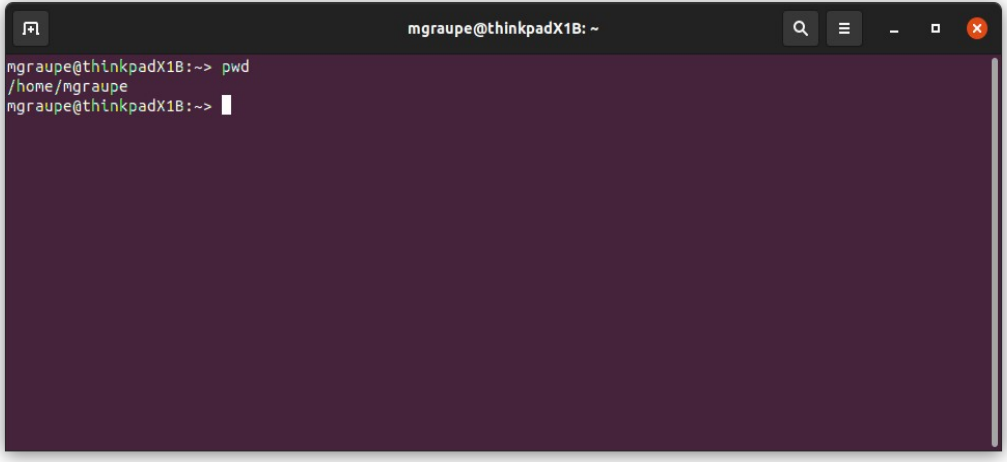
Everything starts with the Terminal

- **What is a Terminal ?**
  - Terminal, also known as command line, console or shell
  - allow to accomplish tasks on a computer without the use of graphical user interfaces (GUIs)
  - simple text commands are used to accomplish tasks

Windows terminal (command line, Powershell)



Linux terminal



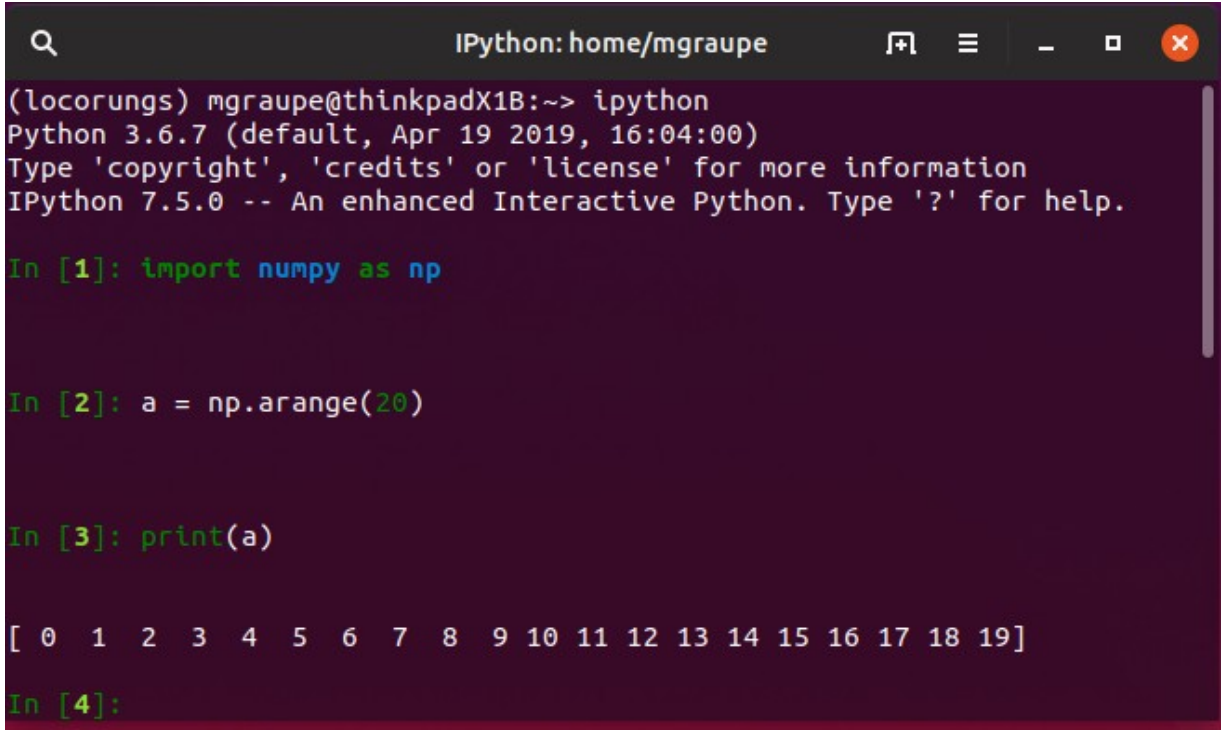
iPython

IPython
Interactive Computing

- Started by typing and executing (by pressing *enter*) **ipython** in the *terminal* application

```
$ ipython
```

- useful for short explorations
- tab completion!

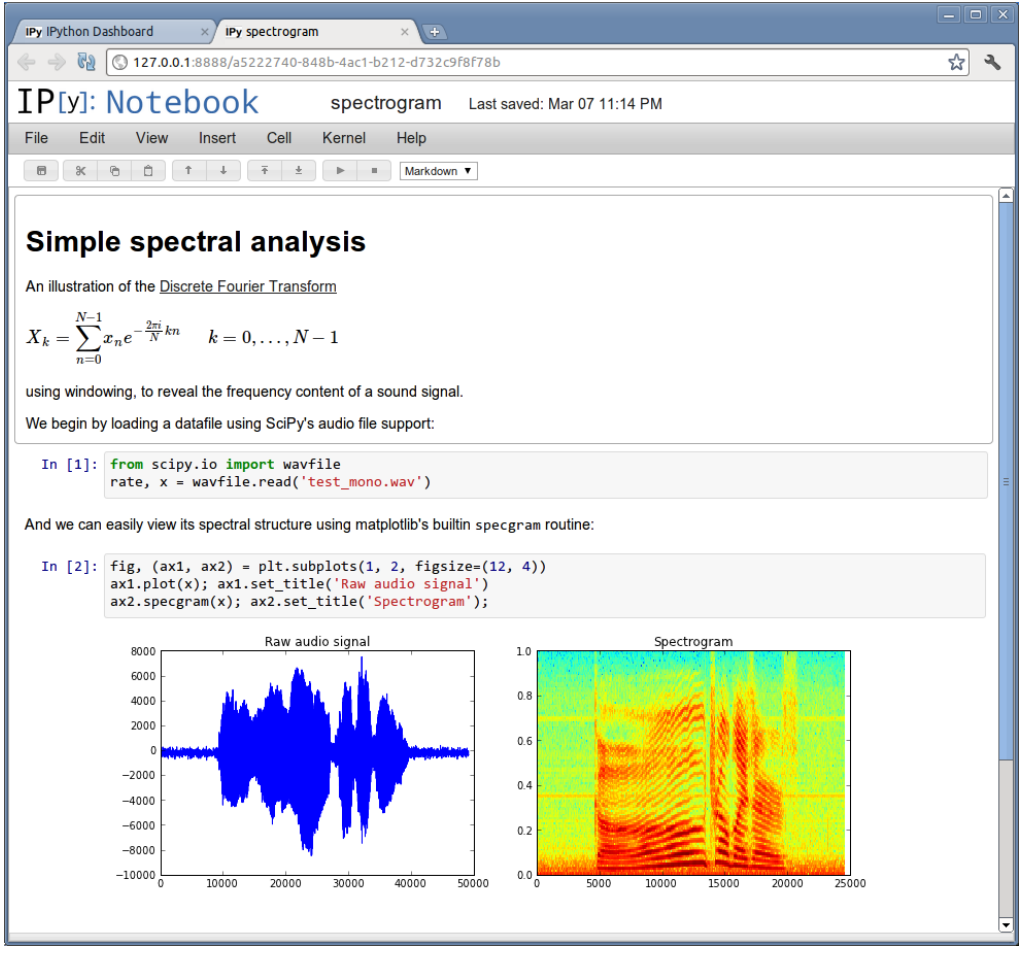


Jupyter Notebook

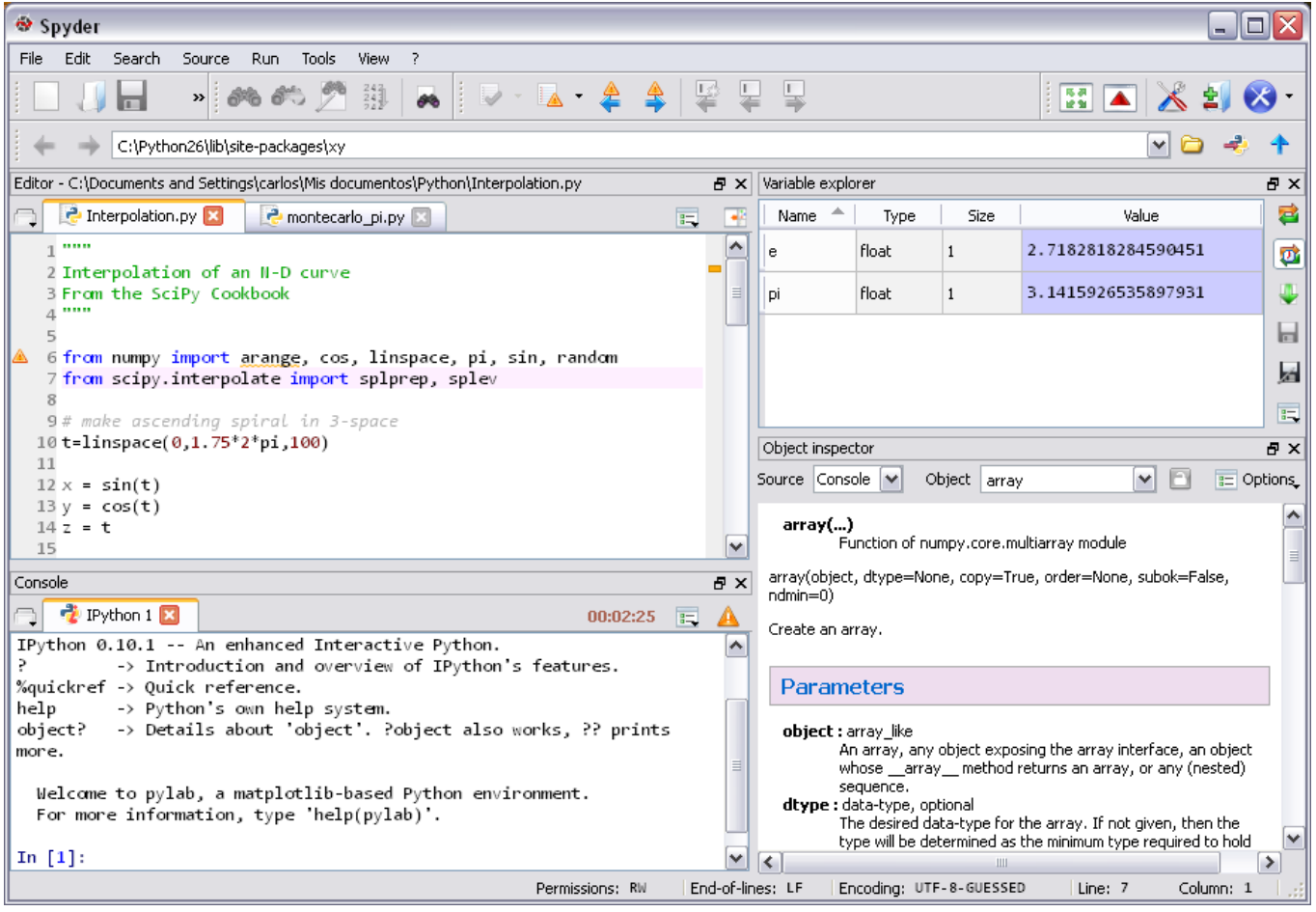
- Started by typing and executing (by pressing *enter*) **jupyter-notebook** in the *terminal* application :

```
$ jupyter-notebook
```

- launched and accessed in a browser (firefox, chrome, safari ...) window

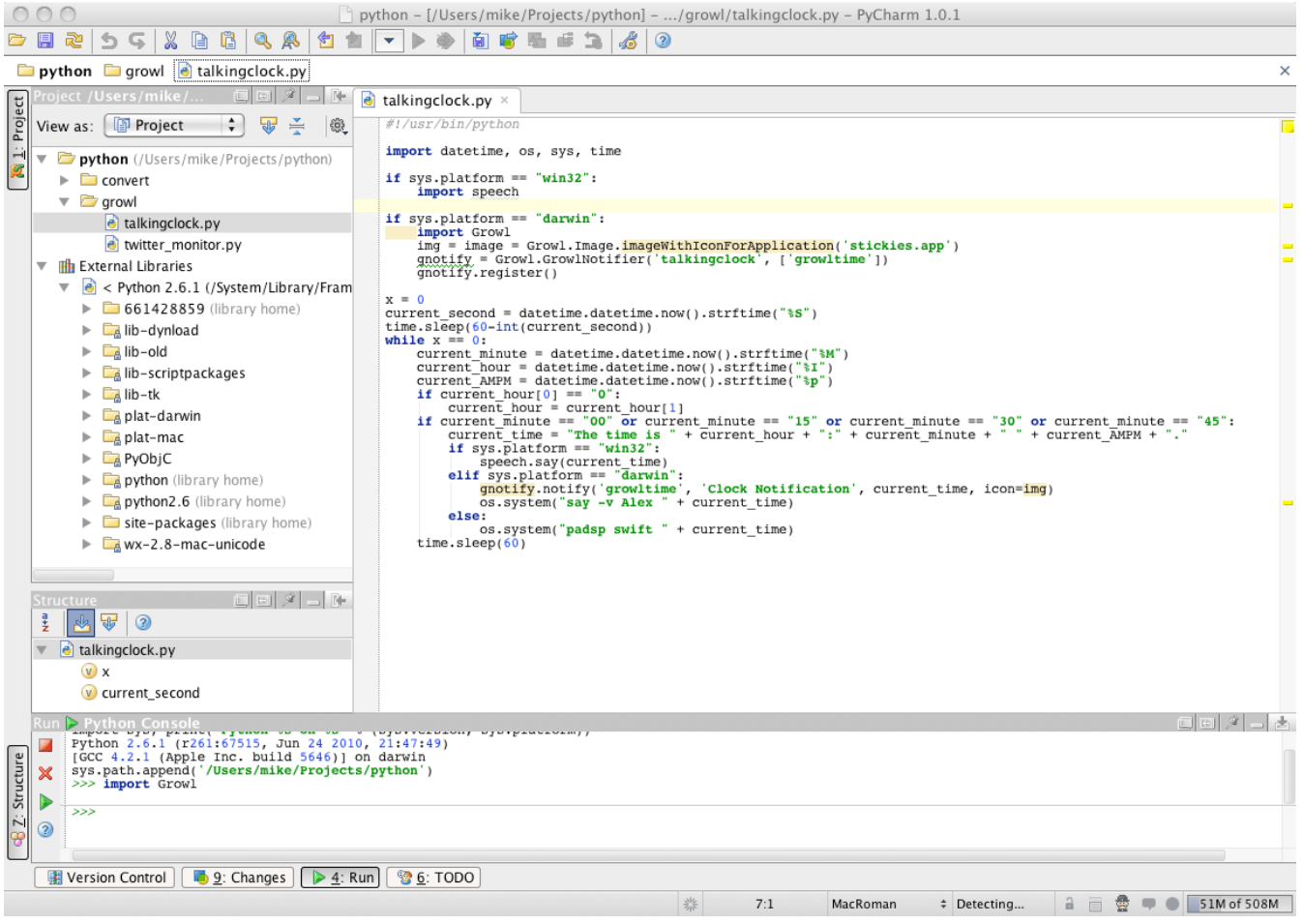


Spyder


Spyder
File Edit Search Source Run Tools View ?
C:\Python26\lib\site-packages\xy
Editor - C:\Documents and Settings\carlos\Mis documentos\Python\Interpolation.py
Interpolation.py
montecarlo_pi.py
"""
Interpolation of an N-D curve
From the SciPy Cookbook
"""
from numpy import arange, cos, linspace, pi, sin, random
from scipy.interpolate import splprep, splev
# make ascending spiral in 3-space
t=linspace(0,1.75*2*pi,100)
x = sin(t)
y = cos(t)
z = t
Variable explorer
Name Type Size Value
e float 1 2.7182818284590451
pi float 1 3.1415926535897931
Object inspector
Source Console Object array Options
array(...)
Function of numpy.core.multiarray module
array(object, dtype=None, copy=True, order=None, subok=False, ndmin=0)
Create an array.
Parameters
object : array_like
An array, any object exposing the array interface, an object whose __array__ method returns an array, or any (nested) sequence.
dtype : data-type, optional
The desired data-type for the array. If not given, then the type will be determined as the minimum type required to hold
Console
IPython 1
00:02:25
IPython 0.10.1 -- An enhanced Interactive Python.
? -> Introduction and overview of IPython's features.
%quickref -> Quick reference.
help -> Python's own help system.
object? -> Details about 'object'. ?object also works, ?? prints more.
Welcome to pylab, a matplotlib-based Python environment.
For more information, type 'help(pylab)'.
In [1]:
Permissions: RW
End-of-lines: LF
Encoding: UTF-8-GUESSED
Line: 7
Column: 1


spyder

PyCharm


python – [/Users/mike/Projects/python] – .../growl/talkingclock.py – PyCharm 1.0.1
python
growl
talkingclock.py
Project /Users/mike/...
View as: Project
python (/Users/mike/Projects/python)
convert
growl
talkingclock.py
twitter_monitor.py
External Libraries
< Python 2.6.1 (/System/Library/Fram
661428859 (library home)
lib-dynload
lib-old
lib-scriptpackages
lib-tk
plat-darwin
plat-mac
PyObjC
python (library home)
python2.6 (library home)
site-packages (library home)
wx-2.8-mac-unicode
Structure
talkingclock.py
x
current_second
#!/usr/bin/python
import datetime, os, sys, time
if sys.platform == "win32":
import speech
if sys.platform == "darwin":
import Growl
img = image = Growl.Image.imageWithIconForApplication('stickies.app')
gnotify = Growl.GrowlNotifier('talkingclock', ['growltime'])
gnotify.register()
x = 0
current_second = datetime.datetime.now().strftime("%S")
time.sleep(60-int(current_second))
while x == 0:
current_minute = datetime.datetime.now().strftime("%M")
current_hour = datetime.datetime.now().strftime("%I")
current_AMPM = datetime.datetime.now().strftime("%p")
if current_hour[0] == "0":
current_hour = current_hour[1]
if current_minute == "00" or current_minute == "15" or current_minute == "30" or current_minute == "45":
current_time = "The time is " + current_hour + ":" + current_minute + " " + current_AMPM + "."
if sys.platform == "win32":
speech.say(current_time)
elif sys.platform == "darwin":
gnotify.notify('growltime', 'Clock Notification', current_time, icon=img)
os.system("say -v Alex " + current_time)
else:
os.system("padsp swift " + current_time)
time.sleep(60)
Run Python Console
Python 2.6.1 (r261:67515, Jun 24 2010, 21:47:49)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
sys.path.append('/Users/mike/Projects/python')
>>> import Growl
>>>
Version Control
9: Changes
4: Run
6: TODO
7:1
MacRoman
Detecting...
51M of 508M

Executing Python programs

- Python programs can be run either interactively or as scripts stored in a file
- An interpreter is started by calling **ipython** (or plain **python, or jupyter-notebook**)

```
mgraupe@atp:~$ ipython3
Python 3.5.7 (default, Apr  4 2019, 12:02:34)
Type "copyright", "credits" or "license" for more information.

In [1]: print('Hello World!')
Hello World!
In [2]: x = 3
In [3]: print(x+5)
8
In [4]: exit
mgraupe@atp:~$
```

- Scripts are supplied as arguments to the interpreter

```
mgraupe@atp:~$ python hello_world.py
Hello world!
```

Online resources : introductions and references

- **W3Schools - Python Tutorials :**
  `https://www.w3schools.com/python/default.asp`
- The Python documentation index :
  `https://docs.python.org/3.6/`
- Python library reference :
  `https://docs.python.org/3.6/library/`
- Dive into Python :
  `http://histo.ucsf.edu/BMS270/diveintopython3-r802.pdf`
- Activestate Python [popular Python recipes] :
  `http://code.activestate.com/recipes/langs/python/`
- Python tutorial :
  `https://docs.python.org/3.6/tutorial/index.html`
- Numpy tutorial :
  `http://www.time.mk/trajkovski/teaching/imi/2010-fall/NumPy/Tentative%20NumPy%20Tutorial%20-.html`
- Scipy reference :
  `http://docs.scipy.org/doc/scipy/reference/genindex.html`

Online resources : general

- a simple Google search :
  - use the keyword “python”
  - specify your operating system (*window, linux, mac*) for package installation, importing queries
  - use the best matching terminology for code questions
  - common sites for useful help : *stackoverflow*, *askubuntu*, *github*

Online resources : ask ChatGPT for code

GR How can I create an array and plot it in python?

:

1. Install required libraries (if not already installed):
   You can install NumPy and Matplotlib using pip if you haven't already:

```bash
pip install numpy matplotlib
```

2. Import the necessary libraries:
   In your Python script or Jupyter Notebook, import NumPy and Matplotlib:

```python
import numpy as np
import matplotlib.pyplot as plt
```

3. Create an array:
   You can create a NumPy array by using the `np.array()` function. For example, let's create a simple array of numbers:

```python
# Create an array of numbers from 0 to 9
my_array = np.array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

4. Plot the array:
   To plot the array, you can use Matplotlib's `plt.plot()` function. Here's a basic example:

```python
# Plot the array
plt.plot(my_array)

# Add labels and title (optional)
plt.xlabel('X-axis')
plt.ylabel('Y-axis')
plt.title('Array Plot')

# Show the plot
plt.show()
```

This code will create a simple line plot of your array.

Attention! Code can be erroneous.

Online resources : ask ChatGPT to interpret code

GR

What does the following python code do ?

```
import numpy as np
import matplotlib.pyplot as plt

%matplotlib inline

t = np.linspace(0,10,1001)
tau = 2. y = np.exp(-t/tau)  # multiple commands on a line are separted by ;

plt.plot(t,y)
```

The provided Python code performs the following actions:

1. Imports the necessary libraries:
   - It imports NumPy as `np` and Matplotlib as `plt`. These libraries are commonly used for numerical operations and plotting, respectively.
2. `%matplotlib inline`:
   - This is a special Jupyter Notebook command that tells the notebook to display Matplotlib plots directly within the notebook rather than opening them in separate windows. It's not required in regular Python scripts, as it's specific to Jupyter Notebook.
3. Creates a time array `t`:
   - It generates an array `t` using `np.linspace()` that spans from 0 to 10 with 1001 evenly spaced points. This array represents a time series.
4. Defines a decay function `y`:
   - It calculates an exponential decay function `y` using the formula `y = np.exp(-t/tau)`. Here, `tau` is a time constant set to 2.0.
5. Plots `t` against `y`:
   - It uses `plt.plot(t, y)` to create a line plot of the time array `t` on the x-axis and the exponential decay values `y` on the y-axis.

Overall, this code generates an exponential decay curve and plots it using Matplotlib, with the resulting plot displayed in the Jupyter Notebook output cell (thanks to `%matplotlib inline`). The decay curve is based on the exponential decay function with a time constant `tau` of 2.0, and it covers the time range from 0 to 10.

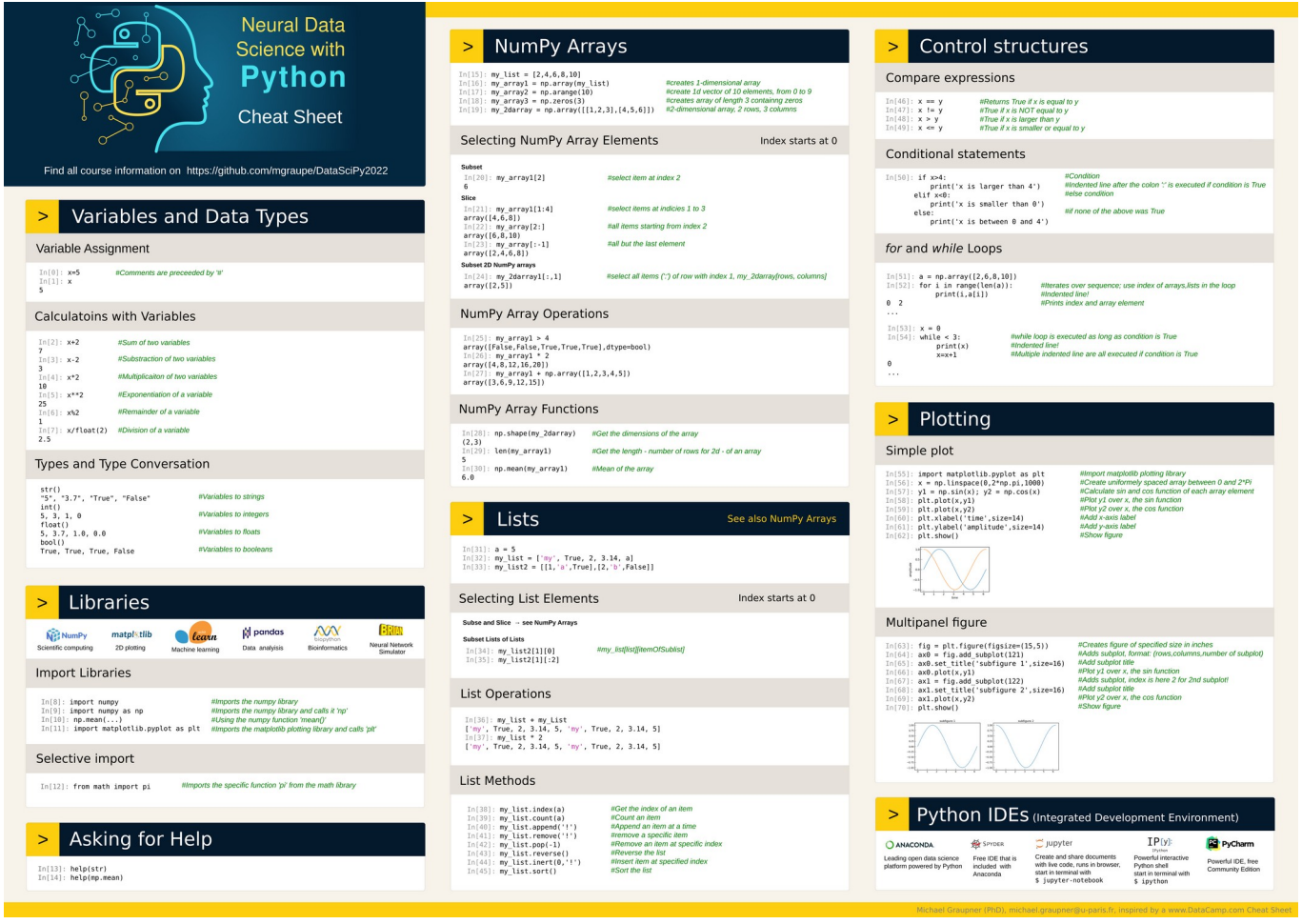
Online resources : DataCamp

- an interactive to learn, practice and develop further your programming skills
- ideal to to dive into a programming language for starters (videos, extensive help, hints, small assignments with direct feedback)
- learn and extend your programming skills at your own pace
- a commercial website, you have access through this course : https://learn.datacamp.com/

Online resources : Neuroscience

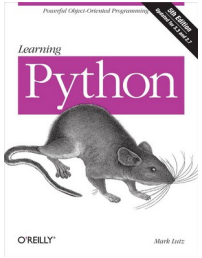
- Front Neuroinform 2015 – *Python in Neuroscience*
  `http://journal.frontiersin.org/article/10.3389/fninf.2015.00011/full`
- BCCN cours - *Advanced Scientific Programming in Python* :
  `https://python.g-node.org/wiki/schedule`
- Brian simulator :
  `http://briansimulator.org/`

General reference for the course : Cheat Sheet

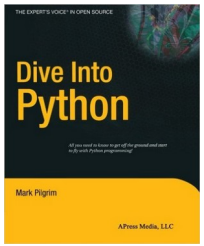


- Contains basic Python concepts and information
- Reference for often used code in class

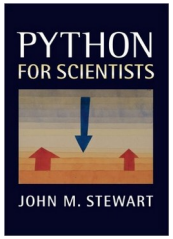
General Python books



- Learning Python, 5th Edition
  Mark Lutz
  ISBN : 978-1-4493-5573-9

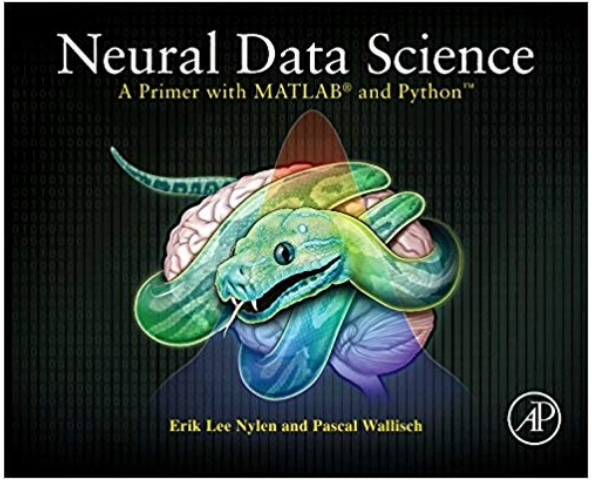


- Dive Into Python (3)
  Mark Pilgrim
  ISBN: 978-1590593561 (978-1430224150)



- Python for Scientists
  John M. Stewart
  ISBN: 978-1107686427

Neuroscience specific book



- Neural Data Science
  A primer with Matlab and Python
  Erik Lee Nylen (Author), Pascal Wallisch (Author)
  ISBN-10: 9780128040430

Workflow of the course lecture

1) **All course material** (.pdf file of lecture; .ipynb for tutorial; .ipynb for homework assignment) can be accessed on github (code repository site) :
   https://github.com/mgraupe/NeuralDataSciPy2024

2) **Visit course website** : Launch the browser ( “Navigateur Web”) and navigate to the link above

3) **Download lecture** : Click on lecture link and hit the **Download** button (file will be downloaded automatically to the downloads – Téléchargements – folder); annotate lecture PDF

Workflow of the course tutorial

1) **Tutorial material :** can be accessed on github, launch the browser (Navigateur Web) and got to:
   https://github.com/mgraupe/NeuralDataSciPy2024
2) **Save tutorial file** : Click on the tutorial link, hit the **Raw** button (the raw file content will be displayed), save (Enregister sous ...) the raw file to your computer
   Attention : make sure that the file ending remains **.ipynb**
3) **Launch jupyter-notebook :** Start the **terminal** application ( "Emulateur de Terminal") on your computer, launch the notebook environment by typing and executing **$ jupyter-notebook** , the jupyter environment starts up in the browser in the directory in which it was started
4) **Load the jupyter-notebook file :** In the jupyter environment, you first see the directory and file structure on your computer (relative to the directory in which jupyter was started), **navigate** to the downloaded **.ipynb** file and click on it to launch it
5) **Start editing**
6) **You can follow the tutorial progress/coding of the lecturer on Deepnote.**
   allows you to copy code into your own Jupyter notebook.