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Boosting Your Jupyter Notebook Productivity

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14-18 minutes

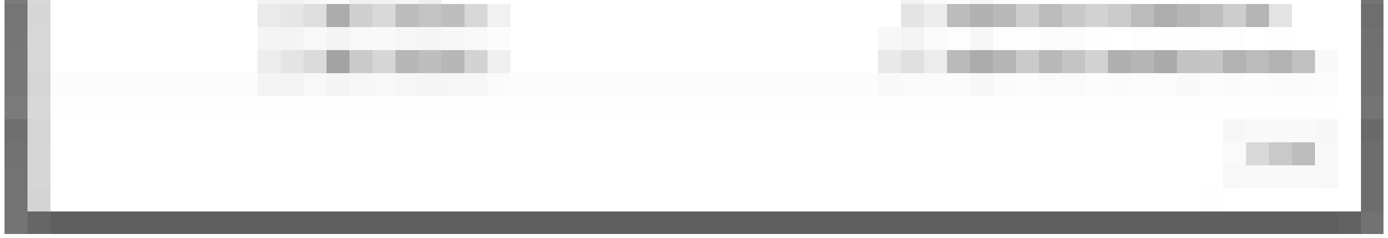
First of all, I want to point out that it is very flexible tool to create readable analyses, because one can keep code, images, comments, formula and plots together:

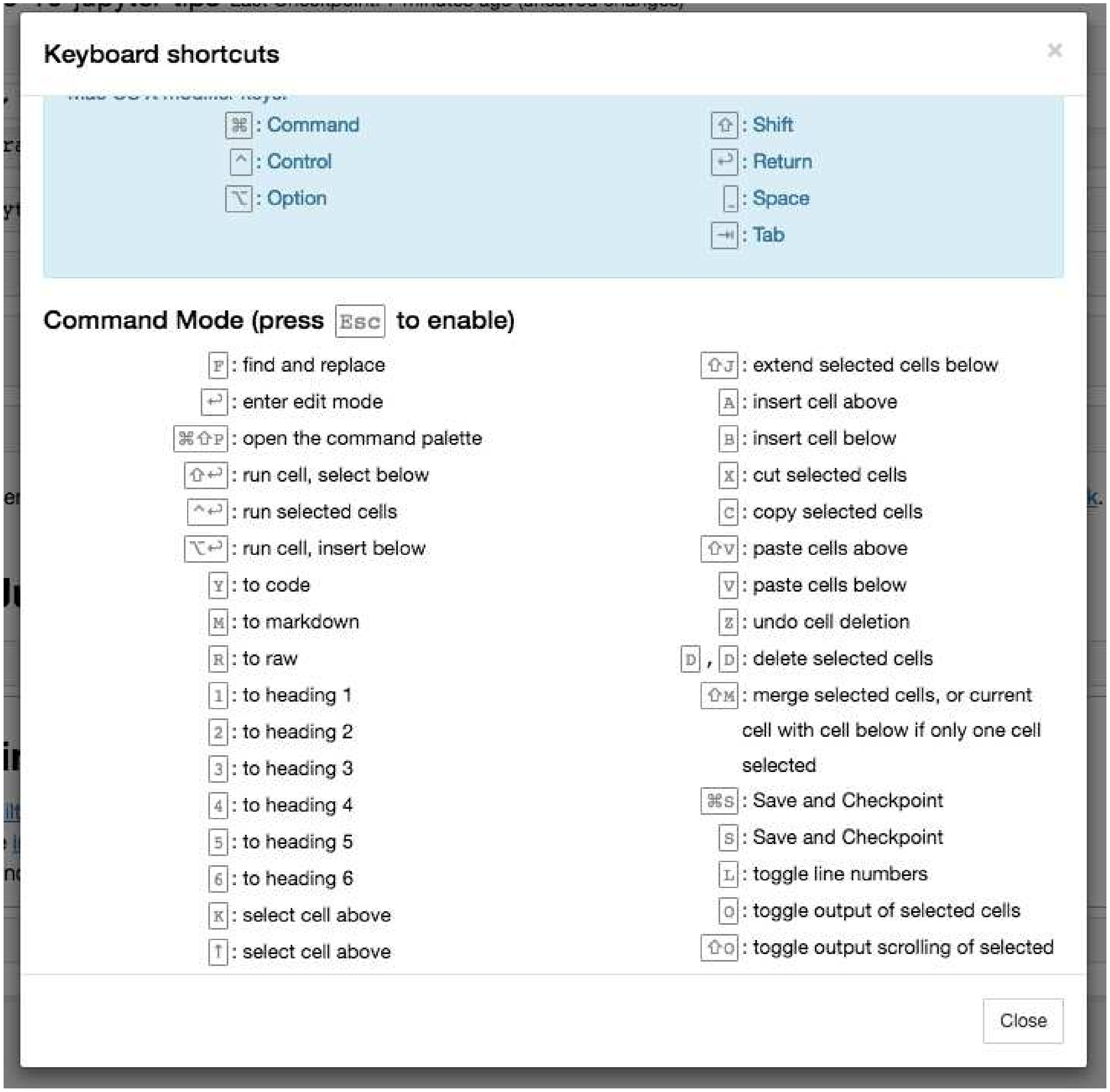
Jupyter is very extensible, supports other programming languages, easily hosted on almost any server — you just only need to have ssh or http access to a server. And it is completely free.

List of hotkeys is shown in **Help > Keyboard Shortcuts** (list is extended from time to time, so don't hesitate to look at it again).

This gives an idea of how you're expected to interact with notebook. If you're using notebook constantly, you'll of course learn most of the list. In particular:

- `Esc + F` Find and replace to search only over the code, not outputs
- `Esc + O` Toggle cell output
- You can select several cells in a row and delete / copy / cut / paste them. This is helpful when you need to move parts of a notebook





Keyboard shortcuts

⌘ : Command	⇧ : Shift
^ : Control	↩ : Return
⌥ : Option	␣ : Space
	⇥ : Tab

Command Mode (press Esc to enable)

F : find and replace	⇧J : extend selected cells below
↩ : enter edit mode	A : insert cell above
⌘⇧P : open the command palette	B : insert cell below
⇧↩ : run cell, select below	X : cut selected cells
^↩ : run selected cells	C : copy selected cells
⌥↩ : run cell, insert below	⇧V : paste cells above
Y : to code	V : paste cells below
M : to markdown	Z : undo cell deletion
R : to raw	D , D : delete selected cells
1 : to heading 1	⇧M : merge selected cells, or current cell with cell below if only one cell selected
2 : to heading 2	⌘S : Save and Checkpoint
3 : to heading 3	S : Save and Checkpoint
4 : to heading 4	L : toggle line numbers
5 : to heading 5	O : toggle output of selected cells
6 : to heading 6	⇧O : toggle output scrolling of selected
K : select cell above	
T : select cell above	

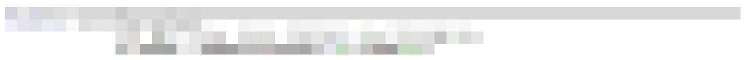
Close

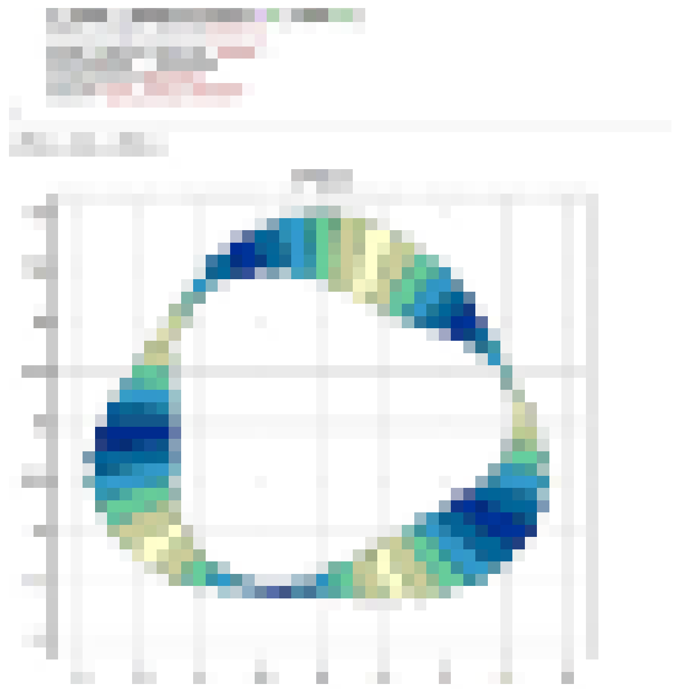
Simplest way is to share notebook file (.ipynb), but not everyone is using notebooks, so the options are

- convert notebooks to html file
- share it with gists , which are rendering the notebooks.
- store your notebook e.g. in dropbox and put the link to nbviewer. nbviewer will render the notebook
- github renders notebooks (with some limitations, but in most cases it is ok), which makes it very useful to keep history of your research (if research is public)

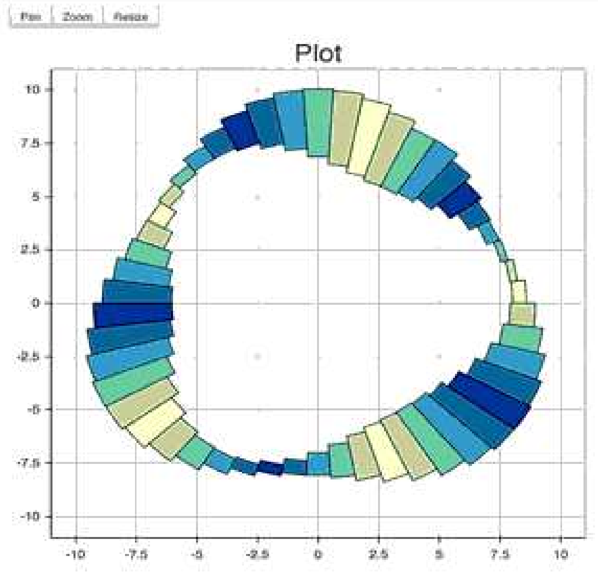
There are many plotting options:

- matplotlib (de-facto standard), activated with `%matplotlib inline`
- `%matplotlib notebook` is interactive regime, but very slow, since rendering is done on server-side.
- mpld3 provides alternative renderer (using d3) for matplotlib code. Quite nice, though incomplete
- bokeh is a better option for building interactive plots
- plot.ly can generate nice plots, but those will cost you money





```
In [4]: annular_wedge(
            cx, cy, rmin, rmax, theta[:-1], theta[1:],
            x_range = Range1d(start=-11, end=11),
            y_range = Range1d(start=-11, end=11),
            inner_radius_units="data",
            outer_radius_units="data",
            fill_color = colors,
            line_color="black",
            tools="pan,zoom,resize"
        )
```



Magics are turning simple python into *magical python*. Magics are the key to power of ipython.

In [1]:

```
# list available python magics
%lsmagic
```

Out[1]:

```
Available line magics:
%alias  %alias_magic  %autocall  %automagic
%autosave  %bookmark  %cat  %cd  %clear  %colors
%config  %connect_info  %cp  %debug  %dhist  %dirs
%doctest_mode  %ed  %edit  %env  %gui  %hist
%history  %killbgscripts  %ldir  %less  %lf  %lk
%ll  %load  %load_ext  %loadpy  %logoff  %logon
%logstart  %logstate  %logstop  %ls  %lsmagic  %lx
%macro  %magic  %man  %matplotlib  %mkdir  %more
%mv  %notebook  %page  %pastebin  %pdb  %pdef
%pdoc  %pfile  %pinfo  %pinfo2  %popd  %pprint
%precision  %profile  %prun  %psearch  %psource
%pushd  %pwd  %pycat  %pylab  %qtconsole
%quickref  %recall  %rehashx  %reload_ext  %rep
%rerun  %reset  %reset_selective  %rm  %rmdir
```

```
%run  %save  %sc  %set_env  %store  %sx  %system
%tb  %time  %timeit  %unalias  %unload_ext  %who
%who_ls  %whos  %xdel  %xmodeAvailable cell
magics:
%%!  %%HTML  %%SVG  %%bash  %%capture  %%debug
%%file  %%html  %%javascript  %%js  %%latex
%%perl  %%prun  %%pypy  %%python  %%python2
%%python3  %%ruby  %%script  %%sh  %%svg  %%sx
%%system  %%time  %%timeit  %%writefileAutomagic
is ON, % prefix IS NOT needed for line magics.
```

You can manage environment variables of your notebook without restarting the jupyter server process. Some libraries (like theano) use environment variables to control behavior, %env is the most convenient way.

In [2]:

```
# %env - without arguments lists environmental
variables
%env OMP_NUM_THREADS=4env: OMP_NUM_THREADS=4
```

You can call any shell command. This in particular useful to manage your virtual environment.

In [3]:

```
!pip install numpy
!pip list | grep TheanoRequirement already
satisfied (use --upgrade to upgrade): numpy in
/Users/axelr/.venvs/rep/lib/python2.7/site-
packages
Theano (0.8.2)
```

sometimes output isn't needed, so we can either use `pass` instruction on new line or semicolon at the end

In [4]:

```
%matplotlib inline
from matplotlib import pyplot as plt
import numpy
```

In [5]:

```
# if you don't put semicolon at the end, you'll
have output of function printed
plt.hist(numpy.linspace(0, 1, 1000)**1.5);
```

In [6]:

```
from sklearn.cross_validation import
```

```
train_test_split
# show the sources of train_test_split function in
the pop-up window
train_test_split??
```

In [7]:

```
# you can use ? to get details about magics, for
instance:
%pycat?
```

will output in the pop-up window:

```
Show a syntax-highlighted file through a
pager.This magic is similar to the cat utility,
but it will assume the file
to be Python source and will show it with syntax
highlighting.This magic command can either take a
local filename, an url,
an history range (see %history) or a macro as
argument ::%pycat myscript.py
%pycat 7-27
%pycat myMacro
%pycat http://www.example.com/myscript.py
```

%run can execute python code from .py files — this is a well-documented behavior.

But it also can execute other jupyter notebooks! Sometimes it is quite useful.

NB. %run is not the same as importing python module.

In [8]:

```
# this will execute all the code cells from
different notebooks
%run ./2015-09-29-NumpyTipsAndTricks1.ipynb[49 34
49 41 59 45 30 33 34 57]
[172 177 209 197 171 176 209 208 166 151]
[30 33 34 34 41 45 49 49 57 59]
[209 208 177 166 197 176 172 209 151 171]
[1 0 4 8 6 5 2 9 7 3]
['a' 'b' 'c' 'd' 'e' 'f' 'g' 'h' 'i' 'j']
['b' 'a' 'e' 'i' 'g' 'f' 'c' 'j' 'h' 'd']
['a' 'b' 'c' 'd' 'e' 'f' 'g' 'h' 'i' 'j']
[1 0 6 9 2 5 4 8 3 7]
[1 0 6 9 2 5 4 8 3 7]
[ 0.93551212  0.75079687  0.87495146  0.3344709
0.99628591  0.34355057
  0.90019059  0.88272132  0.67272068  0.24679158]
[8 4 5 1 9 2 7 6 3 0][-5 -4 -3 -2 -1  0  1  2  3
4]
[0 0 0 0 0 0 1 2 3 4]
['eh' 'cl' 'ah' ..., 'ab' 'bm' 'ab']
['ab' 'ac' 'ad' 'ae' 'af' 'ag' 'ah' 'ai' 'aj' 'ak'
'al' 'am' 'an' 'bc' 'bd'
 'be' 'bf' 'bg' 'bh' 'bi' 'bj' 'bk' 'bl' 'bm' 'bn'
'cd' 'ce' 'cf' 'cg' 'ch'
 'ci' 'cj' 'ck' 'cl' 'cm' 'cn' 'de' 'df' 'dg' 'dh'
'di' 'dj' 'dk' 'dl' 'dm'
 'dn' 'ef' 'eg' 'eh' 'ei' 'ej' 'ek' 'el' 'em' 'en'
'fg' 'fh' 'fi' 'fj' 'fk'
 'fl' 'fm' 'fn' 'gh' 'gi' 'gj' 'gk' 'gl' 'gm' 'gn'
'hi' 'hj' 'hk' 'hl' 'hm'
 'hn' 'ij' 'ik' 'il' 'im' 'in' 'jk' 'jl' 'jm' 'jn'
'kl' 'km' 'kn' 'lm' 'ln'
 'mn']
[48 33  6 ...,  0 23  0]
['eh' 'cl' 'ah' ..., 'ab' 'bm' 'ab']
```

```
['eh' 'cl' 'ah' ..., 'ab' 'bm' 'ab']
['bf' 'cl' 'dn' ..., 'dm' 'cn' 'dj']
['bf' 'cl' 'dn' ..., 'dm' 'cn' 'dj'][ 2.29711325
1.82679746  2.65173344 ...,  2.15286813  2.308737
2.15286813]
1000 loops, best of 3: 1.09 ms per loop
The slowest run took 8.44 times longer than the
fastest. This could mean that an intermediate
result is being cached.
10000 loops, best of 3: 21.5 µs per loop0.416
0.416
```

loading code directly into cell. You can pick local file or file on the web.

After uncommenting the code below and executing, it will replace the content of cell with contents of file.

In [9]:

```
# %load http://matplotlib.org/mpl_examples
/pylab_examples/contour_demo.py
```

In [10]:

```
data = 'this is the string I want to pass to
```

```
different notebook'
%store data
del data # deleted variableStored 'data' (str)
```

In [11]:

```
# in second notebook I will use:
%store -r data
print datathis is the string I want to pass to
different notebook
```

In [12]:

```
# pring names of string variables
%who strdata
```

When you need to measure time spent or find the bottleneck in the code, ipython comes to the rescue.

In [13]:

```
%%time
import time
time.sleep(2) # sleep for two secondsCPU times:
user 1.23 ms, sys: 4.82 ms, total: 6.05 ms
Wall time: 2 s
```

In [14]:

```
# measure small code snippets with timeit !
import numpy
%timeit numpy.random.normal(size=100)The slowest
run took 13.85 times longer than the fastest. This
could mean that an intermediate result is being
cached.
100000 loops, best of 3: 6.35 µs per loop
```

In [15]:

```
%%writefile pythoncode.pyimport numpy
def append_if_not_exists(arr, x):
    if x not in arr:
        arr.append(x)
        def some_useless_slow_function():
    arr = list()
    for i in range(10000):
        x = numpy.random.randint(0, 10000)
        append_if_not_exists(arr, x)
```

```
Overwriting pythoncode.py
```

In [16]:

```
# shows highlighted source of the newly-created
file
%pycat pythoncode.py
```

In [17]:

```
from pythoncode import some_useless_slow_function,
append_if_not_exists
```

In [18]:

```
# shows how much time program spent in each
function
%prun some_useless_slow_function()
```

Example of output:

```
26338 function calls in 0.713 seconds   Ordered
by: internal time   ncalls  tottime  percall
cumtime  percall filename:lineno(function)
    10000    0.684    0.000    0.685    0.000
pythoncode.py:3(append_if_not_exists)
    10000    0.014    0.000    0.014    0.000
{method 'randint' of 'mtrand.RandomState' objects}
        1    0.011    0.011    0.713    0.713
pythoncode.py:7(some_useless_slow_function)
```

```
         1    0.003    0.003    0.003    0.003
{range}
      6334    0.001    0.000    0.001    0.000
{method 'append' of 'list' objects}
         1    0.000    0.000    0.713    0.713
<string>:1(<module>)
         1    0.000    0.000    0.000    0.000
{method 'disable' of '_lsprof.Profiler' objects}
```

In [19]:

```
%load_ext memory_profiler
```

In [20]:

```
# tracking memory consumption (show in the pop-up)
%mprun -f append_if_not_exists
some_useless_slow_function()('',)
```

Example of output:

```
Line #    Mem usage    Increment   Line Contents
================================================
     3     20.6 MiB      0.0 MiB   def
append_if_not_exists(arr, x):
     4     20.6 MiB      0.0 MiB       if x not in
```

```
arr:
     5     20.6 MiB      0.0 MiB
arr.append(x)
```

%lprun is line profiling, but it seems to be broken for latest IPython release, so we'll manage without magic this time:

In [21]:

```
import line_profiler
lp = line_profiler.LineProfiler()
lp.add_function(some_useless_slow_function)
lp.runctx('some_useless_slow_function()',
locals=locals(), globals=globals())
lp.print_stats()Timer unit: 1e-06 sTotal time:
1.27826 s
File: pythoncode.py
Function: some_useless_slow_function at line 7Line
#      Hits          Time  Per Hit   % Time  Line
Contents
==============================================================
     7
def some_useless_slow_function():
     8          1            5      5.0       0.0
arr = list()
     9      10001        17838      1.8       1.4
for i in range(10000):
    10      10000        38254      3.8       3.0
x = numpy.random.randint(0, 10000)
    11      10000      1222162    122.2      95.6
append_if_not_exists(arr, x)
```

Jupyter has own interface for ipdb. Makes it possible to go inside the function and investigate what happens there.

This is not pycharm and requires much time to adapt, but when debugging on the server this can be the only option (or use pdb from terminal).

In [22]:

```
#%%debug filename:line_number_for_breakpoint
# Here some code that fails. This will activate
interactive context for debugging
```

A bit easier option is `%pdb`, which activates debugger when exception is raised:

In [23]:

```
# %pdb# def pick_and_take():
#     picked = numpy.random.randint(0, 1000)
#     raise NotImplementedError()
    # pick_and_take()
```

markdown cells render latex using MathJax.

P(A|B)=P(B|A)P(A)P(B)P(A|B)=P(B|A)P(A)P(B)

Markdown is an important part of notebooks, so don’t forget to use its expressiveness!

If you’re missing those much, using other computational kernels:

- %%python2
- %%python3
- %%ruby
- %%perl
- %%bash
- %%R

is possible, but obviously you’ll need to setup the corresponding kernel first.

In [24]:

```
%%ruby
puts 'Hi, this is ruby.'Hi, this is ruby.
```

In [25]:

```
%%bash
echo 'Hi, this is bash.'Hi, this is bash.
```

A number of solutions are available for querying/processing large data samples:

- ipyparallel (formerly ipython cluster) is a good option for simple map-reduce operations in python. We use it in rep to train many machine learning models in parallel
- pyspark
- spark-sql magic %%sql

Services like mybinder give an access to machine with jupyter notebook with all the libraries installed, so user can play for half an hour with your code having only browser.

You can setup your own system with jupyterhub, this is very handy when you organize mini-course or workshop and don't have time to care about students machines.

Sometimes the speed of numpy is not enough and I need to write some fast code. In principle, you can compile function in the dynamic library and write python wrappers…

But it is much better when this boring part is done for you, right?

You can write functions in cython or fortran and use those directly from python code.

First you’ll need to install:

```
!pip install cython fortran-magic
```

In [26]:

```
%load_ext Cython
```

In [27]:

```
%%cython
def myltiply_by_2(float x):
    return 2.0 * x
```

In [28]:

```
myltiply_by_2(23.)
```

Out[28]:

```
46.0
```

Personally I prefer to use fortran, which I found very convenient for writing number-crunching functions.

In [29]:

```
%load_ext fortranmagic/Users/axelr/.venvs/rep/lib
/python2.7/site-packages/IPython/utils
/path.py:265: UserWarning: get_ipython_cache_dir
has moved to the IPython.paths module
  warn("get_ipython_cache_dir has moved to the
IPython.paths module")
```

In [30]:

```
%%fortran
subroutine compute_fortran(x, y, z)
    real, intent(in) :: x(:), y(:)
    real, intent(out) :: z(size(x, 1))     z =
sin(x + y)end subroutine compute_fortran
```

In [31]:

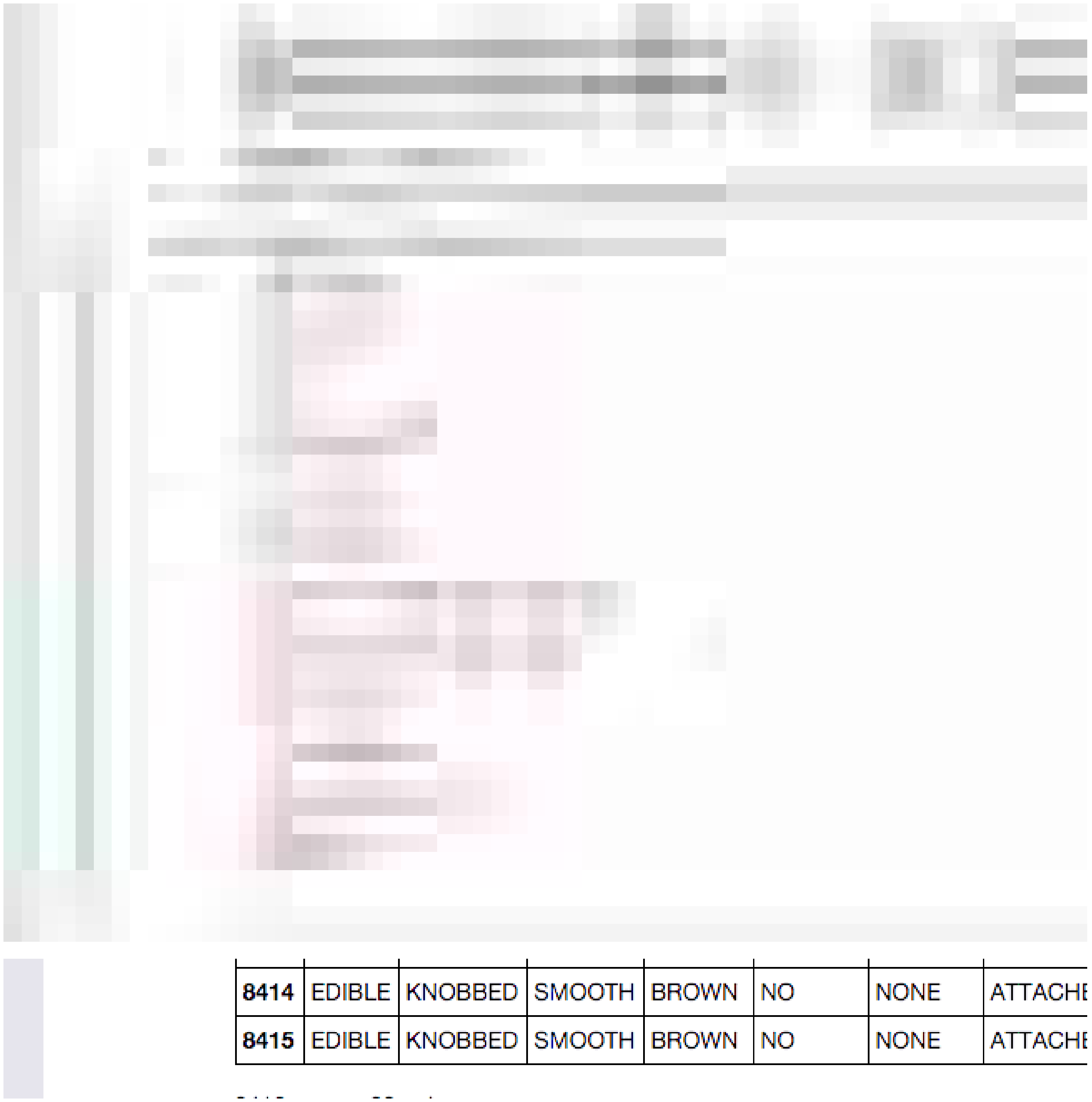
```
compute_fortran([1, 2, 3], [4, 5, 6])
```

Out[31]:

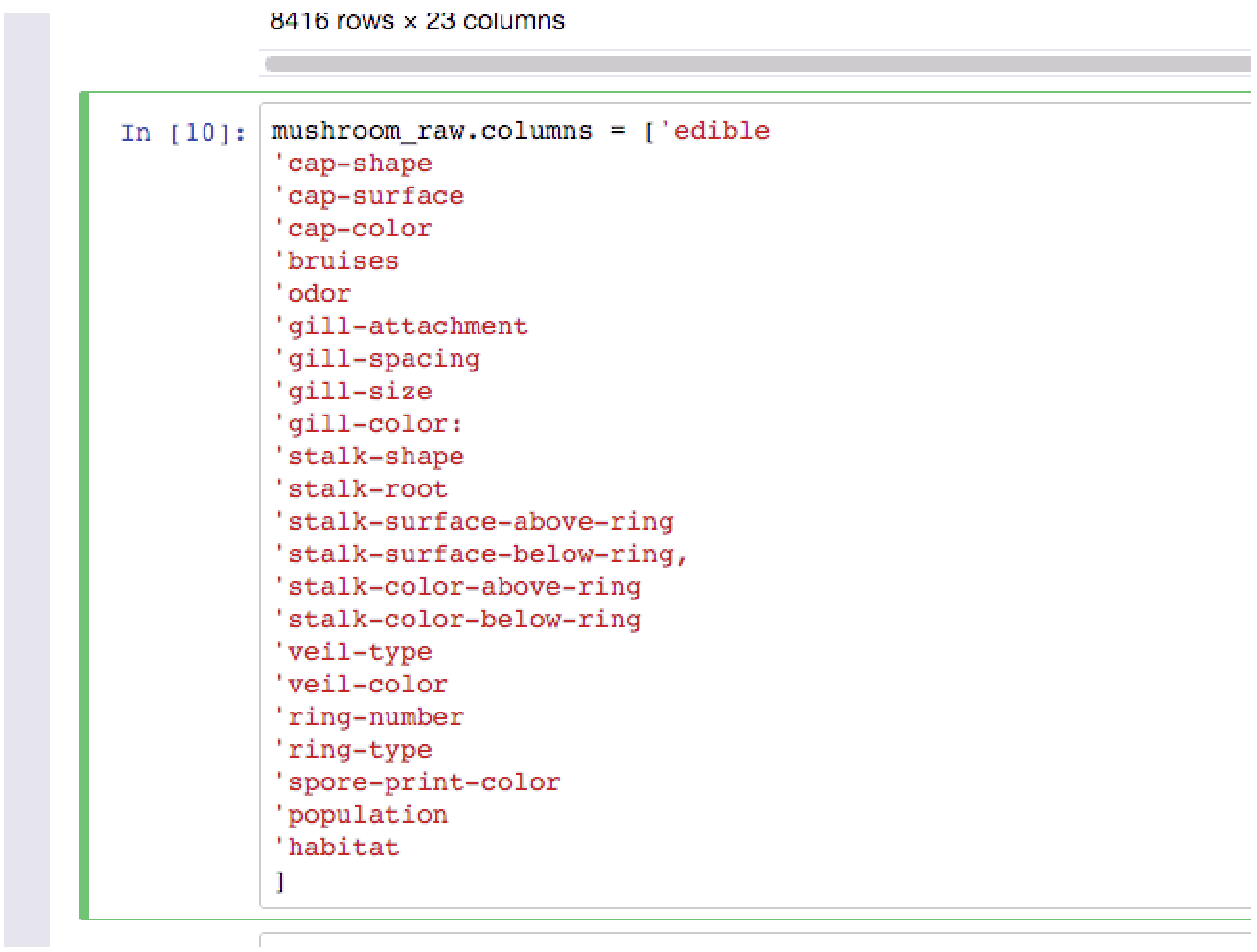
```
array([-0.95892429,  0.65698659,  0.41211849],
dtype=float32)
```

I also should mention that there are different jitter systems which can speed up your python code.

Since recently jupyter supports multiple cursors (in a single cell), just like sublime ot intelliJ!



8414	EDIBLE	KNOBBED	SMOOTH	BROWN	NO	NONE	ATTACHE
8415	EDIBLE	KNOBBED	SMOOTH	BROWN	NO	NONE	ATTACHE



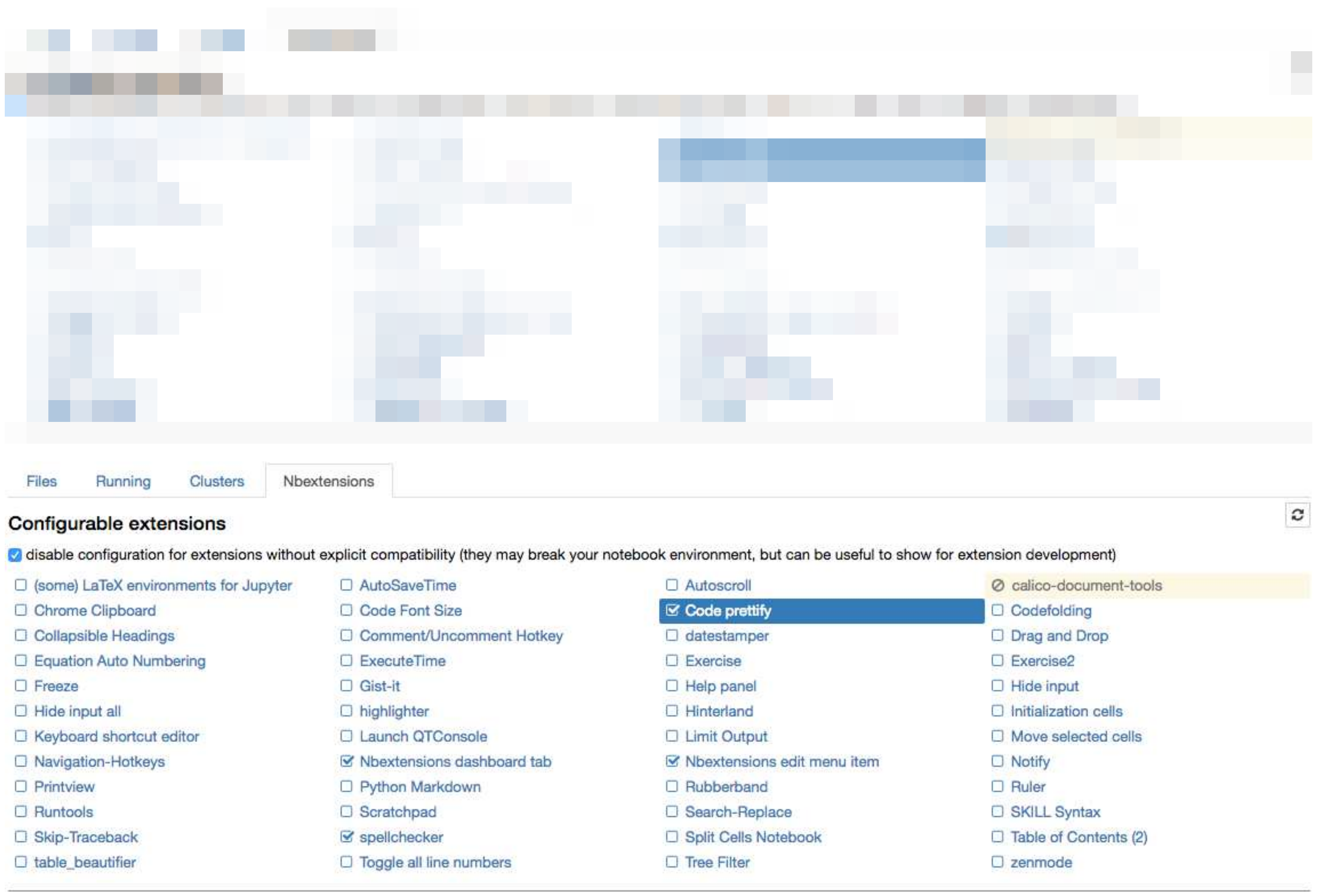
```
8416 rows × 23 columns
```

```
In [10]: mushroom_raw.columns = ['edible
'cap-shape
'cap-surface
'cap-color
'bruises
'odor
'gill-attachment
'gill-spacing
'gill-size
'gill-color:
'stalk-shape
'stalk-root
'stalk-surface-above-ring
'stalk-surface-below-ring,
'stalk-color-above-ring
'stalk-color-below-ring
'veil-type
'veil-color
'ring-number
'ring-type
'spore-print-color
'population
'habitat
]
```

Gif taken from http://swanintelligence.com/multi-cursor-in-jupyter.html

are installed with

```
!pip install https://github.com/ipython-contrib
/jupyter_contrib_nbextensions/tarball/master
!pip install jupyter_nbextensions_configurator
!jupyter contrib nbextension install --user
!jupyter nbextensions_configurator enable --user
```



Configurable extensions

☑ disable configuration for extensions without explicit compatibility (they may break your notebook environment, but can be useful to show for extension development)

☐ (some) LaTeX environments for Jupyter	☐ AutoSaveTime	☐ Autoscroll	⊘ calico-document-tools
☐ Chrome Clipboard	☐ Code Font Size	☑ Code prettify	☐ Codefolding
☐ Collapsible Headings	☐ Comment/Uncomment Hotkey	☐ datestamper	☐ Drag and Drop
☐ Equation Auto Numbering	☐ ExecuteTime	☐ Exercise	☐ Exercise2
☐ Freeze	☐ Gist-it	☐ Help panel	☐ Hide input
☐ Hide input all	☐ highlighter	☐ Hinterland	☐ Initialization cells
☐ Keyboard shortcut editor	☐ Launch QTConsole	☐ Limit Output	☐ Move selected cells
☐ Navigation-Hotkeys	☑ Nbextensions dashboard tab	☑ Nbextensions edit menu item	☐ Notify
☐ Printview	☐ Python Markdown	☐ Rubberband	☐ Ruler
☐ Runtools	☐ Scratchpad	☐ Search-Replace	☐ SKILL Syntax
☐ Skip-Traceback	☑ spellchecker	☐ Split Cells Notebook	☐ Table of Contents (2)
☐ table_beautifier	☐ Toggle all line numbers	☐ Tree Filter	☐ zenmode

this is a family of different extensions, including e.g. **jupyter spell-checker and code-formatter**, that are missing in jupyter by default.

Extension by Damian Avila makes it possible to show notebooks as demonstrations. Example of such presentation: http://bollwyvl.github.io/live_reveal/#/7

It is very useful when you teach others e.g. to use some library.

Notebooks are displayed as HTML and the cell output can be HTML, so you can return virtually anything: video/audio/images.

In this example I scan the folder with images in my repository and show first five of them:

In [32]:

```
import os
from IPython.display import display, Image
names = [f for f in os.listdir('../images
/ml_demonstrations/') if f.endswith('.png')]
for name in names[:5]:
    display(Image('../images/ml_demonstrations/' +
name, width=300))
```

because magics and bash calls return python variables:

In [33]:

```
names = !ls ../images/ml_demonstrations/*.png
names[:5]
```

Out[33]:

```
['../images/ml_demonstrations
/colah_embeddings.png',
 '../images/ml_demonstrations/convnetjs.png',
 '../images/ml_demonstrations/decision_tree.png',
 '../images/ml_demonstrations
/decision_tree_in_course.png',
 '../images/ml_demonstrations/dream_mnist.png']
```

Long before, when you started some long-taking process and at some point your connection to ipython server dropped, you completely lost the ability to track the computations process (unless you wrote this information to file). So either you interrupt the kernel and potentially lose some progress, or you wait till it completes without any idea of what is happening.

`Reconnect to kernel` option now makes it possible to connect again to running kernel without interrupting computations and get the newcoming output shown (but some part of output is already lost).

Like this one. Use nbconvert to export them to html.

- IPython built-in magics
- Nice interactive presentation about jupyter by Ben Zaitlen
- Advanced notebooks part 1: magics and part 2: widgets

- Profiling in python with jupyter
- 4 ways to extend notebooks
- IPython notebook tricks
- Jupyter vs Zeppelin for big data