Data types – numbers (1)

- Python supports integer, floating point and complex valued numbers by default:

```
>>> 2+2
4
>>> # This is a comment
... 2+2
4
>>> # Integer division returns the floor:
... 7/3
2
>>> 7.0 / 2  # but this works...
3.5
>>> 1.0j * 1.0j
(-1+0j)
```

Data types – numbers (2)

- Assignments and conversions:

```
>>> a=3.0+4.0j
>>> float(a)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: can't convert complex to float; use abs(z)
>>> a.real
3.0
>>> a.imag
4.0
>>> abs(a)  # sqrt(a.real**2 + a.imag**2)
5.0
```

Special variables

- Example: last result „_“ (only in interactive mode):

```
>>> tax = 12.5 / 100
>>> price = 100.50
>>> price * tax
12.5625
>>> price + _
113.0625
>>> round(_, 2)
113.06
```

- Many more in ipython!

Data types – strings

- Sequences of chars (like e.g. in C), but immutable!

```
>>> word = 'Help' + 'A'
>>> word
'HelpA'
>>> '<' + word*5 + '>'
'<HelpAHelpAHelpAHelpAHelpA>'
>>> 'str' 'ing'                    #  <-  This is ok
'string'
>>> word[4]
'A'
>>> word[0:2]
'He'
>>> word[2:]    # Everything except the first two characters
'lpA'
```

Data types – lists

- Lists may contain different types of entries at once!
- First element has index: 0, last element: length-1.

```
>>> a = ['spam', 'eggs', 100, 1234]
>>> a
['spam', 'eggs', 100, 1234]
>>> a[0]
'spam'
>>> a[-2]
100
>>> a[1:-1]
['eggs', 100]
>>> a[:2] + ['bacon', 2*2]
['spam', 'eggs', 'bacon', 4]
```

The first program (1)

- Counting Fibonacci series

```
>>> # Fibonacci series:
... # the sum of two elements defines the next
... a, b = 0, 1
>>> while b < 10:
...     print b
...     a, b = b, a+b
...
1
1
2
3
5
8
```

The first program (2)

- Counting Fibonacci series (with a colon after the print)

```
>>> # Fibonacci series:
... # the sum of two elements defines the next
... a, b = 0, 1
>>> while b < 10:
...     print b,
...     a, b = b, a+b
...
1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987
```

Conditionals – if

- Divide cases in if/then/else manner:

```
>>> x = int(raw_input("Please enter an integer: "))
Please enter an integer: 42
>>> if x < 0:
...      x = 0
...      print 'Negative changed to zero'
... elif x == 0:
...      print 'Zero'
... elif x == 1:
...      print 'Single'
... else:
...      print 'More'
...
More
```

Control flow – for (1)

- Python‘s for-loop:

```
>>> # Measure the length of some strings:
... a = ['two', 'three', 'four']
>>> for x in a:
...     print x, len(x)
...
two 3
three 5
four 4
```

- is indeed a for-each-loop!

Control flow – for (2)

- What about a counting for loop?
- Quite easy to get:

```
>>> a = ['Mary', 'had', 'a', 'little', 'lamb']
>>> for i in range(len(a)):
...     print i, a[i]
...
0 Mary
1 had
2 a
3 little
4 lamb
```

Defining functions (1)

- Functions are one of the most important way to abstract from problems and to design programs:

```
>>> def fib(n):    # write Fibonacci series up to n
...     """Print a Fibonacci series up to n."""
...     a, b = 0, 1
...     while a < n:
...         print a,
...         a, b = b, a+b
...
>>> # Now call the function we just defined:
... fib(2000)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597
```

Defining functions (2)

- Functions are (themselves) just Python symbols!

```
>>> fib
<function fib at 10042ed0>
>>> f = fib
>>> f(100)
0 1 1 2 3 5 8 13 21 34 55 89
```

- No explicit return value needed (default: “None”)

```
>>> fib(0)
>>> print fib(0)
None
```

Defining functions (3)

- Fibonacci series with a list of numbers as return value:

```
>>> def fib2(n): # return Fibonacci series up to n
...     """Return a list containing the Fibonacci series up to n."""
...     result = []
...     a, b = 0, 1
...     while a < n:
...         result.append(a)    # see below
...         a, b = b, a+b
...     return result
...
>>> f100 = fib2(100)    # call it
>>> f100                # write the result
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
```

Function argument definitions (1)

- Named default arguments:

```
def ask_ok(prompt, retries=4, complaint='Yes or no, please!'):
    while True:
        ok = raw_input(prompt)
        if ok in ('y', 'ye', 'yes'):
            return True
        if ok in ('n', 'no', 'nop', 'nope'):
            return False
        retries = retries - 1
        if retries < 0:
            raise IOError('refuse user')
        print complaint
```

Function argument definitions (2)

- Calling strategy in more detail:

```
def parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):
    print "-- This parrot wouldn't", action,
    print "if you put", voltage, "volts through it."
    print "-- Lovely plumage, the", type
    print "-- It's", state, "!"

parrot(1000)
parrot(action = 'VOOOOOM', voltage = 1000000)
parrot('a thousand', state = 'pushing up the daisies')
parrot('a million', 'bereft of life', 'jump')
```

Excurse: lambda abstraction

- If you want, you can go functional with Python, e.g. using the provided lambda abstractor:

```
>>> f = lambda x, y: x**2 + 2*x*y + y**2
>>> f(1,5)
36


>>> (lambda x: x*2)(3)
6
```

Modules

- If you have saved this as „fibo.py“:

```
# Fibonacci numbers module
def fib(n): # return Fibonacci series up to n
    result = []
    a, b = 0, 1
    while b < n:
        result.append(b)
        a, b = b, a+b
    return result
```

…you have already written your first Python module. Call it using:

```
>>> import fibo
>>> fibo.fib(100)
[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
```

Summary of Python

- You‘ll learn Python the best:
  … by means of practical use of the language!
  … especially not by listening to lectures!

- Python has a lot more to offer!
  E.g.: A class system, error handling, IO, GUI, Networking

- The slides shown before should have shown that:
  - Getting in touch is quite easy!
  - The learning rate is comparably steep!
  - You get early and valuable experiences of achievements!

- All this makes Python so popular!!

Outline

- Introduction
- Presenting the Python programming language
- Image processing with NumPy and SciPy
- Visualization with matplotlib and the spyder IDE
- Summary

Image processing with NumPy and SciPy

Unfortunately, it is not possible to give a complete introduction in either NumPy or SciPy.
The image processing introduction is based on:
http://scipy-lectures.github.io/advanced/image_processing

More material regarding NumPy can e.g. be found at:
http://numpy.scipy.org

A good beginner's tutorial is provided at:
http://www.scipy.org/Tentative_NumPy_Tutorial

NumPy SciPy.org

Images as *efficient* arrays?!

- In many programming environments, like e.g. MatLab, images are represented as random access arrays
- However, Python‘s built-in array is often neither flexible nor powerful enough for image processing
- Thus: use NumPy arrays for image representation.
- Idea of a first (very basic) workflow:
  - Load images using scipy.misc (via PIL)
  - Process the images using NumPy and Scipy
  - Save the images using scipy.misc (via PIL)

NumPy at a glance

- *„NumPy is the fundamental package needed for scientific computing with Python. It contains among other things: a powerful N-dimensional array object […]"*
  - NumPy Homepage, 2010

- May have required a whole course on its own...
- Still growing scientific user community (SciPy/NumPy)
- Reliable algorithms
- Quite fast, compared to commercial software implementations

Loading and saving images

- Load an image into a NumPy array (requires PIL)

```
>>> import numpy as np
>>> from scipy import misc
>>> img = misc.imread('lena.png‘)
```

- Saving a NumPy array as an image (requires PIL)

```
...
>>> img = misc.imread('lena.png‘)
>>> misc.imsave('lena_copy.png‘, img)
```

- Attention: Usually only 2d- and 3d-arrays with datatype „uint8“ (0 – 255) can be saved as images.
A type conversion may be necessary before saving!

„Hello Image“

- First example: Load, “view” and save an image:

```
...
>>> img = misc.imread('lena.png‘) #or: img = misc.lena()
>>> img
array([[162, 162, 162, ..., 170, 155, 128],
       ...,
       [ 44,  44,  55, ..., 104, 105, 108]])
>>> misc.imsave(img, 'lena_copy.png‘)
```

NumPy image representation (1)

- Gray-value images:

```
...
>>> img
array([[162, 162, 162, ..., 170, 155, 128],
       [162, 162, 162, ..., 170, 155, 128],
       [162, 162, 162, ..., 170, 155, 128],
       ...,
       [ 43,  43,  50, ..., 104, 100,  98],
       [ 44,  44,  55, ..., 104, 105, 108],
       [ 44,  44,  55, ..., 104, 105, 108]])
```

NumPy image representation (2)

- RGB-value images:

```
...
>>> img_rgb
array([[[121, 112, 131], ..., [139, 144,  90]],
       [[ 89,  82, 100], ..., [146, 153,  99]],
       [[ 73,  66,  84], ..., [144, 153,  98]],
       ...,
       [[ 87, 106,  76], ..., [119, 158,  95]],
       [[ 85, 101,  72], ..., [120, 156,  94]],
       [[ 85, 101,  74], ..., [118, 154,  92]]],      dtype=uint8)
```

NumPy slicing and index tricks

- Extract channels using slicing

```
>>> img_rgb[:,:,0]        # <-- red channel
>>> img_rgb[...,0]        # same as above, fix inner-most dim. to 0

>>> img_rgb[...,1]        # <-- green channel

>>> img_rgb[...,2]        # <-- blue channel
>>> img_rgb[...,-1]       # same as above, since blue is the last ch.
```

- Extract sub-images using index ranges:

```
>>> img_rgb[100:200,100:200,0]  # <-- red channel, size 100x100 px

>>> img[100:200,100:200] # <-- 100x100 px of gray-scale image
```

- **Attention**: NumPy often creates views and does not copy your data, when using index tricks!
  → Compare to Call-By-Reference Semantics

Basic Image Processing (1)

- Example: Invert an image (create the negative):

```
...
>>> img_invert = 255 - img
>>> img_rgb_invert  = 255 - img_rgb # <-- works for rgb too!
```

Basic Image Processing (2)

- Example: Threshold an image:

```
...
>>> threshold = 100
>>> mask = img < threshold
>>> masked_img = img.copy()
>>> masked_img[mask] = 0
```

Summary: Image Processing with SciPy and NumPy

- Many image processing algorithms already „onboard“, like e.g. filters and Fourier transformation in scipy.ndimge package
- Enables you to fast process images due to highly sophisticated C-implementation
- Contains a lot of numerical operations
- Time and memory efficient due to referential workflow

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Visualization with matplotlib

“matplotlib is a python 2D plotting library which produces publication quality figures in a variety of hardcopy formats and interactive environments across platforms. matplotlib can be used in python scripts, the python and ipython shell...“

http://matplotlib.org, October 2013

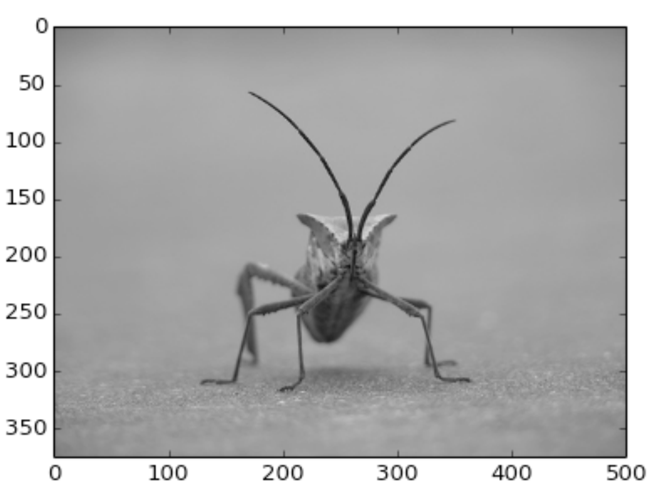
This introduction is based on the matplotlib image tutorial:
http://matplotlib.org/users/image_tutorial.html

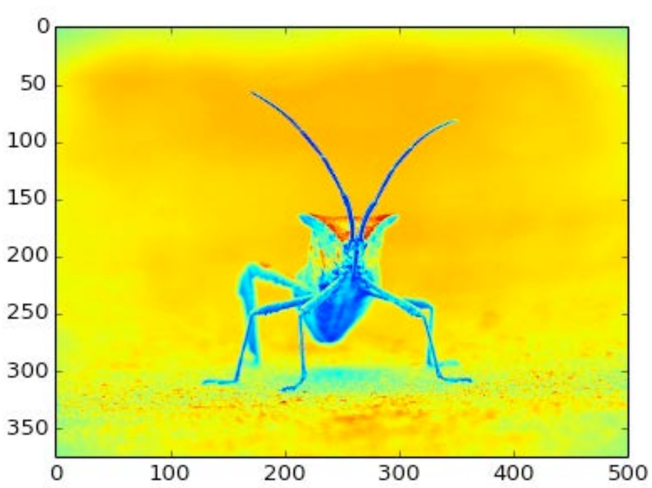
Showing images interactively

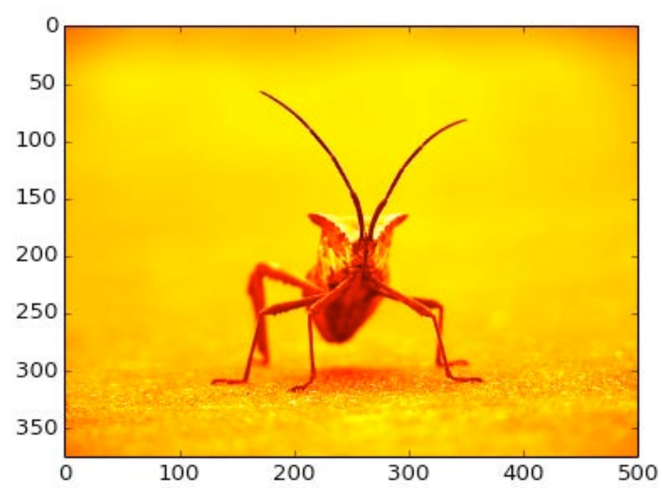
- Use matplotlib to show an image figure:

```
>>> import matplotlib.pyplot as plt
>>> from scipy import misc
>>> img  = misc.imread(‚stinkbug.png‘) # <-- stored as a gray rgb image
>>> lum_img = img[...,0]

>>> img_plot = plt.imshow(img)
>>> img_plot.show()
>>> img_lum_plot = plt.imshow(lum_img)
>>> img_lum_plot.show()
>>> img_lum_plot.set_cmap(gray) # also try hot, spectral etc.
```





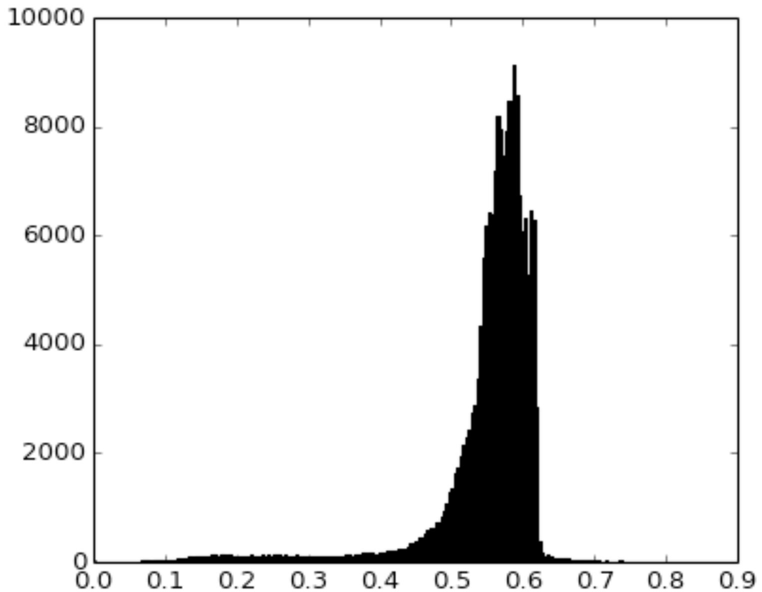


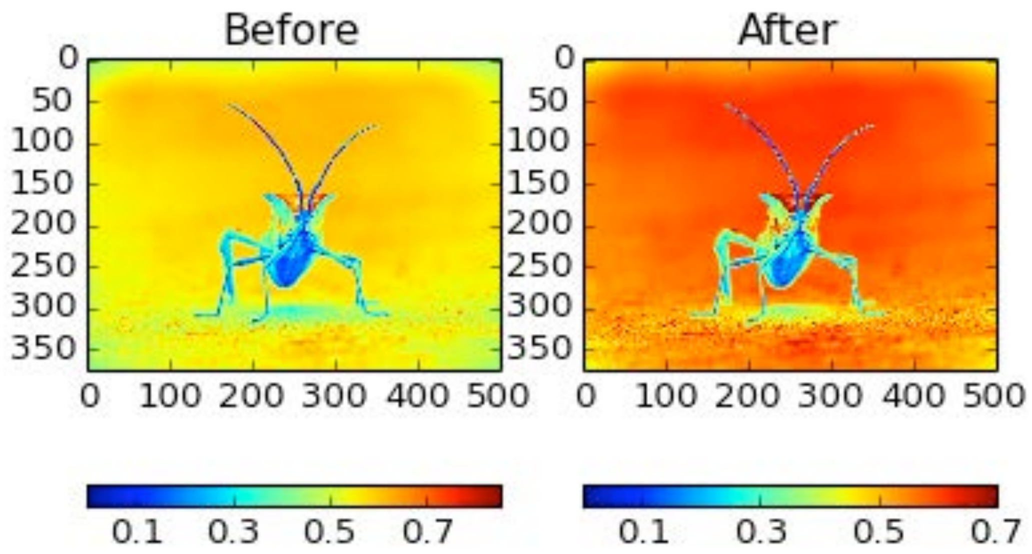
Show with enhanced constast

- Use matplotlib to inspect the histogram:

```
...
>>> plt.hist(lum_img.flatten(), 256, range=(0.0,1.0), fc='k', ec='k')
>>> plt.show()

>>> imgplot.set_clim(0.0,0.7)
```





Visualization issue: Interpolation

- When zooming in, it may be necessary to interpolate the images pixels.
- By default, bilinear interpolation is used. It might be better to use „nearest neighbor“ interpolation to see the pixels:

```
...
>>> img_plot.set_interpolation('nearest‘)
```

- Or, for more accuracy, you may want to try bicubic interpolation:

```
...
>>> img_plot.set_interpolation(‘bicubic‘)
```

Working with the spyder IDE

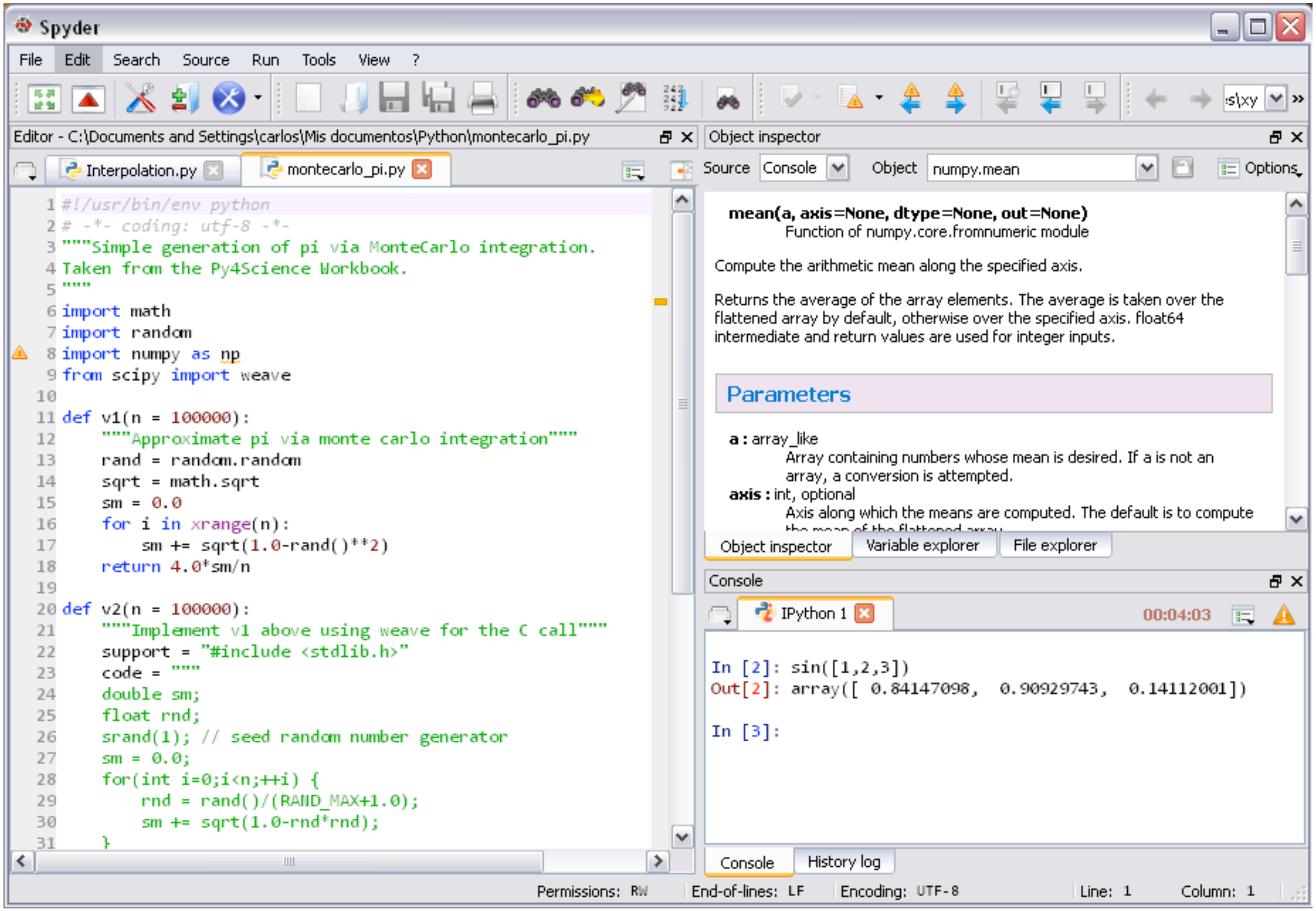
„spyder (previously known as [Pydee](#)) is a powerful interactive development environment for the Python language with advanced editing, interactive testing, debugging and introspection features.[…]

spyder lets you easily work with the best tools of the Python scientific stack in a simple yet powerful environment.[…]“

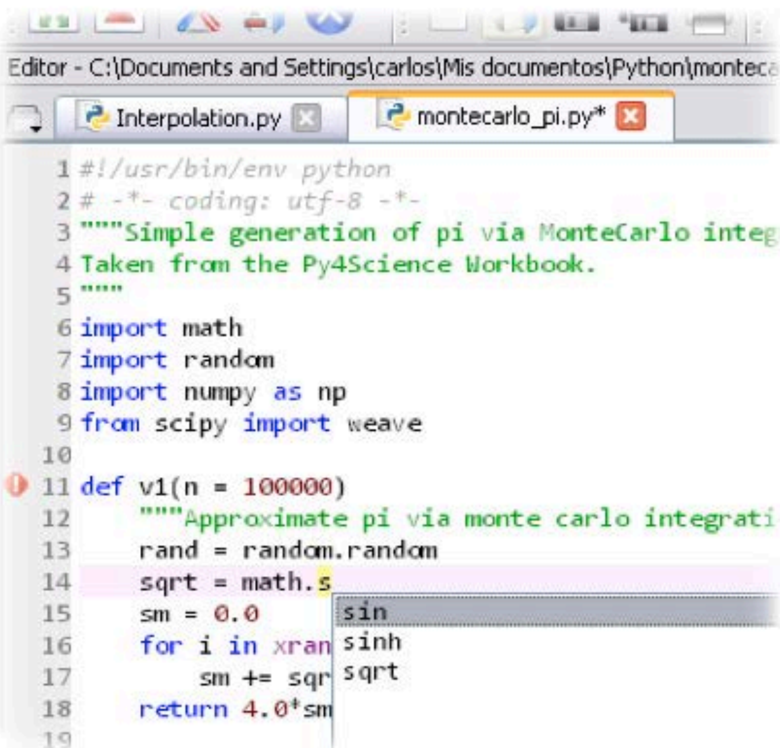
http://code.google.com/p/spyderlib, October 2013

The screenshots of this introduction have been taken from the spyder homepage.

The spyder IDE



spyder - the editor



A powerful editor is a central piece of any good IDE. Spyder's editor has:

- Syntax coloring for Python, C/C++ and Fortran files
- Powerful dynamic code introspection features (powered by rope):
  - Code completion and calltips
  - Go to an object definition with a mouse click
- Class and function browser.
- Occurrence highlighting.
- To-do lists (TODO, FIXME, XXX).
- Get errors and warnings on the fly (provided by pyflakes)
- Breakpoints and conditional breakpoints to use with the python debugger (pdb).

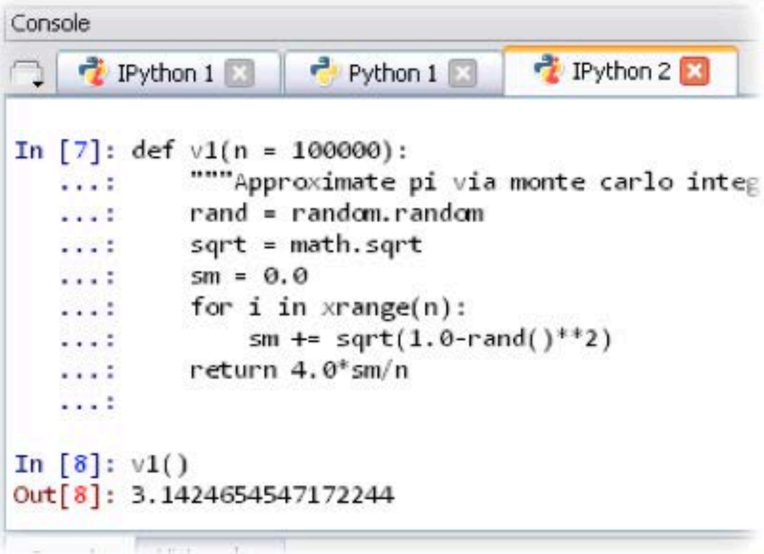
Learn More

spyder - the console

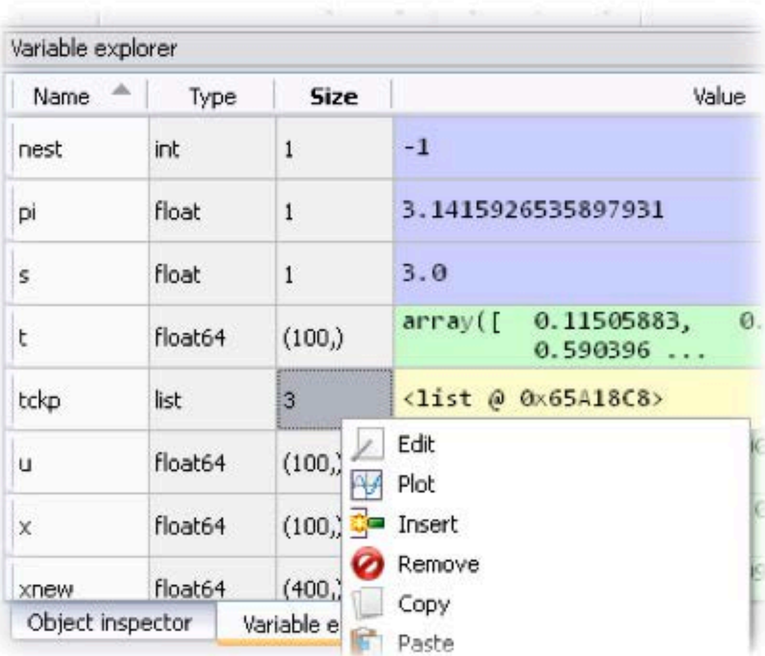
To easily interact with your code as you progress, Spyder lets you

- Open as many Python and Ipython consoles as you want
- Run a whole script or any portion of it from the Editor
- Have code completion and automatic link to documentation through the Object Inspector
- Execute all consoles in a separate process so they don't block the application

Learn More



spyder - the variable explorer



With the Variable Explorer you can browse and analyze all the results your code is producing, and also

- Edit variables with Spyder's Array Editor, which has support for a lot of data types (numbers, strings, lists, arrays, dictionaries)
- Have multiple Array Editors open at once, thus allowing to compare variable contents
- Import/Export data from/to a lot of file types (text files, numpy files, Matlab files)
- Generate 2D plots of list and arrays
- View local variables while you're debugging

Learn More

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Summary (1)

- The Python programming language
  - Readable, meaningful syntax (remember the tabs!)
  - Highly functional, full of functionality
  - Steep learning experience and fast results
  - Perfectly practicable for interactive work
  - Can be extended easily
  - Large global community

Summary (2)

- NumPy and SciPy
  - Efficient Array implementation
  - Loading and saving of images (transparently via PIL)
  - Adds (nature) scientific stuff to Python
  - Contains basic image processing functionality
  - Highly active and widely recommended packages

Summary (3)

- matplotlib
  - Plots everything…
  - Works well with NumPy arrays
- spyder
  - Nice IDE
  - Integrates Scientific work flow (a bit like MatLab)
- Everything is there and freely available: Time to start with the excercises!