

DESIGNSAFE-CI

A NATURAL HAZARDS
ENGINEERING COMMUNITY



A New Cyberinfrastructure for the Natural Hazards Community

Agenda

- Introduction to the Jupyter Notebook
- Programming in Python
- Plotting with Matplotlib
- Putting everything together
 - a scientific notebook from
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What are Jupyter Notebooks?

A web-based, interactive computing tool for capturing the whole computation process: developing, documenting, and executing code, as well as communicating the results.

How do Jupyter Notebooks Work?

An open notebook has exactly one interactive session connected to a kernel which will execute code sent by the user and communicate back results. This kernel remains active if the web browser window is closed, and reopening the same notebook from the dashboard will reconnect the web application to the same kernel.

What's this mean?

Notebooks are an interface to kernel, the kernel executes your code and outputs back to you through the notebook. The kernel is essentially our programming language we wish to interface with.

Jupyter Notebooks, Structure

- Code Cells
 - Code cells allow you to enter and run code
 - Run a code cell using Shift-Enter
- Markdown Cells
 - Text can be added to Jupyter Notebooks using Markdown cells. Markdown is a popular markup language that is a superset of HTML.

Jupyter Notebooks, Structure

- Markdown Cells

- You can add headings:

- # Heading 1

- # Heading 2

- ## Heading 2.1

- ## Heading 2.2

- You can add lists

- 1. First ordered list item

- 2. Another item

- · * Unordered sub-list.

- 1. Actual numbers don't matter, just that it's a number

- · 1. Ordered sub-list

- 4. And another item.

Jupyter Notebooks, Structure

- Markdown Cells

- pure HTML

- `<dl>`

- `<dt>Definition list</dt>`

- `<dd>Is something people use sometimes.</dd>`

- `<dt>Markdown in HTML</dt>`

- `<dd>Does not work very well. Use HTML tags.</dd>`

`</dl>`

- And even, Latex!

- $$e^{i\pi} + 1 = 0$$

Jupyter Notebooks, Workflow

Typically, you will work on a computational problem in pieces, organizing related ideas into cells and moving forward once previous parts work correctly. This is much more convenient for interactive exploration than breaking up a computation into scripts that must be executed together, as was previously necessary, especially if parts of them take a long time to run.

Jupyter Notebooks, Workflow

- Let a traditional paper lab notebook be your guide:
 - Each notebook keeps a historical (and dated) record of the analysis as it's being explored.
 - The notebook is not meant to be anything other than a place for experimentation and development.
 - Notebooks can be split when they get too long.
 - Notebooks can be split by topic, if it makes sense.

Jupyter Notebooks, Shortcuts

- **Shift-Enter**: run cell
 - Execute the current cell, show output (if any), and jump to the next cell below. If **Shift-Enter** is invoked on the last cell, a new code cell will also be created. Note that in the notebook, typing **Enter** on its own *never* forces execution, but rather just inserts a new line in the current cell. **Shift-Enter** is equivalent to clicking the **Cell | Run** menu item.

Jupyter Notebooks, Shortcuts

- **Ctrl-Enter**: run cell in-place
 - Execute the current cell as if it were in “terminal mode”, where any output is shown, but the cursor *remains* in the current cell. The cell’s entire contents are selected after execution, so you can just start typing and only the new input will be in the cell. This is convenient for doing quick experiments in place, or for querying things like filesystem content, without needing to create additional cells that you may not want to be saved in the notebook.

Jupyter Notebooks, Shortcuts

- **Alt-Enter**: run cell, insert below
 - Executes the current cell, shows the output, and inserts a *new* cell between the current cell and the cell below (if one exists).
(shortcut for the sequence **Shift-Enter**, **Ctrl-m a**. (**Ctrl-m a** adds a new cell above the current one.))
- **Esc** and **Enter**: Command mode and edit mode
 - In command mode, you can easily navigate around the notebook using keyboard shortcuts. In edit mode, you can edit text in cells.

Introduction to Python

- Hello World!
- Data types
- Variables
- Arithmetic operations
- Relational operations
- Input/Output
- Control Flow
- More Data Types!
- Matplotlib

the magic number is:

4

Python

```
print "Hello World!"
```

Let's type that line of code into a Code Cell, and hit Shift-Enter:

Hello World!

Python

```
print 5  
print 1+1
```

Let's add the above into another Code Cell, and hit Shift-Enter

5

2

Python - Variables

- You will need to store data into variables
- You can use those variables later on
- You can perform operations with those variables
- Variables are declared with a **name**, followed by '=' and a **value**
 - An integer, string,...
 - When declaring a variable, **capitalization** is important:
'A' <> 'a'

Python - Variables

in a code cell:

```
five = 5
one = 1
print five
print one + one
message = "This is a string"
print message
```

Notice: We're not "typing" our variables, we're just setting them and allowing Python to type them for us.

Python - Data Types

in a code cell:

```
integer_variable = 100  
floating_point_variable = 100.0  
string_variable = "Name"
```

Notice: We're not "typing" our variables, we're just setting them and allowing Python to type them for us.

Python - Data Types

- Variables have a type
- You can check the type of a variable by using the `type()` function:
 - `print type(integer_variable)`
- It is also possible to change the type of some basic types:
 - `str(int/float)`: converts an integer/float to a string
 - `int(str)`: converts a string to an integer
 - `float(str)`: converts a string to a float

Be careful: you can only convert data that actually makes sense to be transformed

Python - Arithmetic Operations

+	Addition	$1 + 1 = 2$
-	Subtraction	$5 - 3 = 2$
/	Division	$4 / 2 = 2$
%	Modulo	$5 \% 2 = 1$
*	Multiplication	$5 * 2 = 10$
//	Floor division	$5 // 2 = 2$
**	To the power of	$2 ** 3 = 8$

Python - Arithmetic Operations

Some experiments:

```
print 5/2
print 5.0/2
print "hello" + "world"
print "some" + 1
print "number" * 5
print 3+5*2
```

Python - Reading from the Keyboard

Let put the following into a new Code Cell:

```
var = input("Please enter a number: ")
```

Let's run this cell!

Python - Reading from the Keyboard

Let put the following into a new Code Cell:

```
var2 = input("Please enter a string: ")
```

Let's run this cell!

put the word **Hello** as your input.

What happened?

Python - Making the output prettier

Let put the following into a new Code Cell:

```
print "The number that you wrote was : ", var
print "The number that you wrote was : %d" % var

print "the string you entered was: ", var2
print "the string you entered was: %s" % var2
```

Want to make it prettier?

 \n for a new line

 \t to insert a tab

for floating points, us %f

Python - Writing to a File

Let put the following into a new Code Cell:

```
my_file = open("output_file.txt", 'w')
vars = "This is a string\n"
my_file.write(vars)
var3 = 10
my_file.write("\n")
my_file.write(str(var3))
var4 = 20.0
my_file.write("\n")
my_file.write(str(var4))
my_file.close()
```

for floating points, us %f

Python - Reading from a File

When opening a file, you need to decide “how” you want to open it:
Just read?

Are you going to write to the file?

If the file already exists, what do you want to do with it?

- r read only (default)
- w write mode: file will be overwritten if it already exists
- a append mode: data will be appended to the existing file

Python - Reading from a File

Let's read from the file we created in the previous cell.

```
my_file = open("output_file.txt", 'r')
content = my_file.read()
print content
my_file.close()
```

Python - Reading from a File

Let's read it line by line

```
my_file = open("output_file.txt", 'r')
vars = my_file.readline()
var5 = my_file.readline()
var6 = my_file.readline()
print "String: ", vars
print "Integer: ", var1
print "Float: ", var2
my_file.close()
```


Python - Reading from a File

Tweak it a bit to make the code easier to read... introducing 'with'!

(remember the MAGIC NUMBER! Hint: it's 4)

```
with open("output_file.txt",'r') as f:
    vars = f.readline()
    var5 = f.readline()
    var6 = f.readline()
    print "String: ", vars
    print "Integer: ", var1
    print "Float: ", var2
```

Python - Control Flow

- So far we have been writing instruction after instruction
- Every instruction is executed
- What happens if we want to have instructions that are only executed if a given condition is true?

Python - if/else/elif

The if/else construction allows you to define conditions in your program

(remember the MAGIC NUMBER! Hint: it's 4)

```
if conditionA:
    statementA
elif conditionB:
    statementB
else:
    statementD
this line will always be executed (after the if/else)
```

Python - if/else/elif

A simple example

```
if var>10:  
    print "You entered a number greater than 10"  
else  
    print "you entered a number less than 10"
```


Python - if/else/elif

The if/else construction allows you to define conditions in your program

(remember the MAGIC NUMBER! Hint: it's 4)

```
if condition1:
    statement1
    if condition2:
        statement2
    else:
        if condition3:
            statement3 # when is this statement executed?
else: # which 'if' does this 'else' belong to?
    statement4 # when is this statement executed?
```

Python - For Loops

When we need to iterate, execute the same set of instructions over and over again... we need to loop! and introducing range()

(remember the MAGIC NUMBER! Hint: it's 4)

```
for x in range(0, 3):  
    print "Let's go %d" % (x)
```

Python - While Loops

Sometimes we need to loop while a condition is true...

(remember the MAGIC NUMBER! Hint: it's 4)

```
i = 0      # Initialization
while (i < 10):  # Condition
    print i    # do_something
    i = i + 1  # Why do we need this?
```

Python - lists

- A list is a sequence, where each element is assigned a position (index)
- First position is 0. You can access each position using []
- Elements in the list can be of different type

```
mylist1 = ["first item", "second item"]
mylist2 = [1, 2, 3, 4]
mylist3 = ["first", "second", 3]
print mylist1[0], mylist1[1]
print mylist2[0]
print mylist3
print mylist3[0], mylist3[1], mylist3[2]
print mylist2[0] + mylist3[2]
```


Python - lists

- It's possible to use slicing:

```
print mylist3[0:3]  
print mylist3
```
- To change the value of an element in a list, simply assign it a new value:

```
mylist3[0] = 10  
print mylist3
```

Python - lists

- There's a function that returns the number of elements in a list
`len(mylist2)`
- Check if a value exists in a list:
`1 in mylist2`
- Delete an element
`len(mylist2)`
`del mylist2[0]`
`print mylist2`
- Iterate over the elements of a list:
`for x in mylist2:`
`print x`

Python - lists

- There are more functions
`max(mylist), min(mylist)`
- It's possible to add new elements to a list:
`my_list.append(new_item)`
- We know how to find if an element exists, but there's a way to return the position of that element:
`my_list.index(item)`
- Or how many times a given item appears in the list:
`my_list.count(item)`

Matplotlib, What is it?

It's a graphing library for Python. It has a nice collection of tools that you can use to create anything from simple graphs, to scatter plots, to 3D graphs. It is used heavily in the scientific Python community for data visualisation.

Matplotlib, First Steps

Let's plot a simple sin wave from 0 to 2 pi.

First lets, get our code started by importing the necessary modules.

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

Matplotlib, First Steps

Let's add the following lines, we're setting up x as an array of 50 elements going from 0 to 2π

```
x = np.linspace(0, 2 * np.pi, 50)
plt.plot(x, np.sin(x))
plt.show() # Show the graph.
```

Let's run our cell!

Matplotlib, a bit more interesting

Let's plot another curve on the axis

```
plt.plot(x, np.sin(x),  
         x, np.sin(2 * x))  
plt.show()
```

Let's run our cell!

Matplotlib, a bit more interesting

Let's see if we can make the plots easier to read

```
plt.plot(x, np.sin(x), 'r-o',  
         x, np.cos(x), 'g--')  
plt.show()
```

Let's run this cell!

Matplotlib, a bit more interesting

Colors:

Blue – ‘b’

Green – ‘g’

Red – ‘r’

Cyan – ‘c’

Magenta – ‘m’

Yellow – ‘y’

Black – ‘k’ (‘b’ is taken by blue so the last letter is used)

White – ‘w’

Matplotlib, a bit more interesting

Lines:

Solid Line – ‘_’

Dashed – ‘--’

Dotted – ‘.’

Dash-dotted – ‘-:’

Often Used Markers:

Point – ‘.’

Pixel – ‘,’

Circle – ‘o’

Square – ‘s’

Triangle – ‘^’

Matplotlib, Subplots

Let's split the plots up into subplots

```
plt.subplot(2, 1, 1) # (row, column, active  
area)  
plt.plot(x, np.sin(x), 'r')  
plt.subplot(2, 1, 2)  
plt.plot(x, np.cos(x), 'g')  
plt.show()
```

using the subplot() function, we can plot two graphs at the same time within the same "canvas". Think of the subplots as "tables", each subplot is set with the number of rows, the number of columns, and the active area, the active areas are numbered left to right, then up to down.

Matplotlib, Scatter Plots

Let's take our sin curve, and make it a scatter plot

```
y = np.sin(x)
plt.scatter(x,y)
plt.show()
```

call the `scatter()` function and pass it two arrays of `x` and `y` coordinates.

Matplotlib, add a touch of color

Let's mix things up, using random numbers and add a colormap to a scatter plot

```
x = np.random.rand(1000)
y = np.random.rand(1000)
size = np.random.rand(1000) * 50
color = np.random.rand(1000)
plt.scatter(x, y, size, color)
plt.colorbar()
plt.show()
```

Matplotlib, add a touch of color

Let's see what we added, and where that takes us

```
...  
plt.scatter(x, y, size, color)  
plt.colorbar()  
...
```

We brought in two new parameters, size and color. Which will varies the diameter and the color of our points. Then adding the colorbar() gives us nice color legend to the side.

Matplotlib, Histograms

A histogram is one of the simplest types of graphs to plot in Matplotlib. All you need to do is pass the hist() function an array of data. The second argument specifies the amount of bins to use. Bins are intervals of values that our data will fall into. The more bins, the more bars.

```
plt.hist(x, 50)  
plt.show()
```

Matplotlib, Contour Plots

Let's play with our preloaded data.

```
import matplotlib.cm as cm

with open('../mydata/ContourData/contourData.dat') as file:
    array2d = [[float(digit) for digit in line.split()] for line in file]
print array2d

nx, ny = np.shape(array2d)

cs = plt.pcolor(array2d, cmap=cm.get_cmap('afmhot'))
cb = plt.colorbar(cs, orientation = 'horizontal')
plt.xlim(0,nx)
plt.ylim(0,ny)
plt.show()
```


Matplotlib, Adding Labels and Legends

Let's go back to our sin/cos curve example, and add a bit of clarification to our plots

```
x = np.linspace(0, 2 * np.pi, 50)
plt.plot(x, np.sin(x), 'r-x', label='Sin(x)')
plt.plot(x, np.cos(x), 'g-^', label='Cos(x)')
plt.legend() # Display the legend.
plt.xlabel('Rads') # Add a label to the x-axis.
plt.ylabel('Amplitude') # Add a label to the
y-axis.
plt.title('Sin and Cos Waves') # Add a graph
title.
plt.show()
```

DesignSafe: Questions?

For additional questions, feel free to contact us

- Email:

training@designsafe-ci.org

- or fill out a ticket:

<https://www.designsafe-ci.org/help/tickets>

An example.

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DesignSafe: References

- <http://www.datadependence.com/2016/04/scientific-python-matplotlib/>
- <http://jupyter-notebook.readthedocs.io/en/latest/notebook.html>
- http://jupyter-notebook-beginner-guide.readthedocs.io/en/latest/what_is_jupyter.html
- <https://github.com/adam-p/markdown-here/wiki/Markdown-Cheatsheet>
- <https://www.codecademy.com/learn/python>

DesignSafe: Next Webinar

DesignSafe: Data Analysis and Plotting using
Jupyter and R

Wednesday, November 9th 1:00p – 3:00p

For additional questions, feel free to contact us

- Email:

training@designsafe-ci.org

- or fill out a ticket:

<https://www.designsafe-ci.org/help/tickets>