jupyter

OpenDreamKit

Computational environments
for research and education

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Simula Research Lab

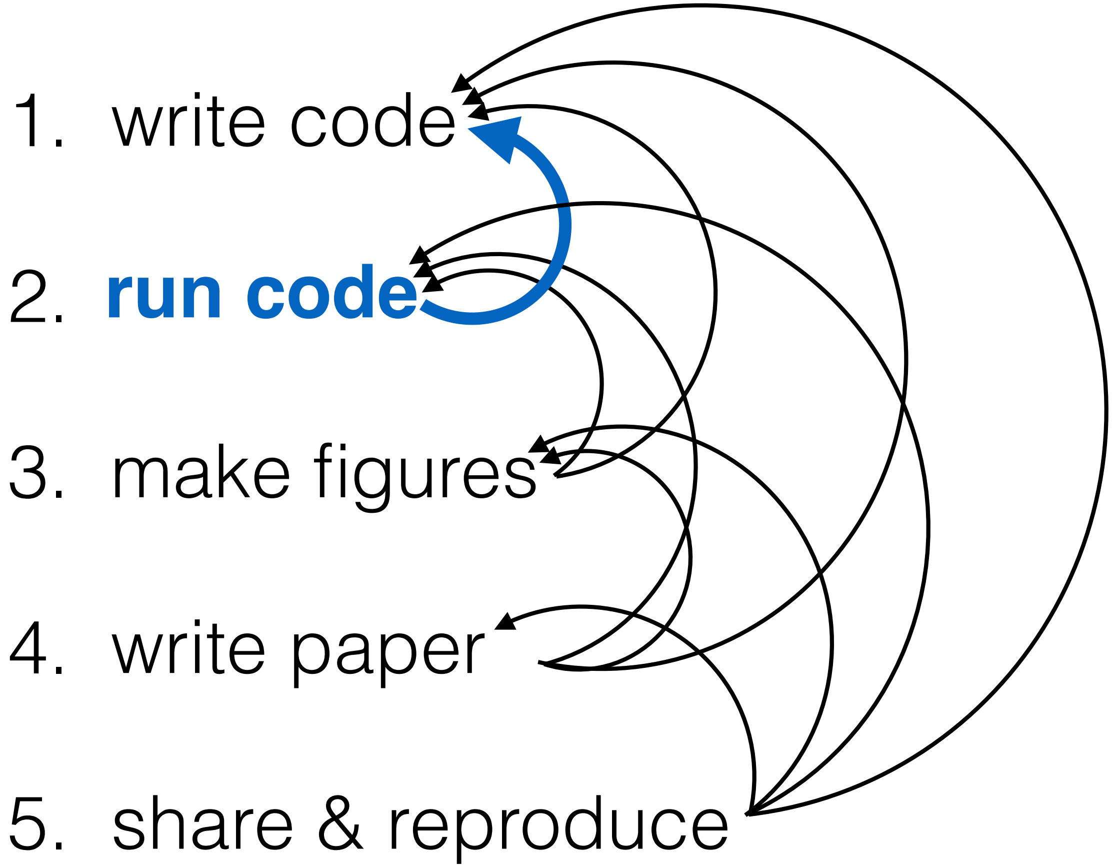
OpenDreamKit

- H2020 project
- 16 Institutions
- 4 Years (2015-2019)

Virtual Research Environments

- Generic (Jupyter, SageMath)
- Domain-specific (OOMMF micromagnetics)

How do we do computational research?



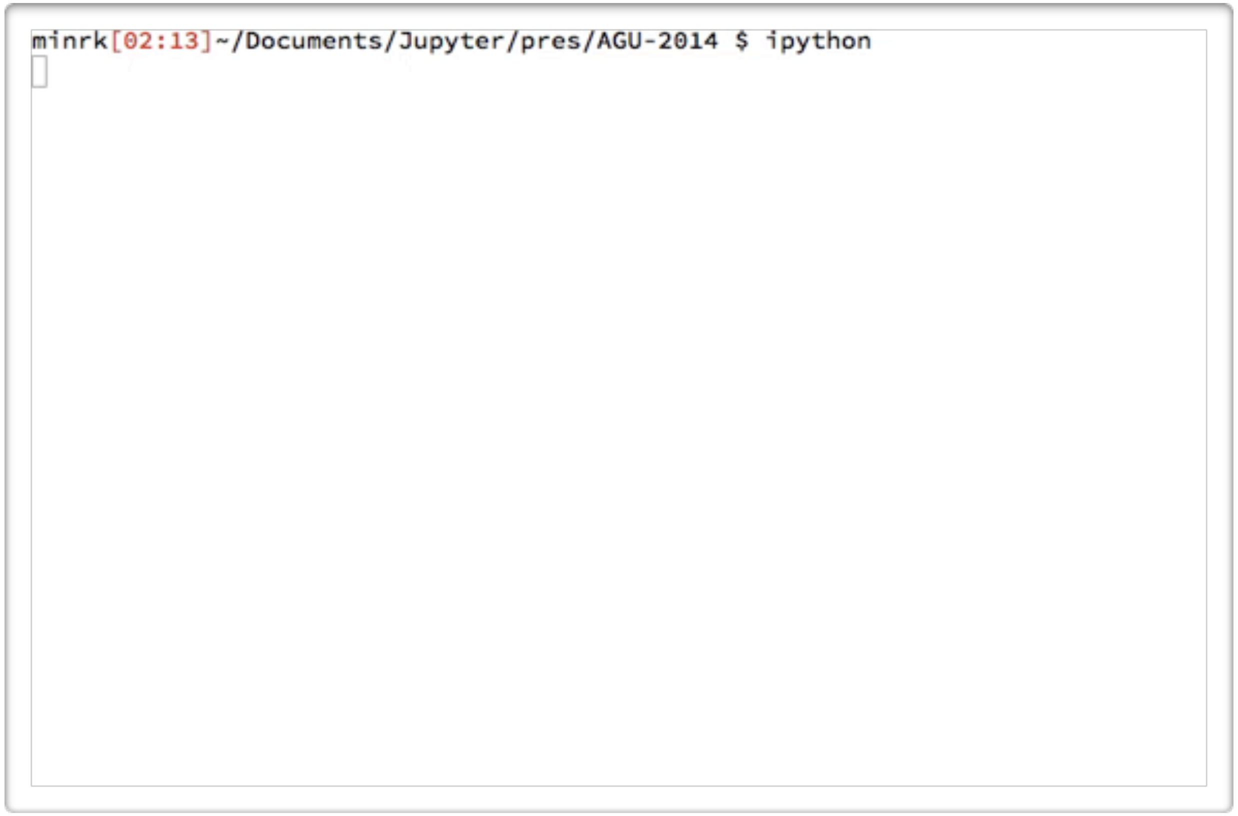
1. write code
2. **run code**
3. make figures
4. write paper
5. share & reproduce

IPython

IPython
Interactive Python

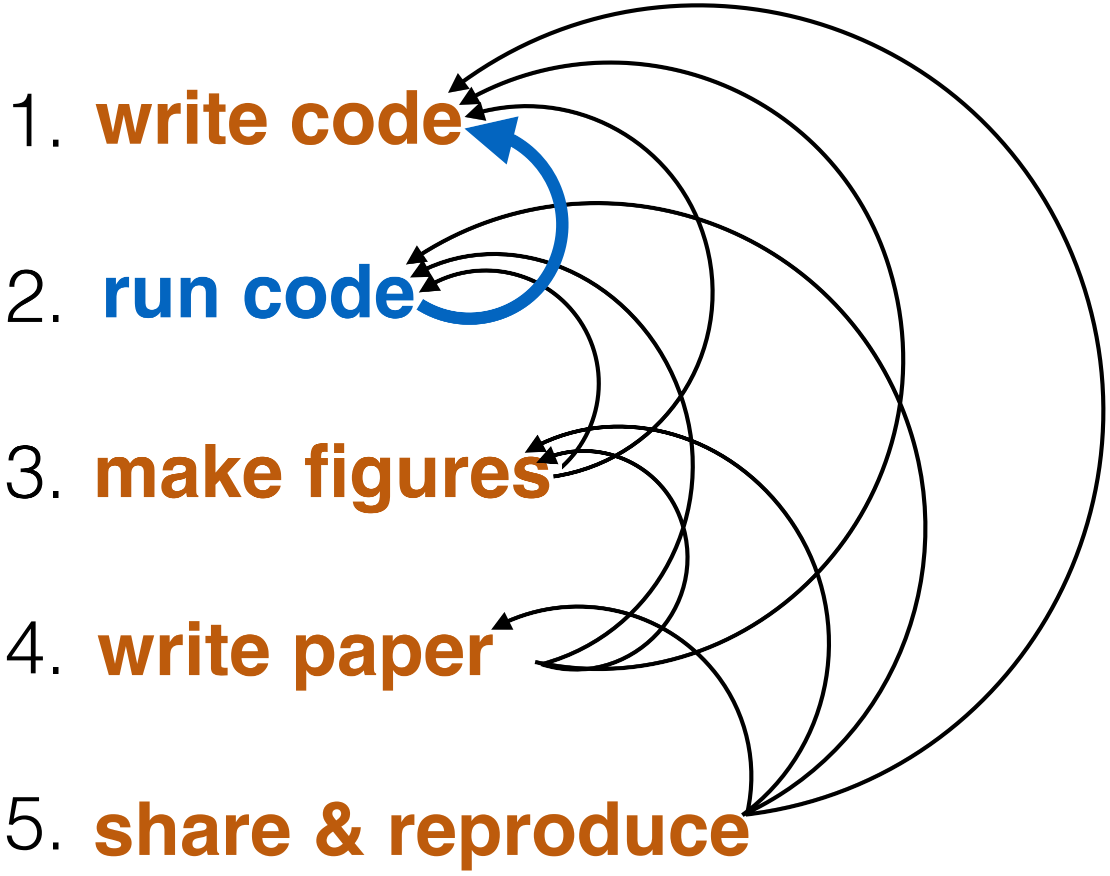
helps run code

- tab completion
- introspection
- %magics



```
minrk[02:13]~/Documents/Jupyter/pres/AGU-2014 $ ipython
```

What about Jupyter?



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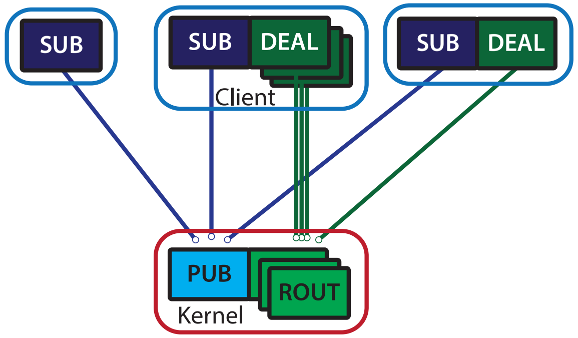
IPython

jupyter

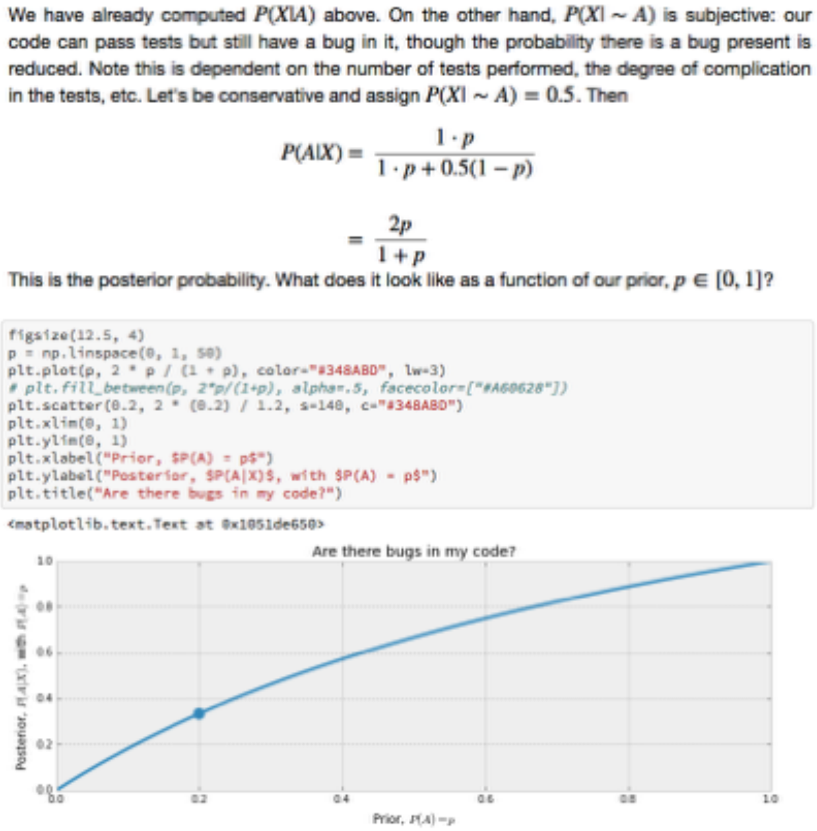
What is Jupyter?

Network Protocol



ØMQ + JSON

Document Format



We have already computed $P(X|A)$ above. On the other hand, $P(X|\sim A)$ is subjective: our code can pass tests but still have a bug in it, though the probability there is a bug present is reduced. Note this is dependent on the number of tests performed, the degree of complication in the tests, etc. Let's be conservative and assign $P(X|\sim A) = 0.5$. Then

$$P(A|X) = \frac{1 \cdot p}{1 \cdot p + 0.5(1-p)}$$

$$= \frac{2p}{1+p}$$

This is the posterior probability. What does it look like as a function of our prior, $p \in [0, 1]$?

```
figsize(12.5, 4)
p = np.linspace(0, 1, 50)
plt.plot(p, 2 * p / (1 + p), color="#348ABD", lw=3)
# plt.fill_between(p, 2*p/(1+p), alpha=.5, facecolor=["#A60628"])
plt.scatter(0.2, 2 * (0.2) / 1.2, s=140, c="#348ABD")
plt.xlim(0, 1)
plt.ylim(0, 1)
plt.xlabel("Prior, $P(A) = p$")
plt.ylabel("Posterior, $P(A|X)$, with $P(A) = p$")
plt.title("Are there bugs in my code?")
```

```
<matplotlib.text.Text at 0x1051de650>
```

Are there bugs in my code?
Posterior, $P(A|X)$, with $P(A)=p$
Prior, $P(A)=p$
0.0
0.2
0.4
0.6
0.8
1.0

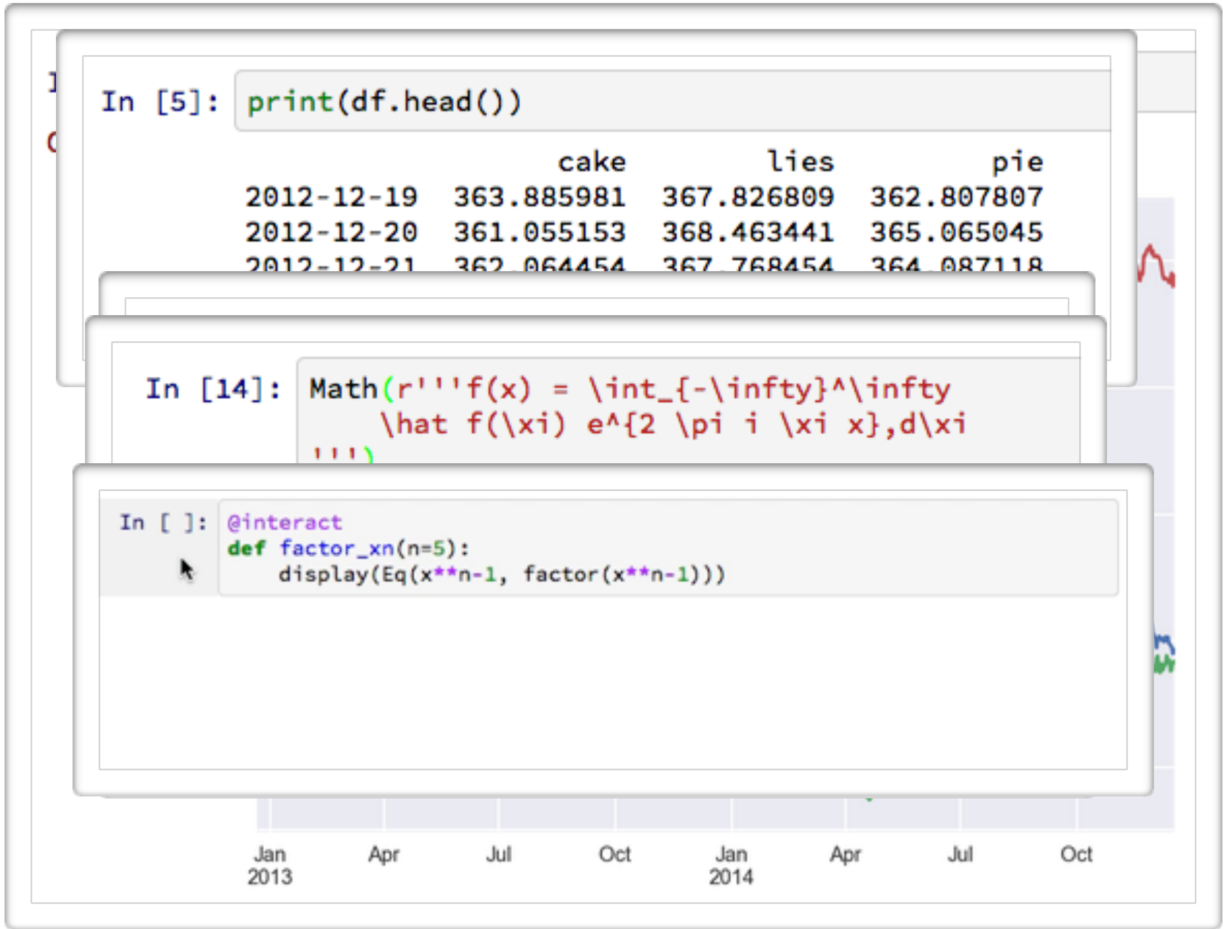
https://github.com/CamDavidsonPilon/Probabilistic-Programming-and-Bayesian-Methods-for-Hackers

Jupyter Protocol

supercharge the P in REP*L

any mime-type output

- text
- svg, png, jpeg
- latex, pdf
- html, javascript
- interactive widgets



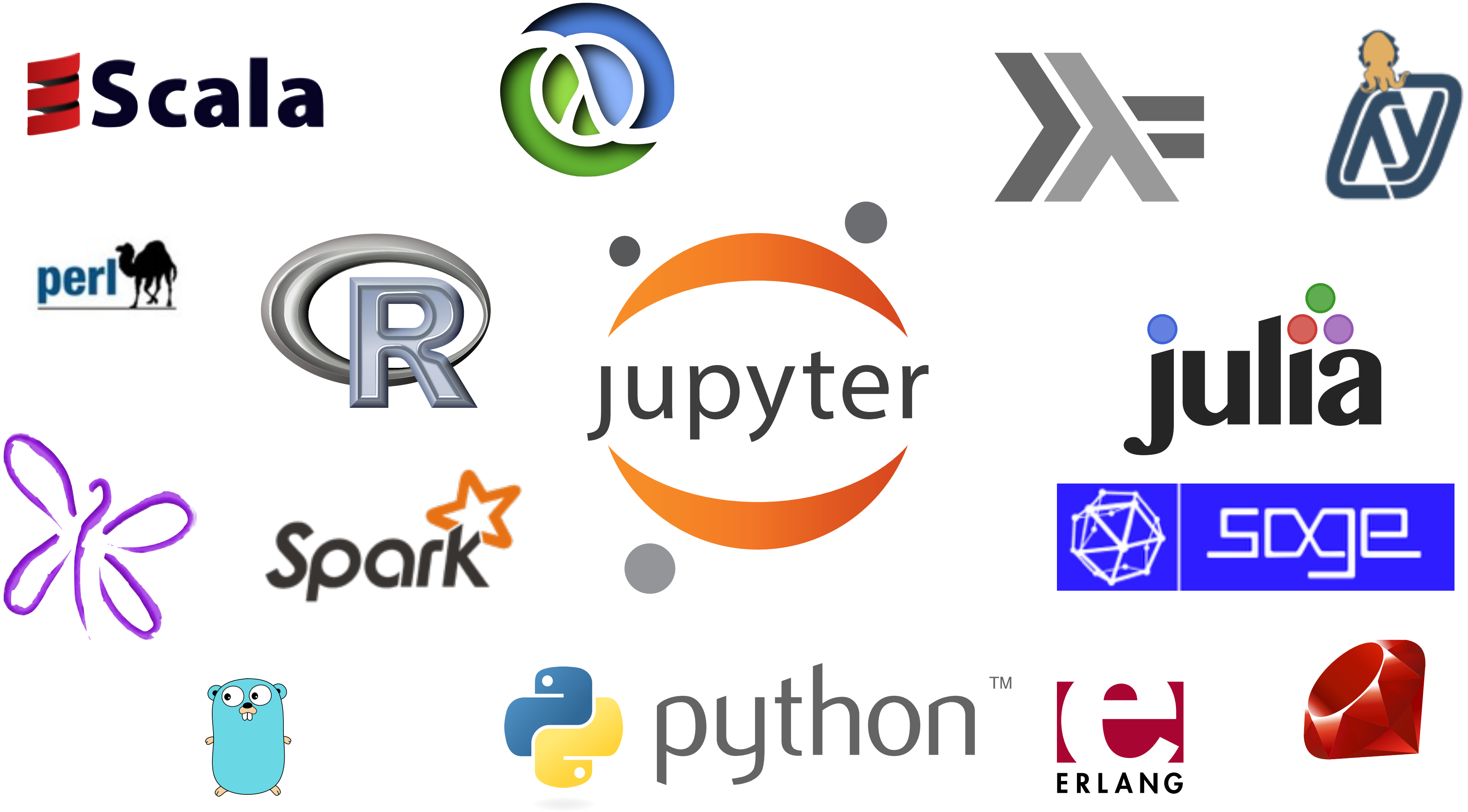
```
In [5]: print(df.head())

                  cake        lies         pie
2012-12-19  363.885981  367.826809  362.807807
2012-12-20  361.055153  368.463441  365.065045
2012-12-21  362.064454  367.768454  364.087118
```

```
In [14]: Math(r'''f(x) = \int_{-\infty}^\infty
             \hat f(\xi) e^{2 \pi i \xi x},d\xi
         ''')
```

```
In [ ]: @interact
        def factor_xn(n=5):
            display(Eq(x**n-1, factor(x**n-1)))
```

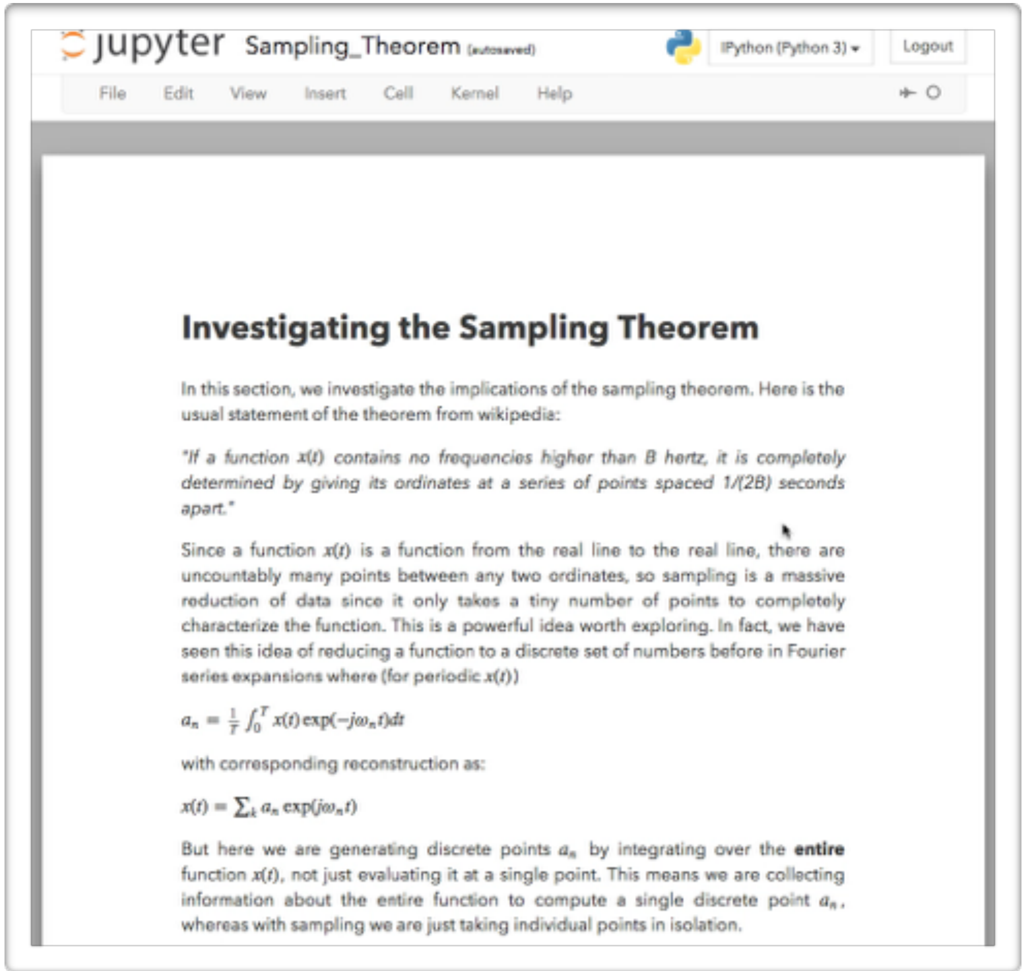
Jupyter Protocol

is language agnostic



Jupyter Notebooks

- notebook = sequence of cells
- text cell = markdown + latex)
- code cell = REP (input + output)
- metadata everywhere



Investigating the Sampling Theorem

In this section, we investigate the implications of the sampling theorem. Here is the usual statement of the theorem from wikipedia:

"If a function $x(t)$ contains no frequencies higher than B hertz, it is completely determined by giving its ordinates at a series of points spaced 1/(2B) seconds apart."

Since a function $x(t)$ is a function from the real line to the real line, there are uncountably many points between any two ordinates, so sampling is a massive reduction of data since it only takes a tiny number of points to completely characterize the function. This is a powerful idea worth exploring. In fact, we have seen this idea of reducing a function to a discrete set of numbers before in Fourier series expansions where (for periodic $x(t)$)

$a_n = \frac{1}{T} \int_0^T x(t) \exp(-j\omega_n t) dt$

with corresponding reconstruction as:

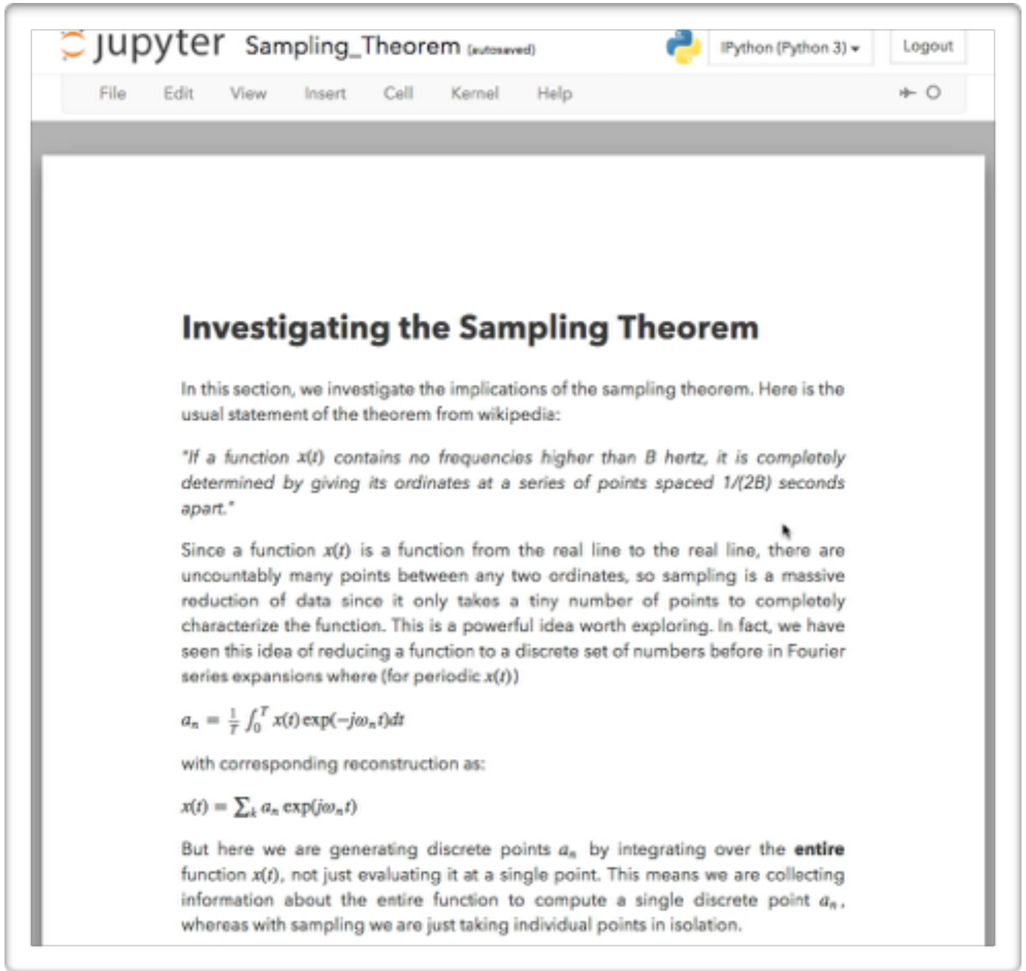
$x(t) = \sum_k a_n \exp(j\omega_n t)$

But here we are generating discrete points a_n by integrating over the **entire** function $x(t)$, not just evaluating it at a single point. This means we are collecting information about the entire function to compute a single discrete point a_n, whereas with sampling we are just taking individual points in isolation.

https://github.com/unpingco/Python-for-Signal-Processing

Jupyter Notebooks

- Plain Text (JSON)
- Publicly documented schema
- Machine readable, easy to understand
- Transformable (nbconvert)



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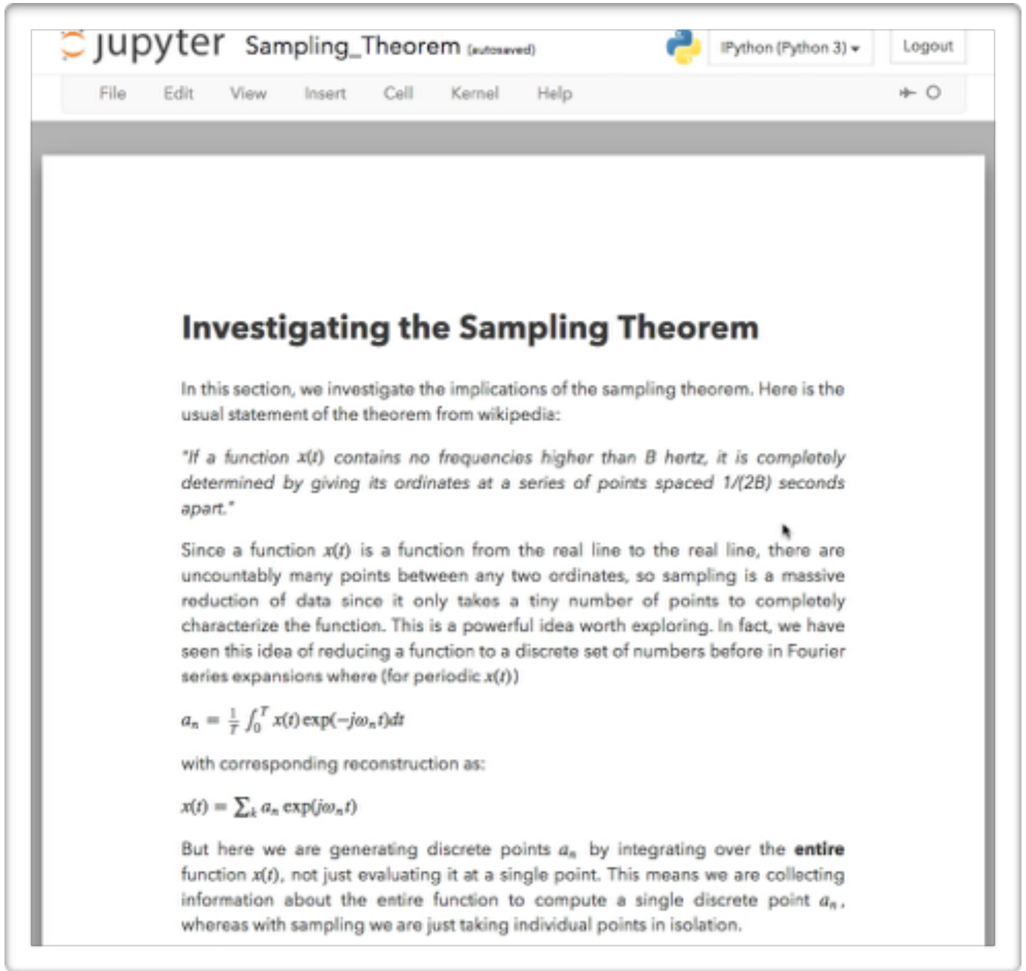
Jupyter Notebooks

- interactive environment
- input format
- output format



jupyter Sampling_Theorem (autosaved)
IPython (Python 3)
Logout
File Edit View Insert Cell Kernel Help

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Lifecycle of a Computational Idea

1. Explore an idea interactively in a Notebook
2. *Build/add to a library based on what you learn*
3. Record and collaborate on analyses in Notebooks
4. Document, demonstrate, and share in Notebooks
5. Computational companions, reproducible papers

Applications of Jupyter Notebooks

- **nbconvert** - convert notebooks to other formats (rst, html, latex/pdf, markdown, script, reveal.js slides)
- **nbviewer** - nbconvert to html on the web
- **nbgrader** - automated grading of notebooks
- **tmpnb** - containerized (docker) transient deployments of notebooks
- **thebe** - transient kernels on the web, without notebooks
- **dexy** - reproducible document-based workflows
- **jupyterhub** - multi-user notebook server for classes, groups
- **binder** - online notebooks populated from GitHub repos

jupyter

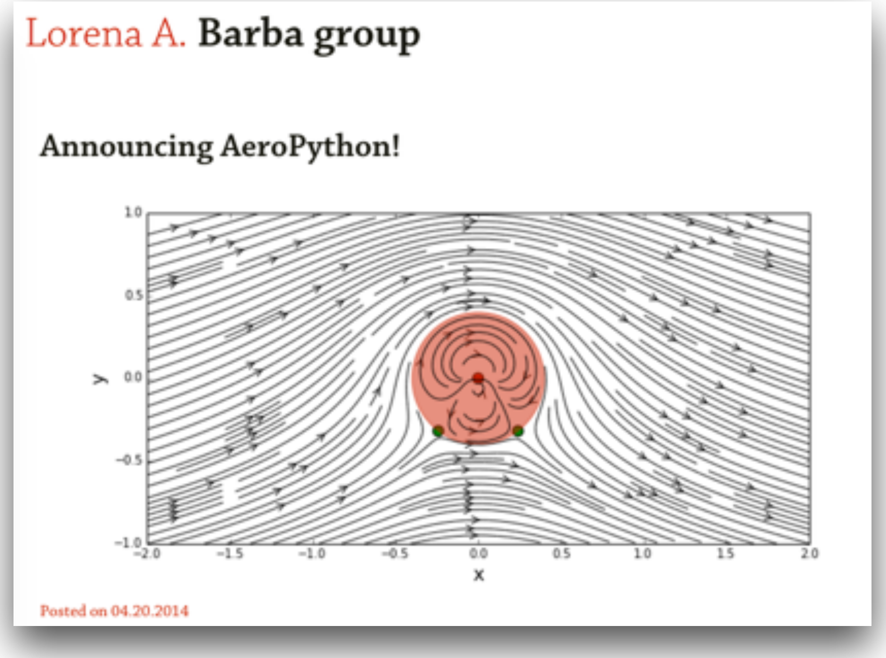
Jupyter in the Classroom

Lorena Barba

AeroPython

Aerodynamics, George Washington U

Flipped Classroom



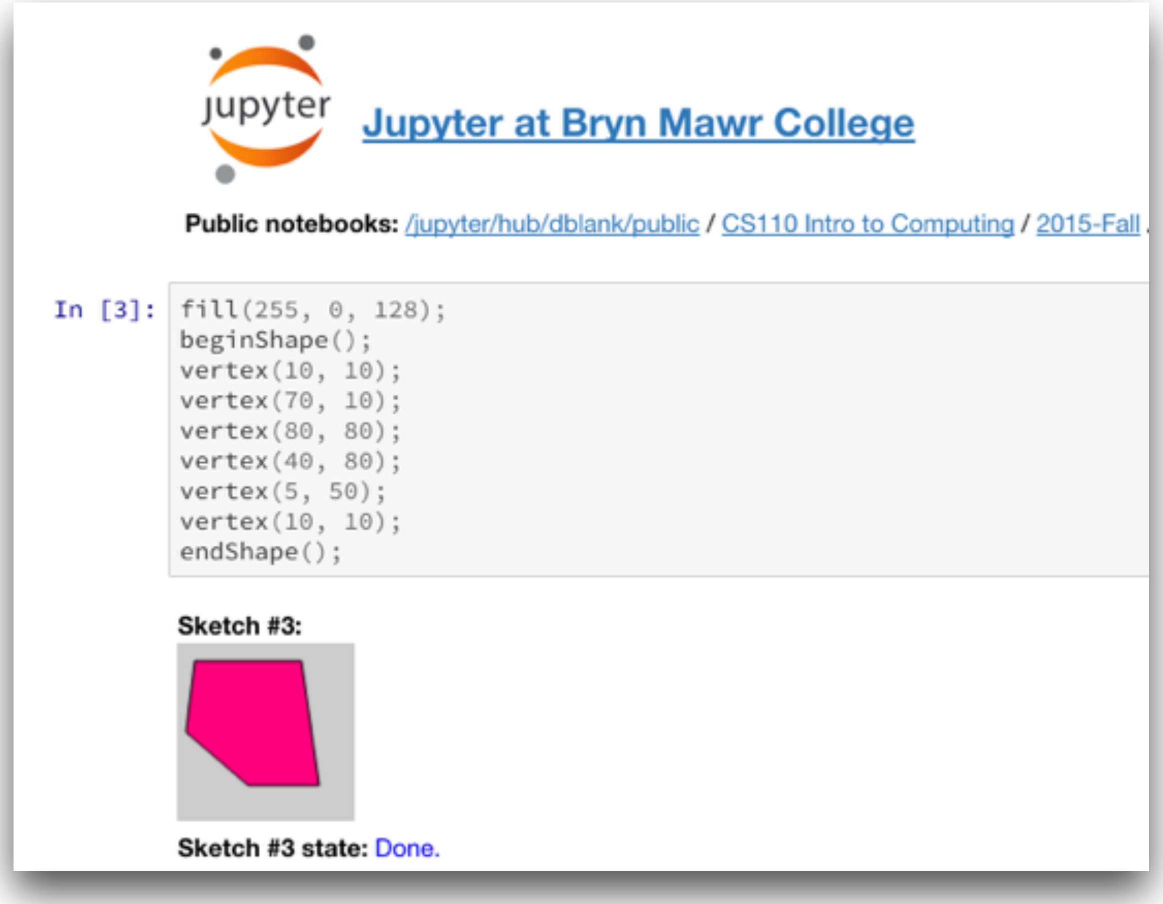
Lorena A. Barba group

Announcing AeroPython!

Posted on 04.20.2014

http://lorenabarba.com/blog/announcing-aeropython

Jupyter in the Classroom



Jupyter at Bryn Mawr College

Public notebooks: /jupyter/hub/dblank/public / CS110 Intro to Computing / 2015-Fall

```
In [3]: fill(255, 0, 128);
        beginShape();
        vertex(10, 10);
        vertex(70, 10);
        vertex(80, 80);
        vertex(40, 80);
        vertex(5, 50);
        vertex(10, 10);
        endShape();
```

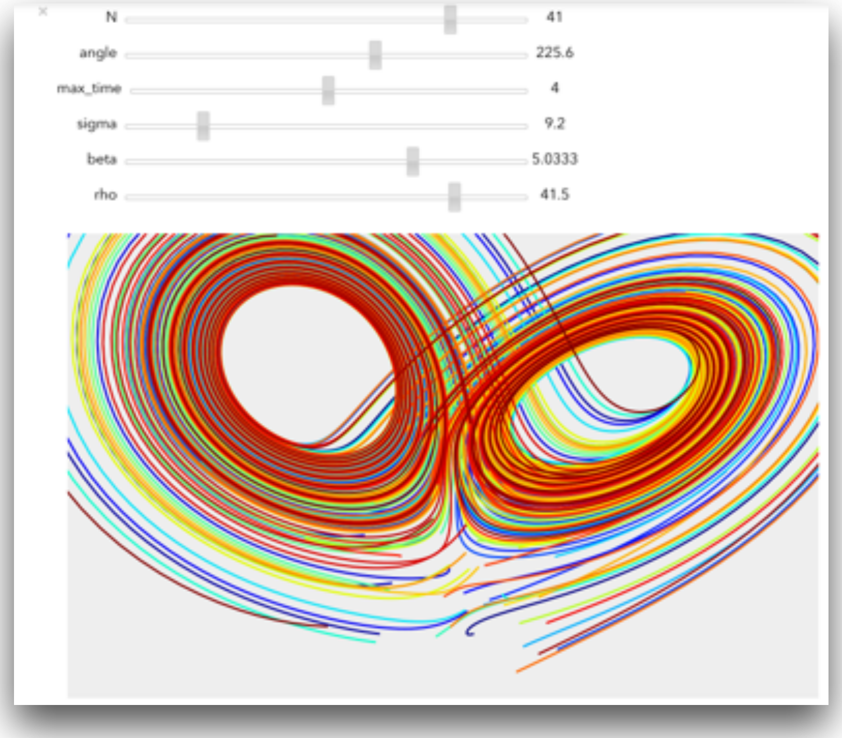
Sketch #3:

Sketch #3 state: Done.

Doug Blank
CS, Brynmawr
Calysto (Multiple languages, not Python)
JupyterHub

Jupyter in the Classroom

Brian Granger
Computational Physics, Cal Poly
JupyterHub

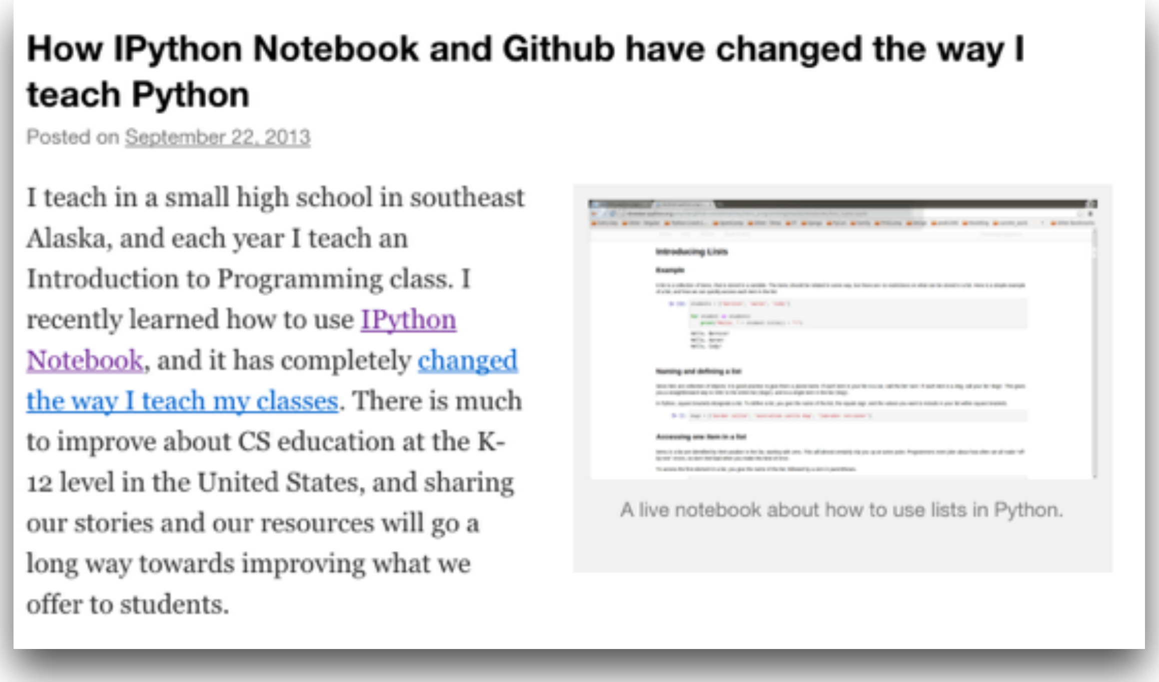


N 41
angle 225.6
max_time 4
sigma 9.2
beta 5.0333
rho 41.5

https://github.com/ellisonbg/phys202-2015

Jupyter in the Classroom

Eric Matthes
High School Programming
Alaska, USA



How IPython Notebook and Github have changed the way I teach Python

Posted on September 22, 2013

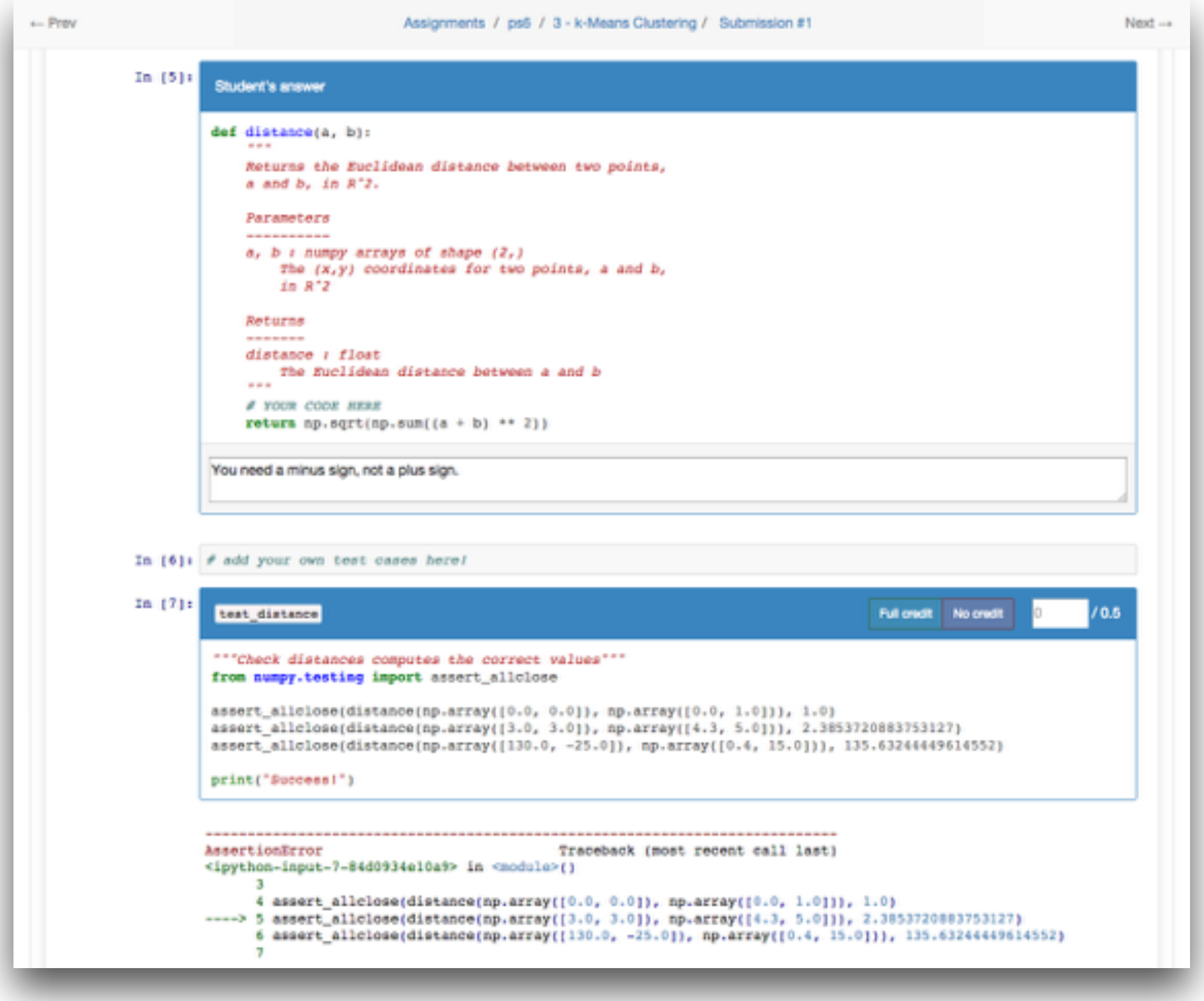
I teach in a small high school in southeast Alaska, and each year I teach an Introduction to Programming class. I recently learned how to use IPython Notebook, and it has completely changed the way I teach my classes. There is much to improve about CS education at the K-12 level in the United States, and sharing our stories and our resources will go a long way towards improving what we offer to students.

A live notebook about how to use lists in Python.

https://peak5390.wordpress.com/2013/09/22/how-ipython-notebook-and-github-have-changed-the-way-i-teach-python/

Jupyter in the Classroom

Jessica Hamrick
Computational Models of Cognition
Psychology, UC Berkeley
220 students
JupyterHub
NBGrader



```
In [5]:
def distance(a, b):
    """
    Returns the Euclidean distance between two points,
    a and b, in R^2.

    Parameters
    ----------
    a, b : numpy arrays of shape (2,)
        The (x,y) coordinates for two points, a and b,
        in R^2

    Returns
    -------
    distance : float
        The Euclidean distance between a and b
    """
    # YOUR CODE HERE
    return np.sqrt(np.sum((a + b) ** 2))
```

You need a minus sign, not a plus sign.

```
In [6]: # add your own test cases here!
```

```
In [7]: test_distance
"""Check distances computes the correct values"""
from numpy.testing import assert_allclose

assert_allclose(distance(np.array([0.0, 0.0]), np.array([0.0, 1.0])), 1.0)
assert_allclose(distance(np.array([3.0, 3.0]), np.array([4.3, 5.0])), 2.3853720883753127)
assert_allclose(distance(np.array([130.0, -25.0]), np.array([0.4, 15.0])), 135.63244449614552)

print("Success!")
```

```
---------------------------------------------------------------------------
AssertionError                            Traceback (most recent call last)
<ipython-input-7-84d0934e10a9> in <module>()
      3
      4 assert_allclose(distance(np.array([0.0, 0.0]), np.array([0.0, 1.0])), 1.0)
----> 5 assert_allclose(distance(np.array([3.0, 3.0]), np.array([4.3, 5.0])), 2.3853720883753127)
      6 assert_allclose(distance(np.array([130.0, -25.0]), np.array([0.4, 15.0])), 135.63244449614552)
      7
```

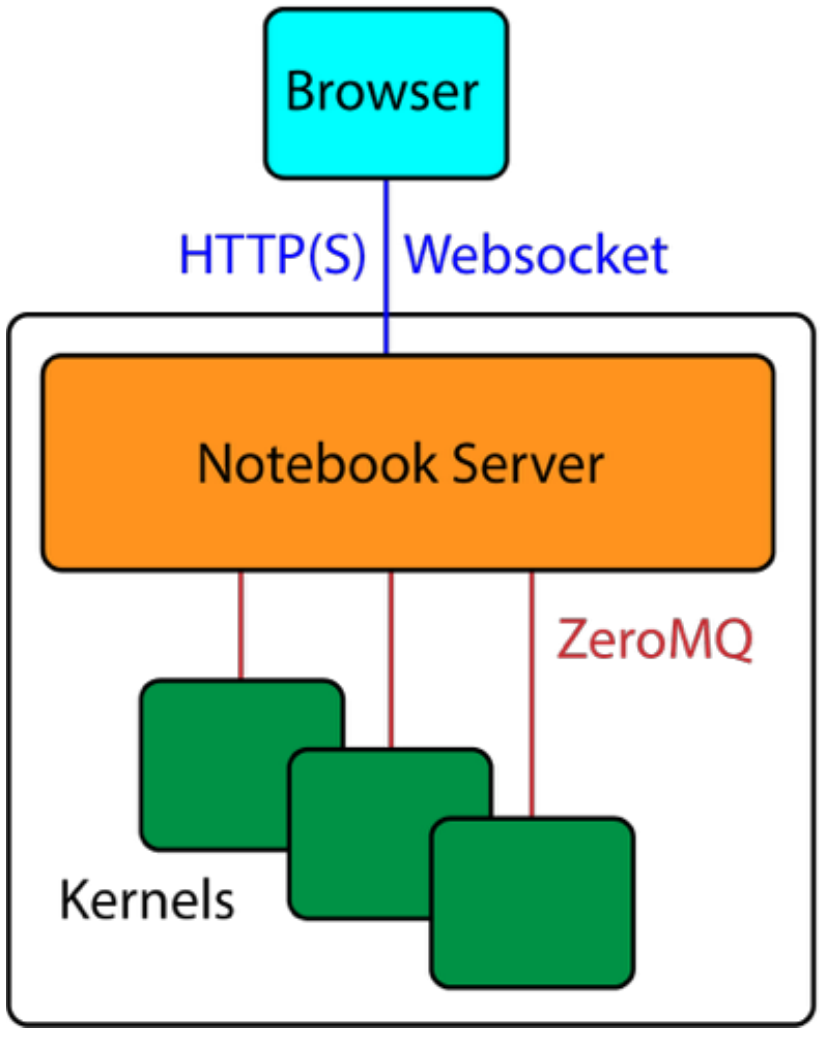
NBGrader

Notebooks as assignments

- distributed to students via JupyterHub
- turned in online
- Test-based auto-grading
- Manual grading of prose assignments

jupyterhub

multi-user notebook server



Browser

HTTP(S)

Websocket

Notebook Server

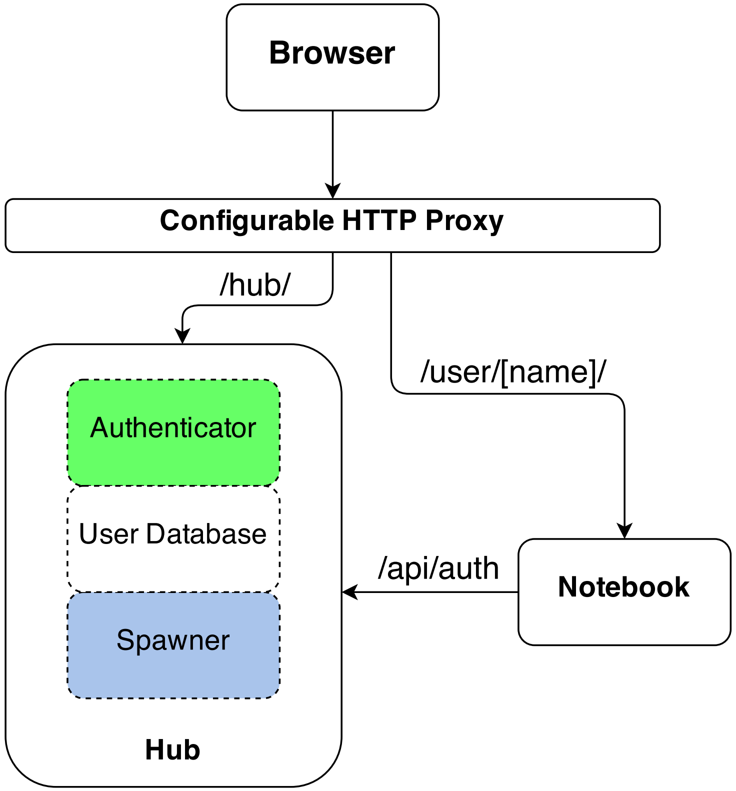
ZeroMQ

Kernels

Notebook Application

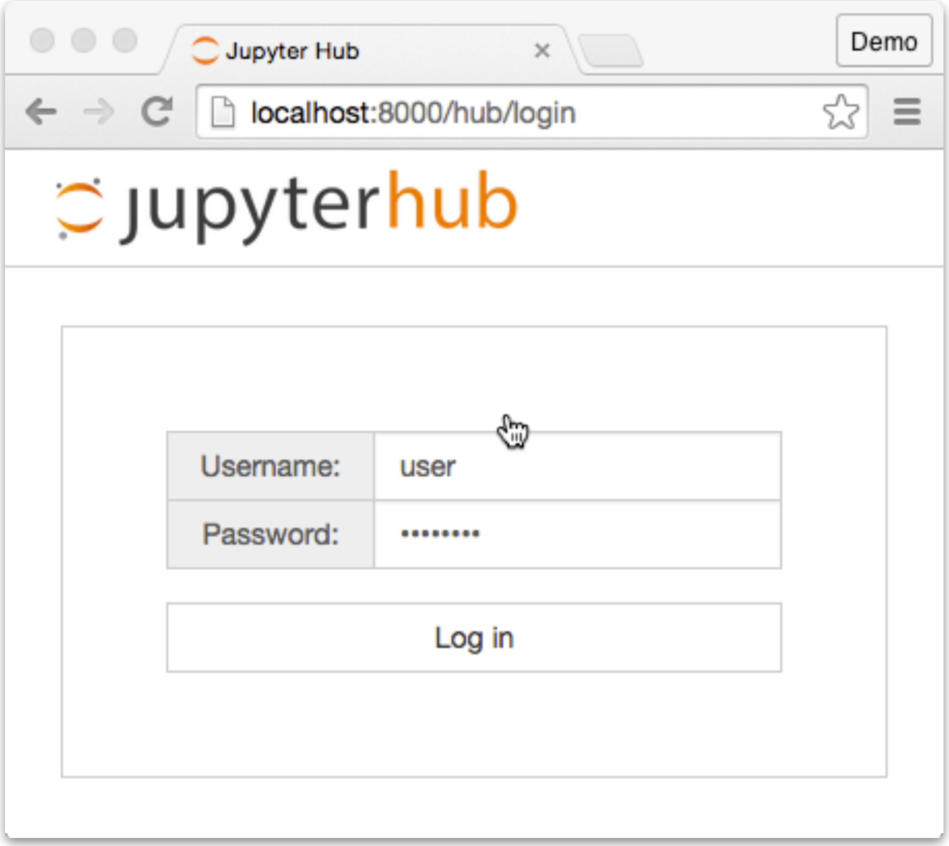
jupyterhub

- Manages authentication
- Spawns single-user servers on-demand
- Resume from db without restarting other components



jupyterhub

- Initial request is handled by Hub
- User authenticates via form / OAuth
- Spawner starts single-user server
- Hub notifies Proxy
- Redirects user to `/user/[name]`
- Single-user Server verifies auth with Hub



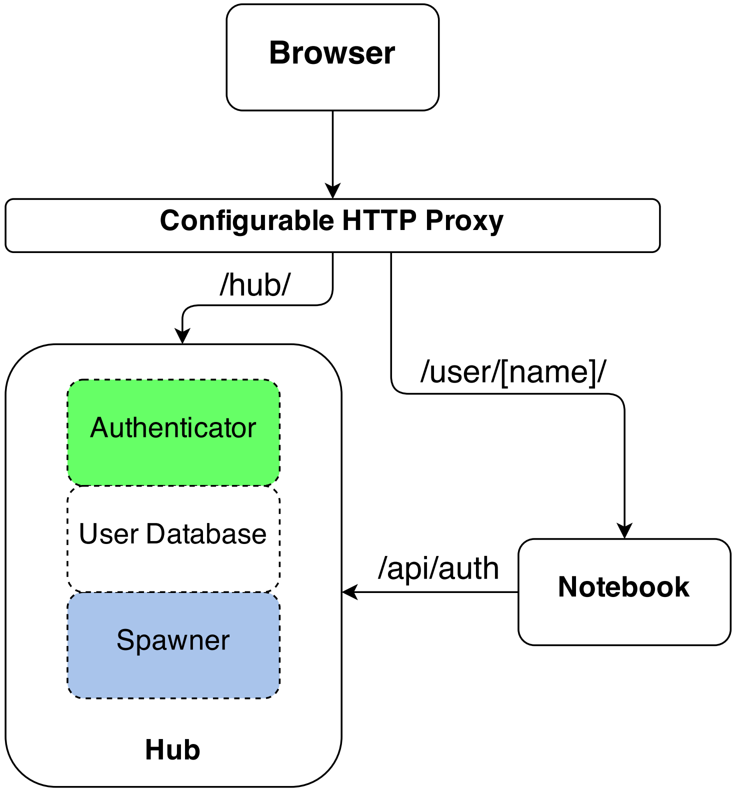
localhost:8000/hub/login

Username: user

Password: •••••••••

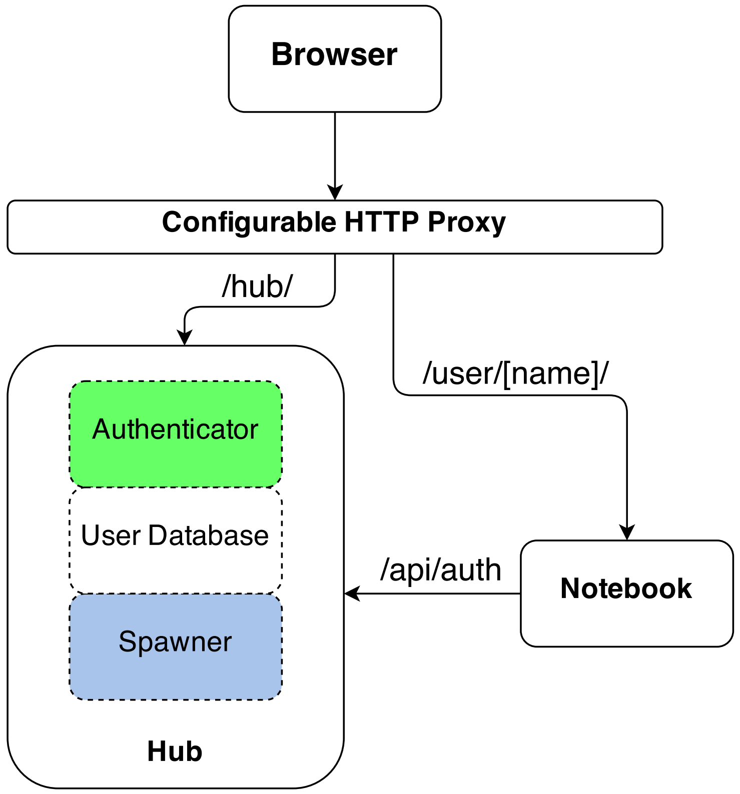
jupyterhub

- Pluggable Authentication
  - PAM, OAuth, SSO, etc.
- Pluggable Spawning
  - Popen, Docker, PBS, EC2, etc.



jupyterhub

- User-controls
  - specify resources √
  - multiple servers per user
- Sharing
  - publishing notebooks for other users
  - long-term: live collaboration



Browser

Configurable HTTP Proxy

/hub/

/user/[name]/

Authenticator

User Database

Spawner

Hub

/api/auth

Notebook

Disce Doce
RERVM COGNOSCERE CAVSAS

The
University
Of
Sheffield.

CERN

BRYN
MAWR
COLLEGE

jupyterhub

THE UNIVERSITY OF CALIFORNIA · BERKELEY · 1868
LET THERE BE LIGHT

WIKIMEDIA
FOUNDATION

NERSC

XSEDE
Extreme Science and Engineering
Discovery Environment

BROOKHAVEN
NATIONAL LABORATORY

jupyter