Teaching coding with nbgrader – lessons learned –

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Teaching situation

- programming language: Python

  Dlaczego warto uczyć w języku python? ↗ youtu.be/CEmg3gdFlaE
  Why teach Python? ↗ youtu.be/X18jt2lVmJY

  - low entry barrier
  - expressive code
  - well suited for serious work
  - freely available, “batteries included
  - Anaconda distribution for coherent environment on current operating systems
- teaching programming to physicists and materials scientists since 2010, typically 10+ students
- next year: mandatory course for 100+ students

Coping with heterogeneity

- students without programming experience and (sometimes) code writing apprehension
- students with knowledge in another programming language
  code often does not look very pythonic
  example: loop over objects vs. loop over indices

students with programming experience should not be bored and should obtain an interesting result from their code

- *but* scientific applications are often considered as an extra mental burden

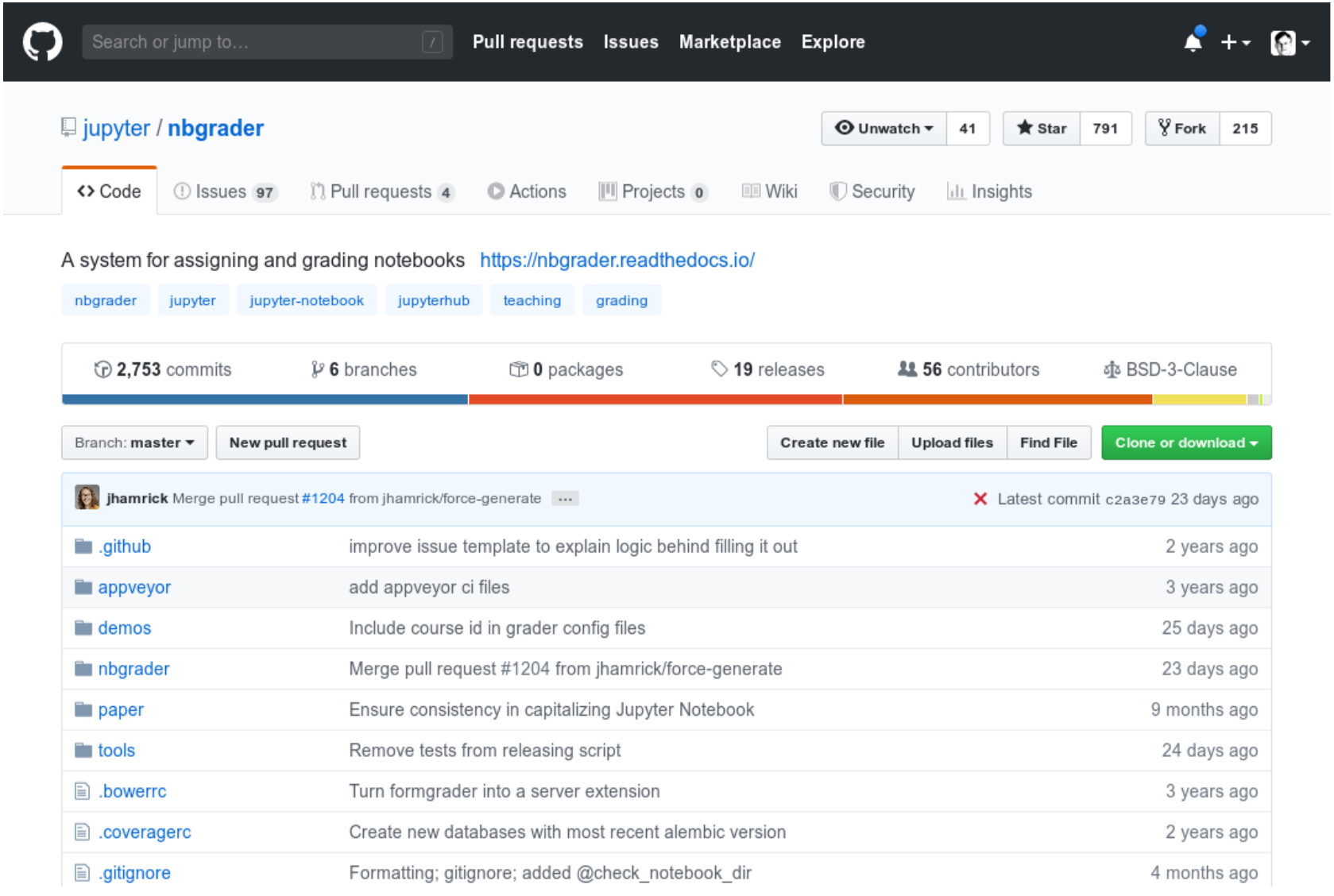
nbgrader

- tool that facilitates creating and grading assignments in the Jupyter notebook
- distributing and collecting assignments
- automatic grading by means of unit tests
- manual grading possible
- feedback can be given to students

- freely available
- open source
- latest version: 0.6.0 released end of August 2019

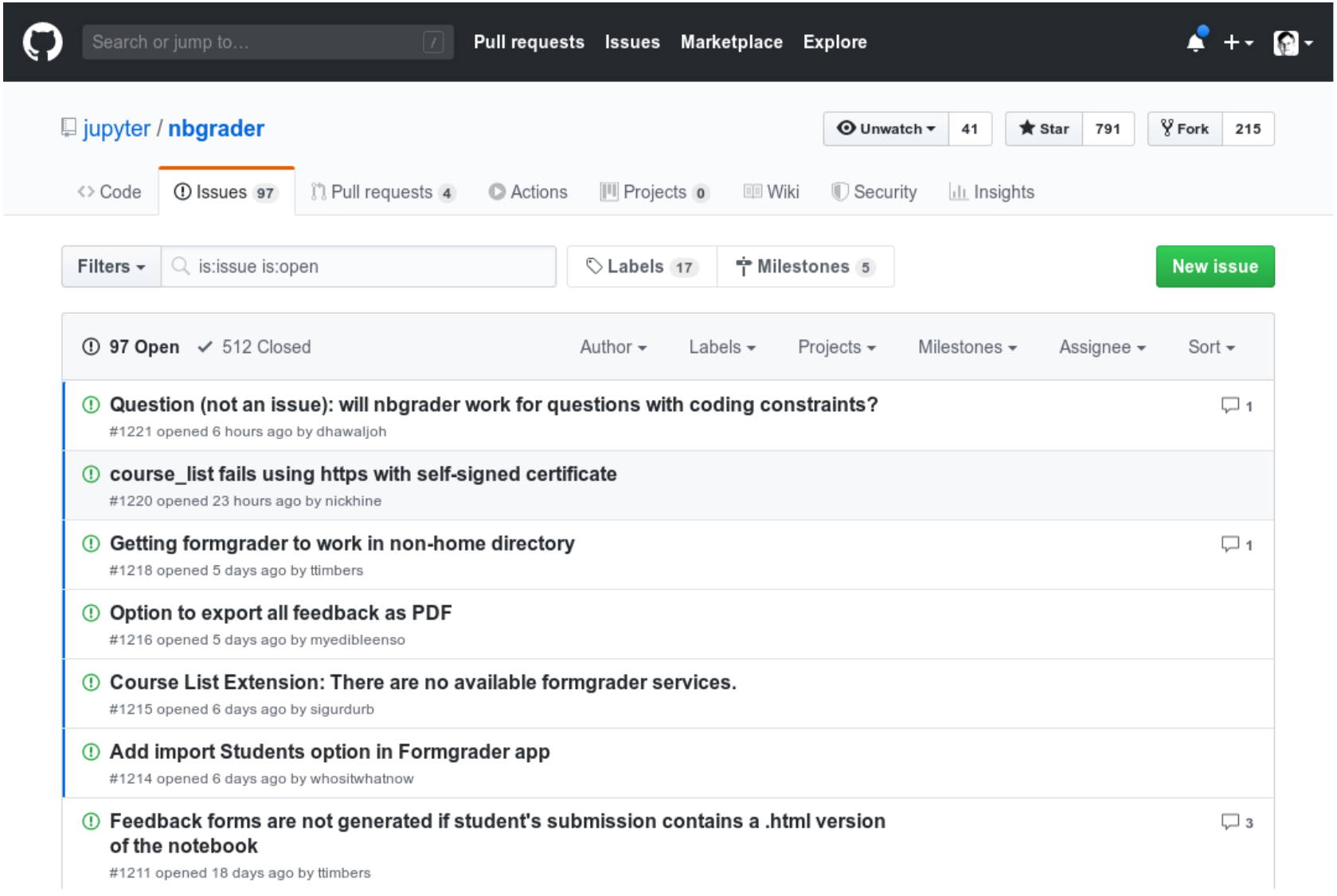
nbgrader on Github

`github.com/jupyter/nbgrader/`



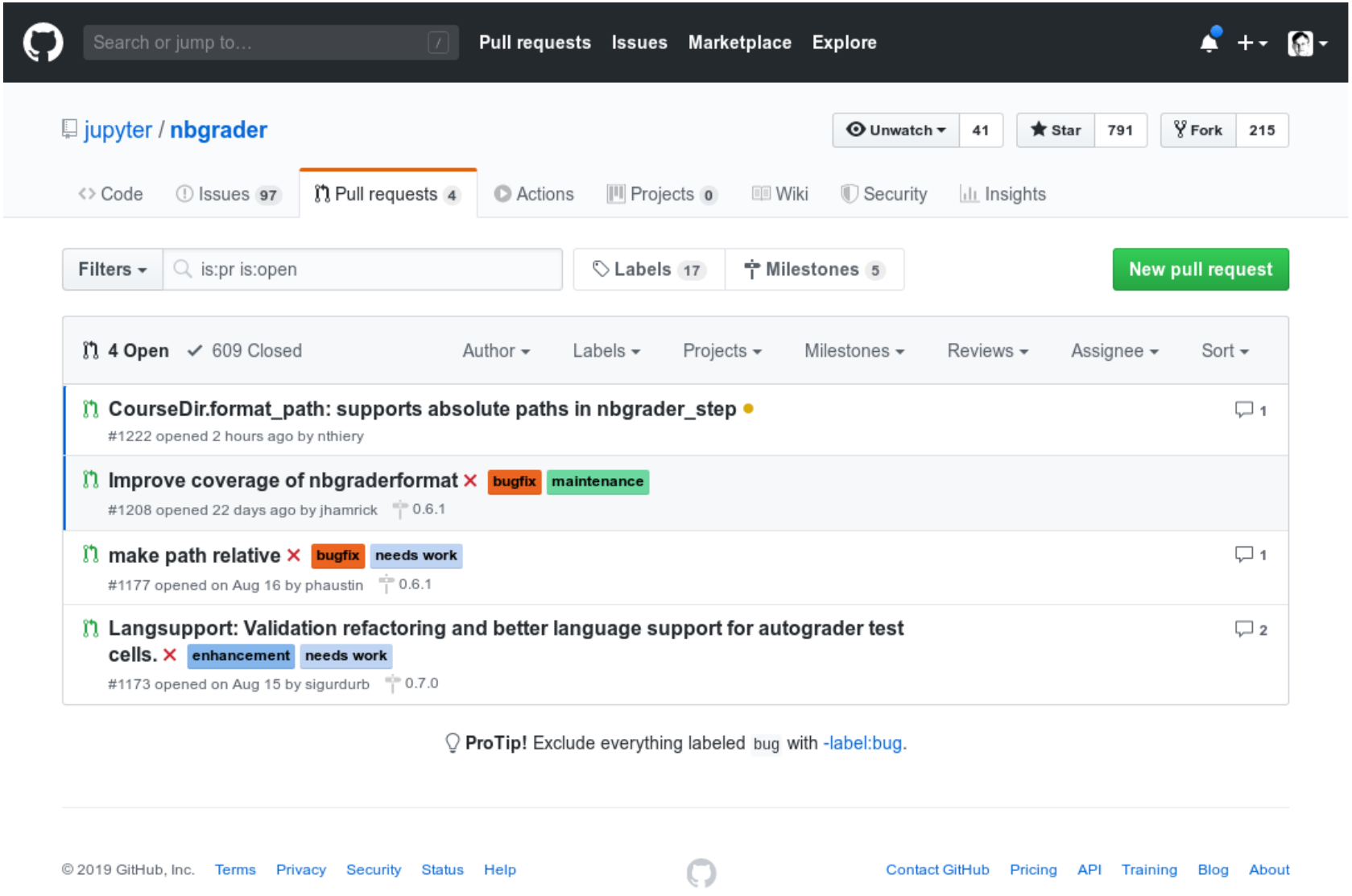
Github issues for nbgrader

report and discuss problems or new features



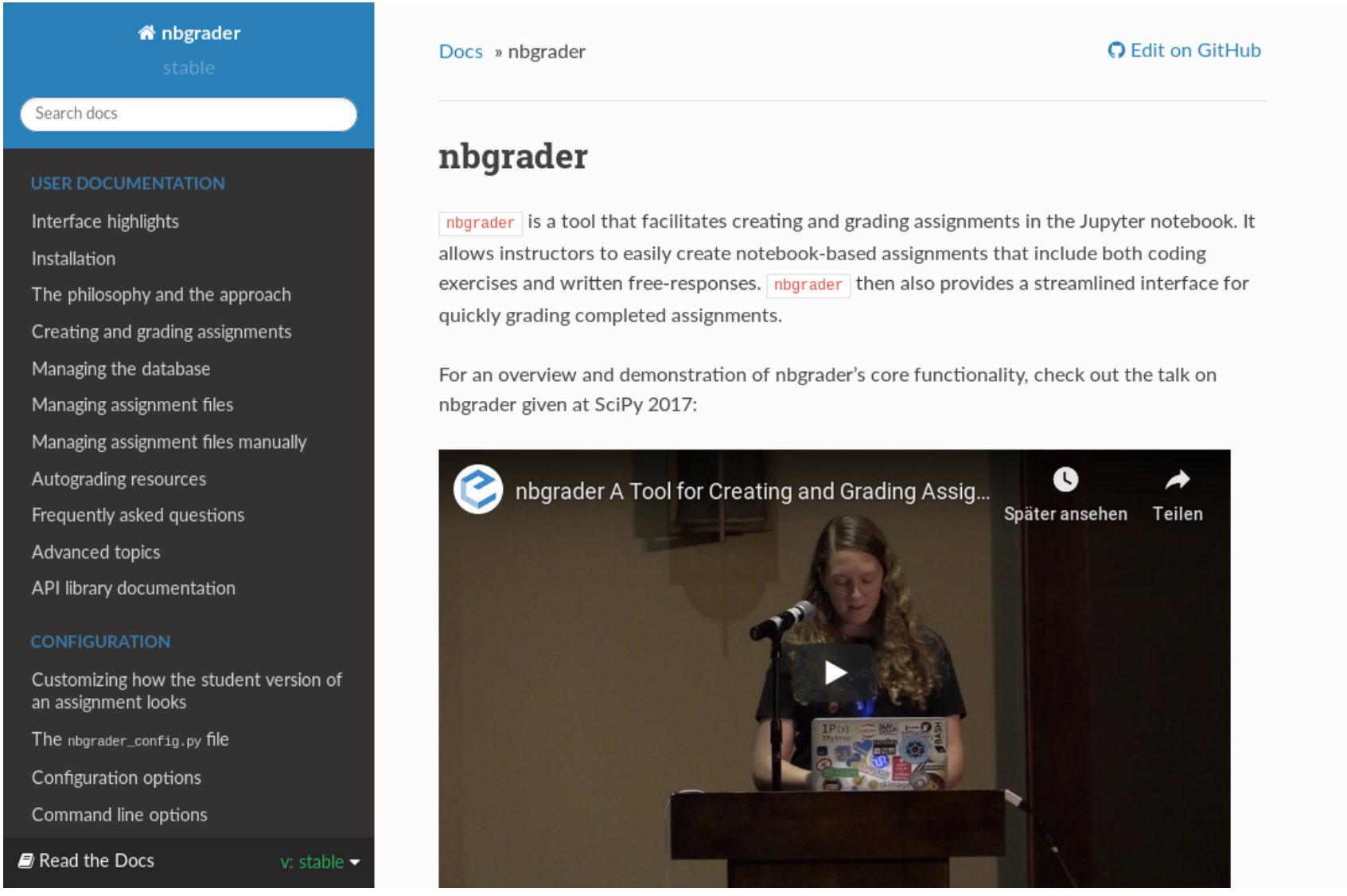
Pull requests for nbgrader

contribute to the code or the documentation



nbgrader documentation

nbgrader.readthedocs.io



Jupyter notebook and Jupyterhub – pros and cons

Jupyter notebook

- notebook allows to guide students through a problem set
- problems related to out-of-order execution
- students might think that programming in Python necessarily implies working with a Jupyter notebook, they should know about IDEs (spyder, ...) and editors (vim, ...)

Jupyterhub

- easily accessible interface to problem sets
- no need to install Python on local computer
- consistent working environment for all students
- *but* may be beginners should gather experience with Python on their own computer

Functions

In [ ]:
```
def diagonalsum(sidelength):
    """Compute sum of diagonal elements on an integer spiral

       sidelength: side length of the grid, needs to be odd
    """
    # YOUR CODE HERE
    raise NotImplementedError()
```

- need to introduce functions very early in the course
  but special aspects (no arguments, no return value, default arguments, keyword arguments, …) not needed
- students get used to logically structured code early on
  but they do not do it themselves
- include docstrings to make task well defined
  students get used to the idea that a function contains a docstring
  but they are not writing the docstring by themselves

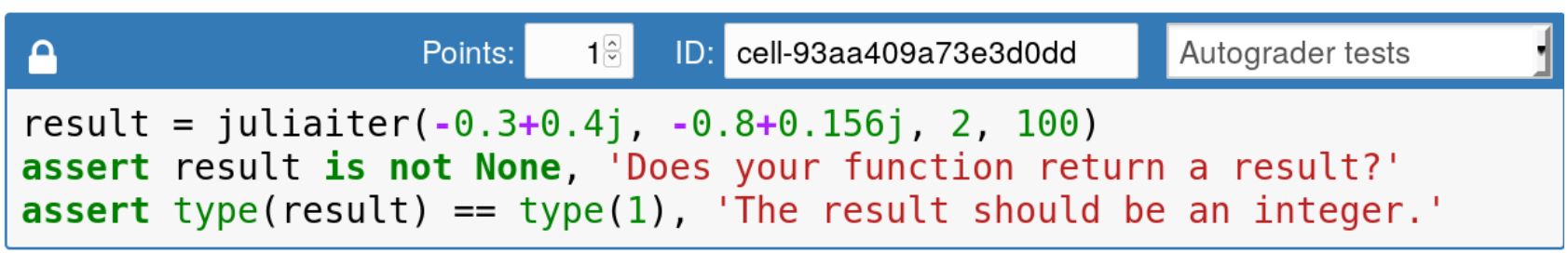
Grading with tests

```
In [ ]: assert diagonalsum(7) == 261, "The example given above does not work out correctly"
        for n in (11, 101, 1001):
            expected = (4*n**3+3*n**2+8*n-9)/6
            assert diagonalsum(n) == expected, "Side length {} yields an incorrect result".format(n)
```

- test-driven development

  but tests are not developed by the students
- tests allow to give feedback through error messages

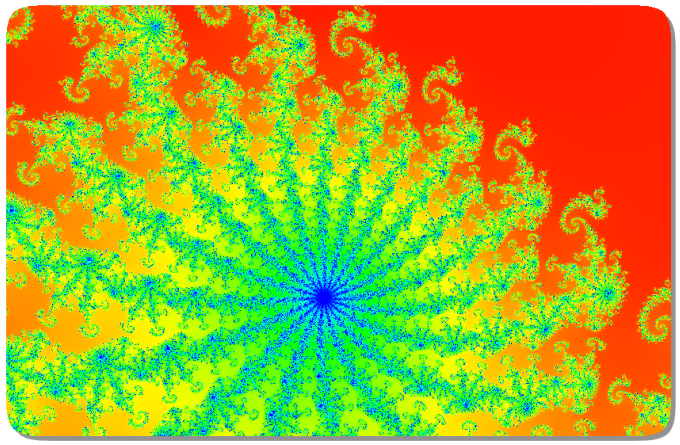
  but students tend to rely on this feedback instead of developing their own critical view on their code
- “Stupid mistakes” will be made not only at the beginning
  - “trivial” standard tests (are results returned, do they have the correct type, . . . ?)
  - + tests of specific functionality which should not disclose the solution



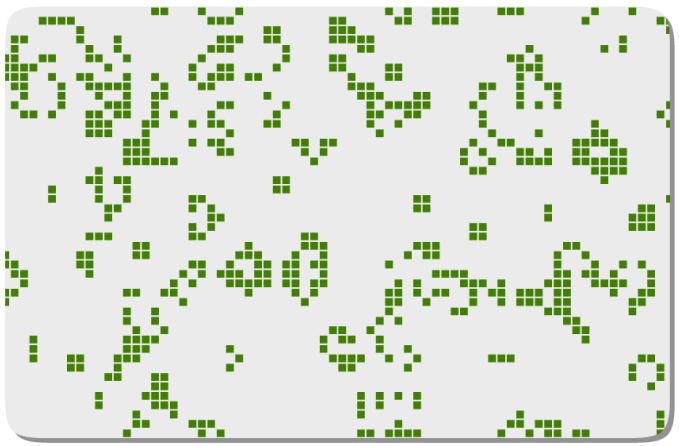
Examples of problem sets I

09	72	43	44	45	46	47	48	49	50	8
08	71	42	21	22	23	24	25	26	51	8
07	70	41	20	7	8	9	10	27	52	8
06	69	40	19	6	1	2	11	28	53	8
05	68	39	18	5	4	3	12	29	54	8
04	67	38	17	16	15	14	13	30	55	8
03	66	37	36	35	34	33	32	31	56	8

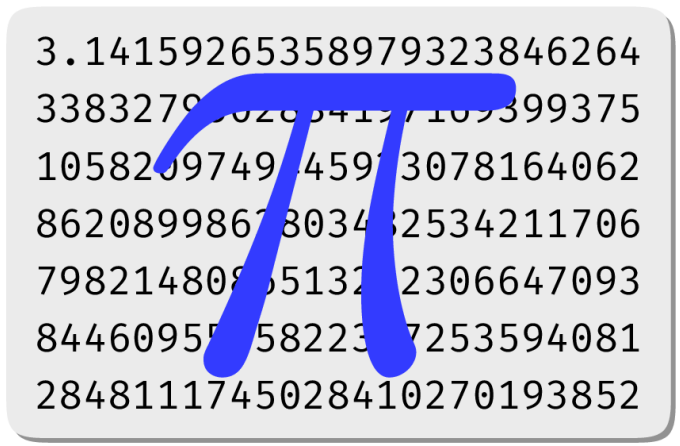
a problem from
Project Euler (`projecteuler.net`)



Julia set



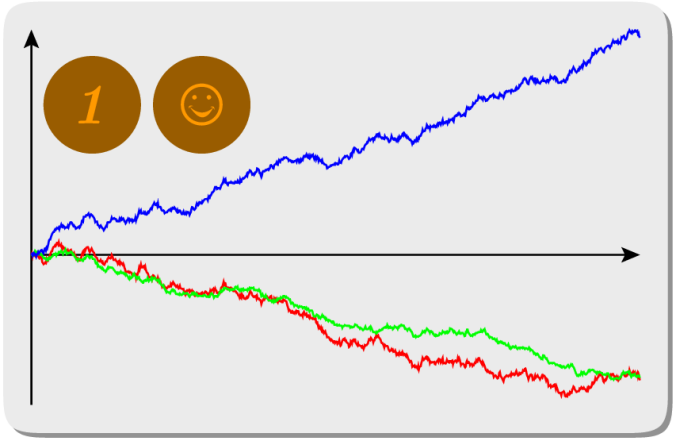
Conway's game of life



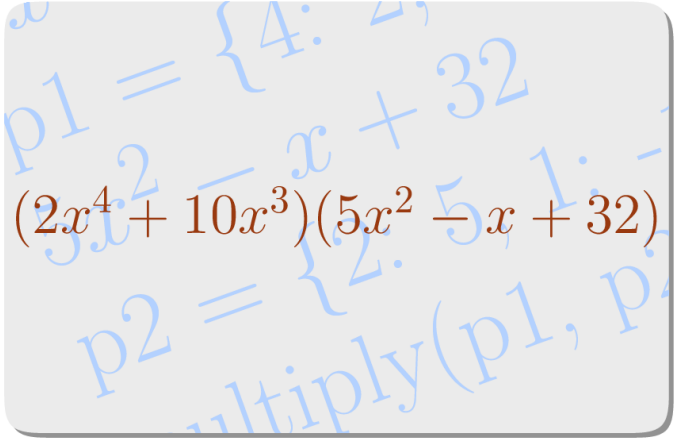
π to a few thousand digits

`https://github.com/marcinofulus/jupyter4edu/tree/master/augsburg/exercises`

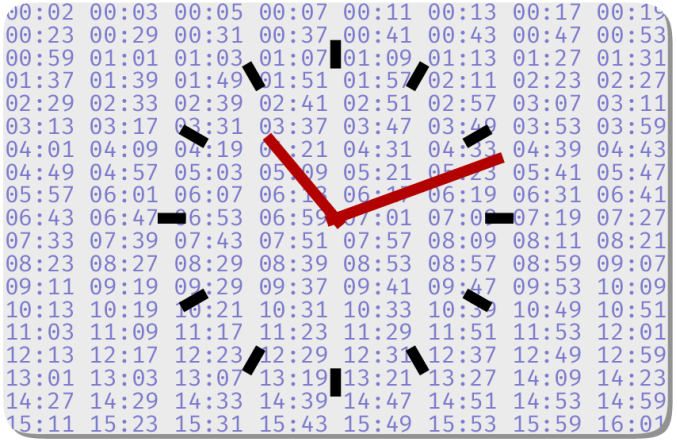
Examples of problem sets II



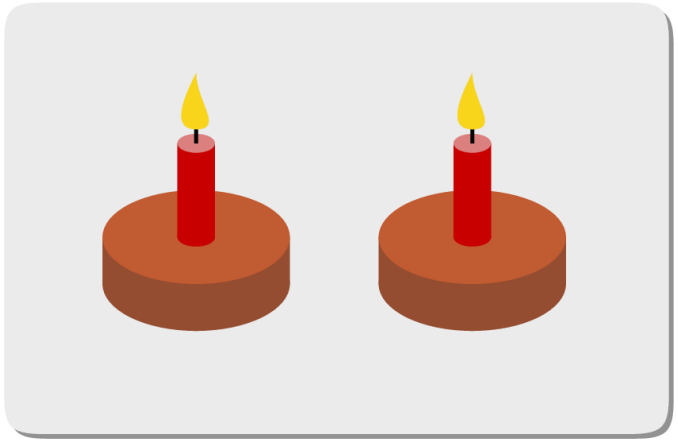
Parrondo paradoxon



symbolic manipulation of polynomials



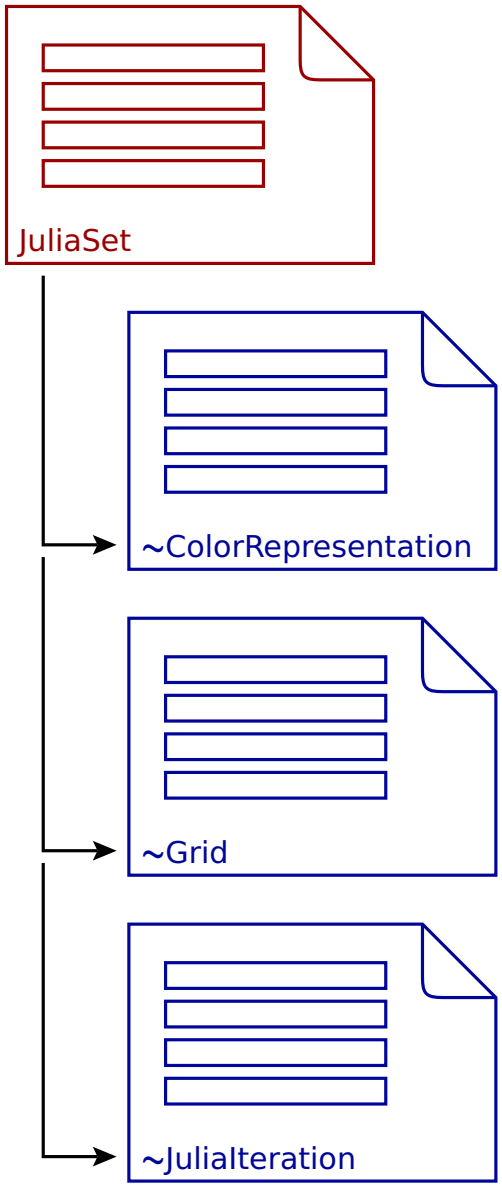
How many primes are times?



birthday problem

https://github.com/marcinofulus/jupyter4edu/tree/master/augsburg/exercises

Branching paths



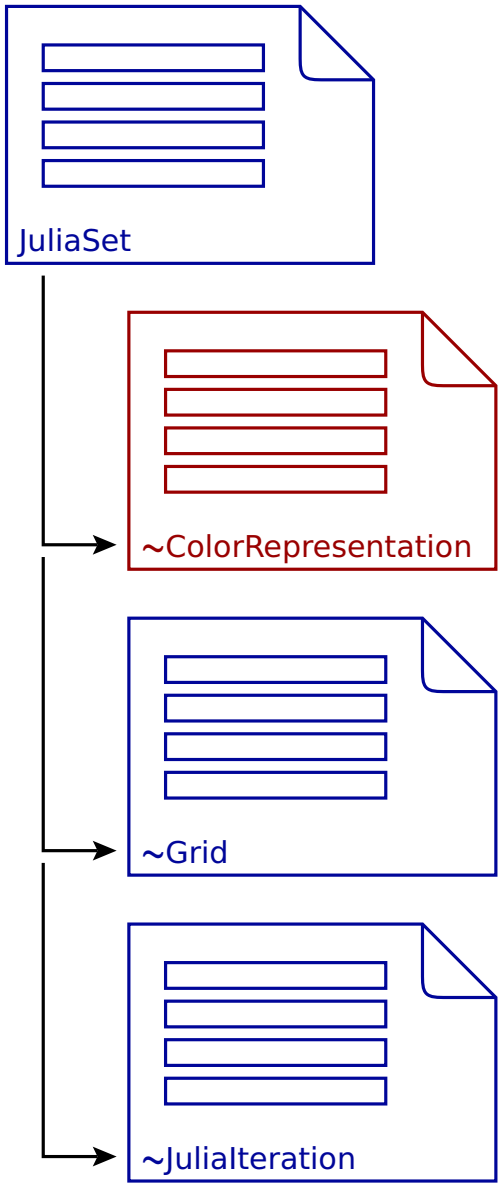
should not set the gridsize too large. It is a good idea to start e.g. with a 100×100 grid. Once your code is working, you can increase the number of grid points. For practical purposes, it makes sense to define a threshold for the absolute value of z beyond which you assume that the series for a given starting value z_0 diverges. A good value could be 2. You should also limit the number of iterations. Here, a good value could be 600. Feel free to play around with these values once your code works.

If you want to tackle the problem without any further help, you can jump over the following three points which are intended to give you some help by splitting the complete problem into smaller parts.

1. Representation of a number by a color
2. Equally spaced numbers on a grid
3. Iteration prescription

In [ ]:
```
%matplotlib inline
import matplotlib.pyplot as plt
import numpy as np

def plot(data, ndim, cmap):
    """Create a 2d graphics from a list of data points

       data: list of ndim² data between 0 and 1
       ndim: side length of grid
       cmap: matplotlib color map mapping interval from 0 to 1 to color

    """
```

Branching paths




```
def colorbar(cmapname):
    gradient = np.linspace(0, 1, 256)
    gradient = np.vstack((gradient, gradient))
    fig = plt.imshow(gradient, aspect=0.05, extent=(0, 1, 0, 1), cmap=plt
    fig.axes.get_yaxis().set_visible(False)

def display_color(x, cmapname):
    rgbcolor = cm.get_cmap(name=cmapname)(float(x), bytes=True, alpha=Fal
    print(rgbcolor)
    return SVG('''<svg height="100" width="100">
                    <rect x="1" y="1" width="50" height="50" fill="rgb(
                </svg>'''.format(*rgbcolor))
```

We start with one of the colormaps provided by the `matplotlib` library called `hot`:

In [3]:
```
colorbar('hot')
```

In the following cell, you can change the argument of the function `display_color` between 0 and 1 and explore how the color changes.

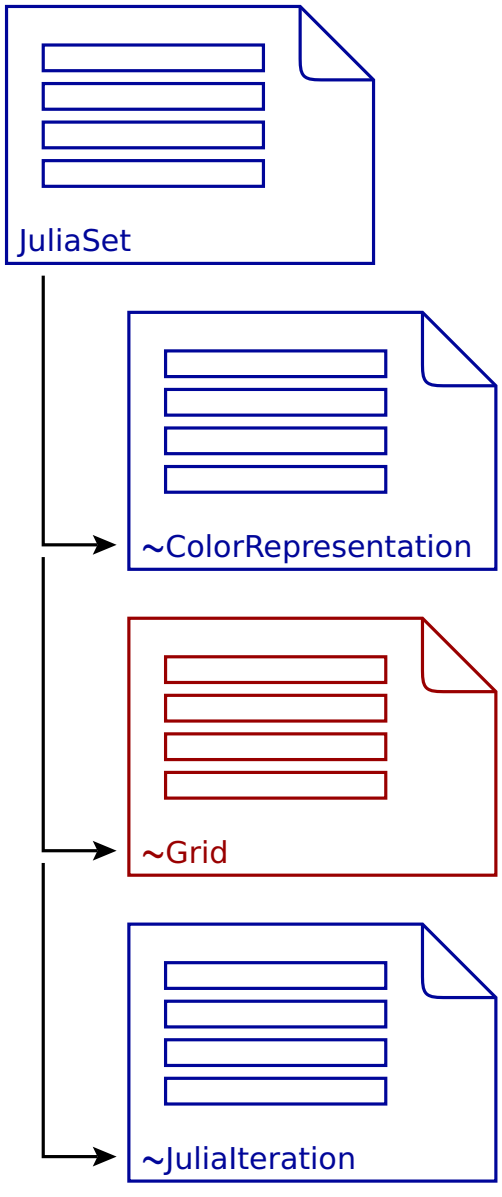
In [4]:
```
display_color(0.9, 'hot')
```

```
(255, 255, 156)
```

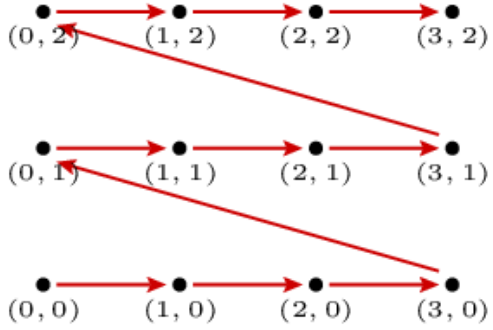
Out[4]:

The `matplotlib` library provides many more colormaps, like e.g. `viridis`. Take a look at Colormaps in Matplotlib for more information. Try out a couple of other colormaps.

Branching paths



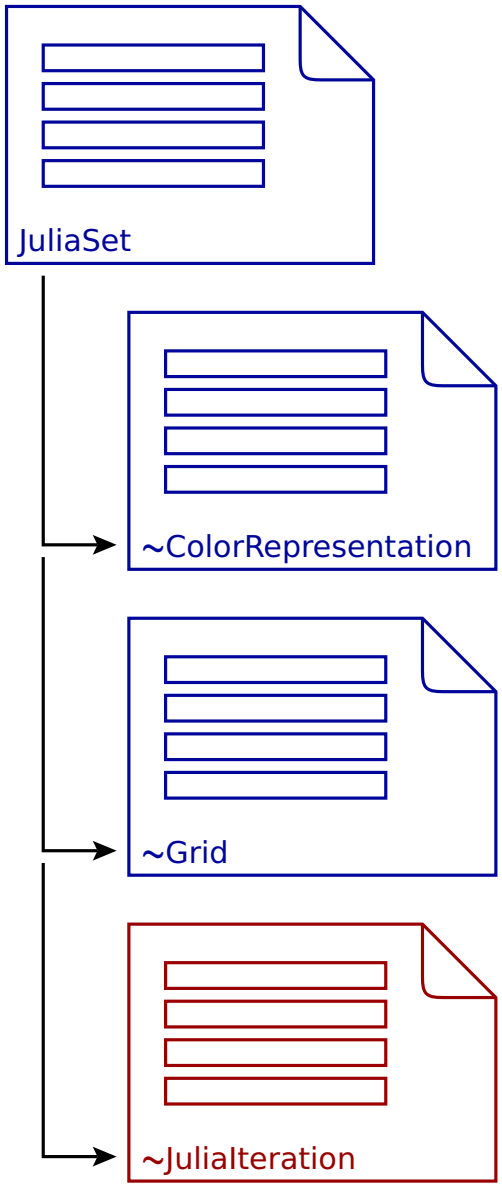
If the code for generating a one-dimensional grid is working, you are ready to extend it to two-dimensional grids. Walk the grid horizontally before making a vertical step like indicated in the following figure.



The output in this case should be the list `[(0, 0), (1, 0), (2, 0), (3, 0), (0, 1), (1, 1), (2, 1), (3, 1), (0, 2), (1, 2), (2, 2), (3, 2)]`.

In [ ]:
```
def grid2d(xmin, xmax, nxpts, ymin, ymax, nypts):
    """Generate a list of coordinate tuples (x, y) on a two-dimensional gric
       The points are equally spaced in each of the two directions between
       (and including) the respective bounds. The grid is first walked along
       the horizontal (x) direction, then along the vertical (y) direction.

       xmin: lower bound in horizontal direction
       xmax: upper bound in horizontal direction
       nxpts: number of points in horizontal direction
       ymin: lower bound in vertical direction
       ymax: upper bound in vertical direction
       nypts: number of points in vertical direction
    """
```

Branching paths



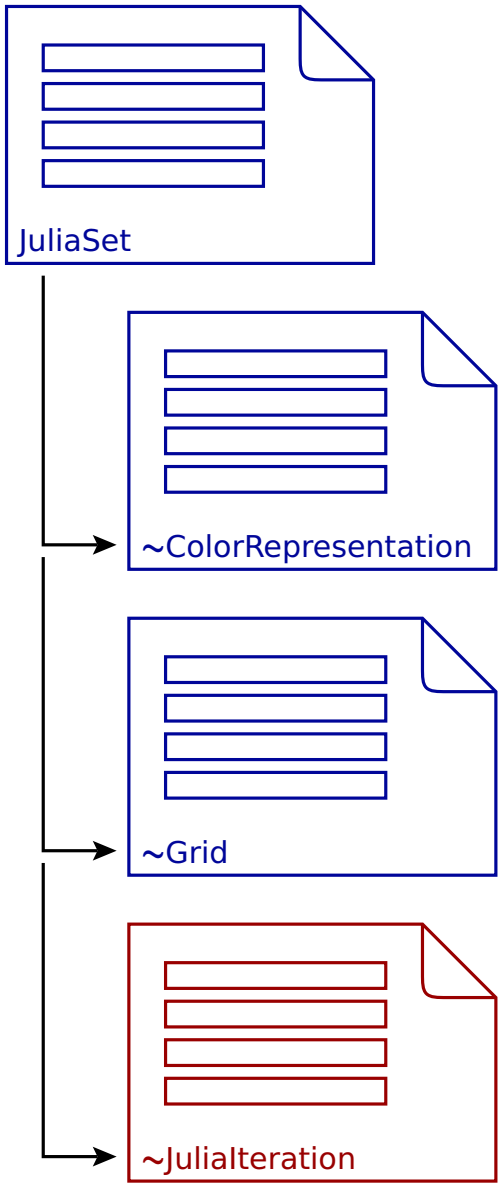
In [ ]:
```
def juliaiter(z0, c, threshold, maxiter):
    """Determine number of iterations needed to cross the threshold

       z0:        initial value for z
       c:         complex number in iteration prescription
       threshold: threshold value to be crossed by |z|
       maxiter:   maximum of iterations
    """
    # YOUR CODE HERE
    raise NotImplementedError()
```

Test your solution by executing the following two cells. Everything is fine if no error message is displayed.

In [ ]:
```
result = juliaiter(-0.3+0.4j, -0.8+0.156j, 2, 100)
assert result is not None, 'Does your function return a result?'
assert type(result) == type(1), 'The result should be an integer.'
```

In [ ]:
```
import math
maxiter = 100
threshold = 2
assert juliaiter(1, 0, threshold, maxiter) == maxiter, 'There is a problem e
z0 = 1.0000001
expected = int(math.log(math.log(threshold)/math.log(z0), 2))+1
assert juliaiter(z0, 0, threshold, maxiter) == expected, 'There is a problem
z0 = -0.3+0.4j
c = -0.8+0.156j
threshold = abs(z0**8+4*z0**6*c+2*z0**4*(3*c**2+c)+4*z0**2*(c**3+c**2)+c**4+
maxiter = 4
assert juliaiter(z0, c, threshold+1e-6, maxiter) == maxiter, 'Wrong number o
assert juliaiter(z0, c, threshold-1e-6, maxiter) == maxiter-1, 'Wrong number
```

Branching paths



- individual path through problem possible
- *but* notebooks are opened in new tabs, it is easy to lose track