Testing, Timing, Documentation, Extras

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Content

- Python modules
- Testing: `pytest` and `unittest`
- Integration testing
- Decorators
- Timing
- Documentation
- Generators

Writing Python Modules

- Every `.py` file can be used as a module Example:

```
import bisection
```

where `bisection.py` is a file in a known folder. This is ok when we only have a few code snippets.

bisection.py

```
import numpy

# a simple bisection algorithm
def bisect(f, a, b, tol = 1e-8, maxit=100):
  ...

# important when used as module and sometimes directly
# code that should only be executed when run directly
if __name__ == '__main__':
    ...
```

- A subdirectory can be a Python module, needs a `__init__.py` file (can be empty).

__init__.py

```
from .bisection import bisect
```

Writing Python Modules

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Software testing

Why do we need software testing?

https://www.openhub.net/p/dune-project
https://www.openhub.net/p/opm

- Unit testing (i.e. testing a small piece of code) (today)
- Integration testing (e.g. test several units together)
- Continuous Integration (today)
- System testing (test the whole product, α, β,...)
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A brief overview on some techniques

- gitlab CI, what could you do
  - https://gitlab.dune-project.org/core/dune-common
  - https://gitlab.dune-project.org/dune-fem/dune-fem
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unittest

Run all unit tests in a specific folder:

```
python -m unittest discover
```

A typical result would look like this:

```
----------------------------------------------------------------------
Ran 2 tests in 0.001s

OK (expected failures=1)
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----------------------------------------------------------------------
Ran 2 tests in 0.001s

OK (expected failures=1)
```

unittest example

A test case with unittest needs to implement a test case class:

test_bisection_unittest.py

```
import unittest
from bisection import bisect

# derive from unittest.TestCase
class TestIdentity(unittest.TestCase):

    # all methods that start with test are executed
    def testRoot(self):
        interval, root = bisect(lambda x: x, -1.2, 1.,tol=1.e-8)
        expected = 0.
        self.assertAlmostEqual(root , expected)

    # this method will be ignored
    def somethingelse(self):
        self.testRoot()

    # test expected failures
    @unittest.expectedFailure
    def testInterval(self):
        interval, root = bisect(lambda x: x, -1.2, -0.5,tol=1.e-8)
        expected = 0.
        self.assertAlmostEqual(root , expected)

if __name__== '__main__':
    unittest.main ()
```

pytest

Like the unittest discover function **pytest** will find all files in a given folder that start with **test**

```
pytest
```

The output will look like this:

```
========================== test session starts ==================
platform linux -- Python 3.11.5, pytest-7.4.0, pluggy-1.2.0
rootdir: ..../pythontesting
plugins: anyio-3.7.1
collected 7 items

test_bisection.py ..FF                                      [ 57%]
test_bisection_unittest.py xx.                              [100%]

============================ FAILURES ===========================
...
======================== short test summary info ================
FAILED test_bisection.py::test[inpt1-0] - assert inf < 1e-08
FAILED test_bisection.py::test[inpt2-inf] - assert inf < 1e-08
======================= 2 failed, 3 passed, 2 xfailed in 0.50s ====
```

Note: **pytest** also runs all tests defined via **unittest!**

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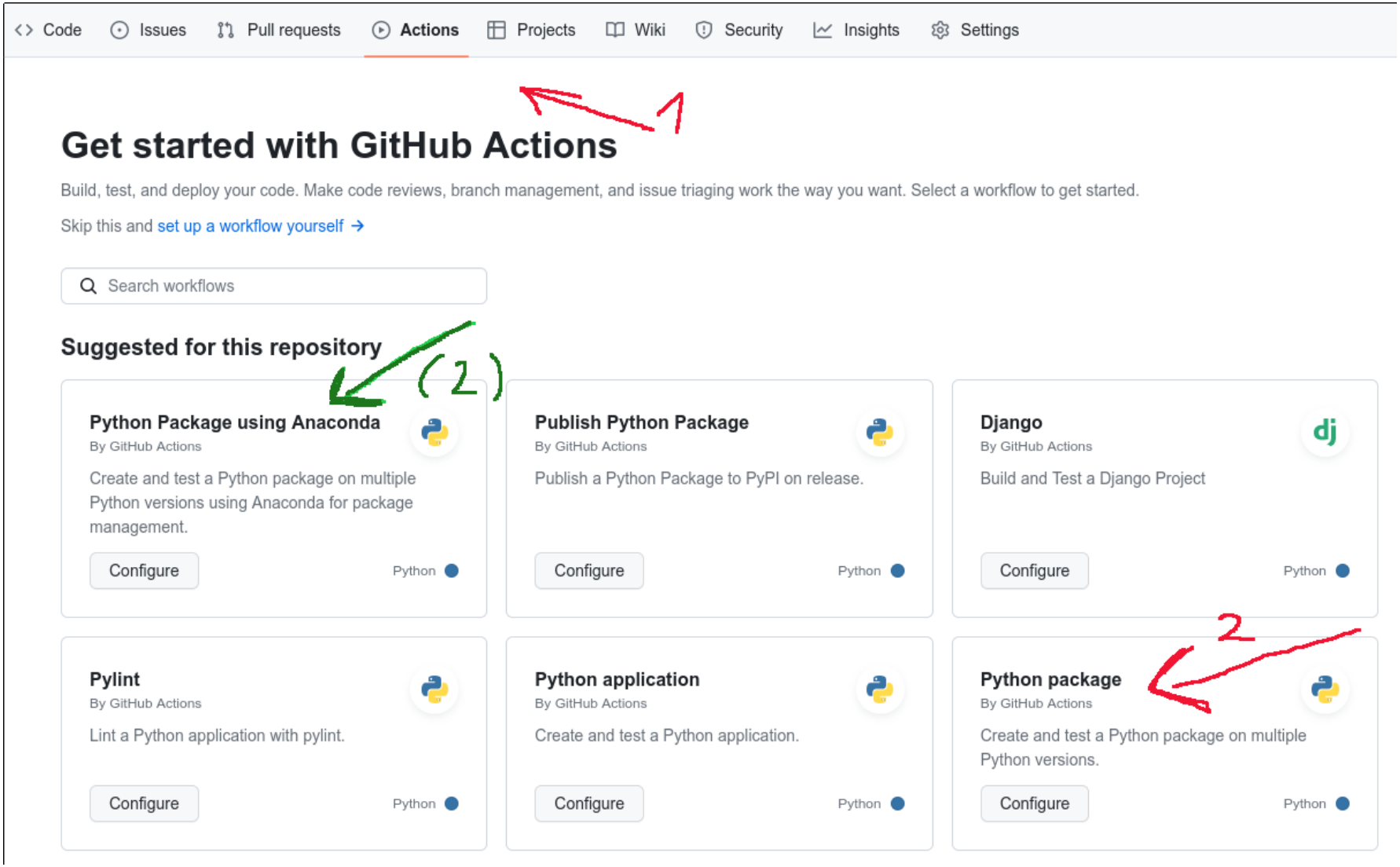
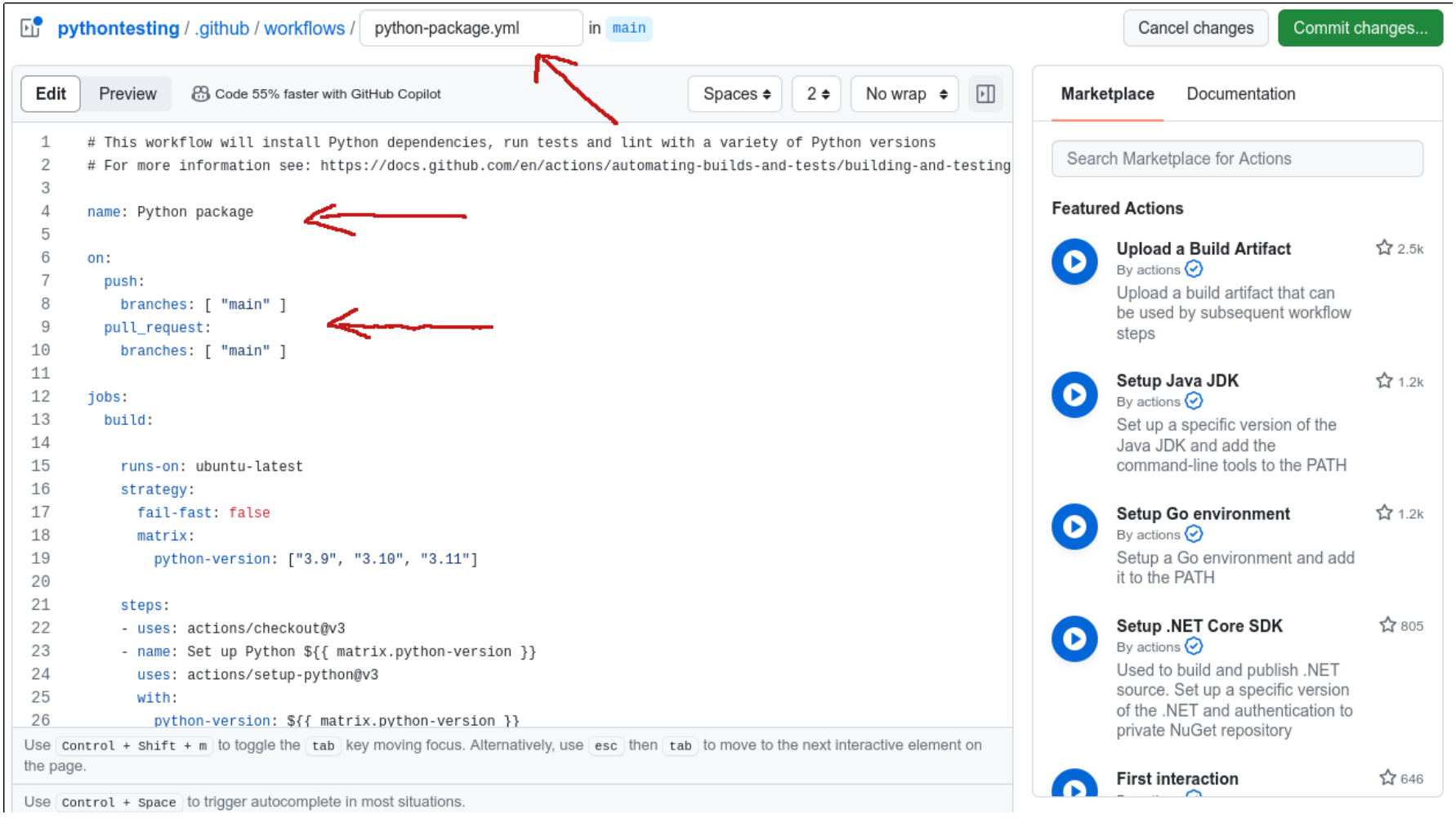
Why pytest?

It's simple to use with github actions if the repo is public.



Github actions



pytest example

test_bisection.py

```
# import the pytest module use with the below tests
import pytest

# list Python modules in requirements.txt
import numpy as np
# own modules cannot be in requirements.txt
from bisection import bisect
# a simple test
def test_root():
    tol = 1.e-8
    interval, root = bisect(lambda x: x, -1.2, 1.,tol=tol)
    assert abs(root) <= tol

def root_param(a, b, maxit):
    tol = 1.e-8
    interval, root = bisect(lambda x: x, a, b,tol=tol,
        maxit=maxit)
    print(root)
    return root

# use parameterize decorators to test different parameter sets
@pytest.mark.parametrize("inpt, exptd",
     [((-1.2, 1, 100), 0), ((-1.2, 1, 10),  0), ((-2, -1, 100),
         np.inf)])
def test(inpt, exptd):
    root = root_param(*inpt)
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```

Q: What does the @ symbol indicate?

pytest example

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Development strategy

In parallel to coding write tests (or maybe even before). Assign one group member to be responsible for testing.

- check the code
- document its use
- and document what has been tested

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Function decorators 1/2

A function decorator is a short hand for modifying an existing function without changing its name.
Example:

```
def how_sparse(A):
  return len(A.reshape(-1).nonzero()[0])
```

Make sure it works also for lists:

```
def cast2array(f):
    def new_function(obj):
        fA = f(array(obj))
        return fA
    return new_function

how_sparse=cast2array(how_sparse)
```

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Function decorators 2/2

The decorator way:

```
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    def new_function(obj):
        fA = f(array(obj))
        return fA
    return new_function

@cast2array
def how_sparse(A):
    return len(A.reshape(-1).nonzero()[0])
```

Timing – the time module

```
from numpy import array, arange
from numpy import sum as npsum

import time

a = array(arange(0,1000))

# default simple way of timing
start = time.time()

# commonly made mistake, use np.sum instead
# default sum implementation does not know about arrays
s = sum(a)

print(f"Standard sum took {time.time() - start:.6e} sec.")

start = time.time()

s = npsum(a)

print(f"Standard sum took {time.time() - start:6e} sec.")
```

Timing – timeit

```
python -m timeit 'sum(range(100))'
```

```
python -m timeit 'sum(range(100))'
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```
python -m timeit -n 10 -r 10 'sum(range(100))'
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Timing – timeit and ipython

In the ipython shell we can simply write

```
%timeit sum(range(100))
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We can use the same parameters

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Note: If no numbers are supplied the suitable values are chosen.

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Timing – decorators

Task: Write a decorator for timing specific functions!

Documentation – README.md

An easy way for project documentation is the `README.md` file. Written in markdown it can display code, math, and normal text.

README.md

```
# pythontesting

This is a simple project to demonstrate testing with Python and
     github.

## Testing frameworks

It is recommended to use [pytest][0]. pytest can also
     automatically include tests
written with [unittest][2].

## Documentation

Python documentation is usually created with [sphinx][1].

[0]: https://pytest.org
[1]: https://www.sphinx-doc.org
[2]: https://docs.python.org/3/library/unittest.html
```

Documentation – sphinx

Install sphinx, e.g. using pip

```
pip install sphinx
```

Using conda this may look different.

Then run the script

```
sphinx-quickstart
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This will create a starting point for your documentation.

You should then make changes and

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make html
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Generators

Definition: A generator generates objects (to be passed to `for` loop). Similar to a list except that the objects need not to exist before entering the loop.
A generator-like object is `range`:

```
for i in range(100000000):
  if i > 10:
    break
```

See also

```
rr = range ( 20 )
print ( rr )
```

`rr`is not a `list`, but a tool which can be used to generate a list:

```
rrl=list(rr)
```

Generators – Python definition

Creation of generators is possible with the keyword `yield`:

```
def odd_numbers(n):
  "generator for odd numbers less than n"
  for k in range(n):
    if k % 2 == 1:
      yield k
```

Then use it like this:

```
g = odd_numbers(10)
for k in g:
  ... # do something with k
```

Infinite generators

Note: Just as in mathematics, generators may be infinite!

```
def odd_numbers():
  "generator for all odd numbers"
  k = 1
  while True:
    if k % 2 == 1:
      yield k
    k += 1
```

```
on = odd_numbers ()
print(on.__next__())
```

Note: Finite generator objects are exhausted after their use!

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Note: Finite generator objects are exhausted after their use!

Generator tools

`enumerate` is used to *enumerate* a generator:

```
g = odd_numbers(10)
for i, x in enumerate(g):
  print(i,x, end=';')

# result: 0 1 ; 1 3 ; 2 5 ; 3 7 ; 4 9 ;
```

`reversed` creates a generator from a list by going backwards:

```
A = [0, 1, 2]
for elt in reversed(A):
  print(elt ,end=' ')

# result: 2 1 0
```

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Iterator tools

Create a generator from another generator.

```
import itertools as it
on = odd_numbers ()
some_on=it.takewhile(lambda n: n < 50 , on)
```

some_on is another generator generating all odd numbers smaller than 50.

```
import itertools as it
on = odd_numbers ()
some_on = it.islice(on , 3, 20 , 3) # start, stop index and steps
```

list(some_on) returns [7, 13, 19, 25, 31, 37]

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List filling patterns

Common programming pattern:

```
L = []
for k in range(n):
  L. append ( some_function (k) )
```

use instead:

```
L = [some_function(k) for k in range(n)]
```

This is called list comprehension!

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Complex List Filling Pattern

```
L = [0, 1]
for k in range(n):
  # call various functions here
  # that compute a "result"
  L.append( result )
```

Use a generato instead!

```
def result_generator(n):
  for k in range(n):
    # call various functions here
    # that compute a "result"
    yield result
```

...and if you really need a list:

```
L = list(result_generator(n)) # no append needed!
```

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Generator comprehension

Just as we had list comprehension, there is also `generator` comprehension:

```
g = (n for n in range(1000) if not n % 100)
# a generator that generates 0, 100 , 200 , ...
```

The odd numbers again:

```
on = (n for n in range(1000) if n % 2)
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Zipping Generators

How to make one generator out of two?

```
from itertools import izip
xg = x_generator()
yg = y_generator()
for x,y in izip(xg ,yg):
  print(x,y)
```

The zipped generator stops as soon as one of the generators is exhausted.

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Further Reading


Wikipedia: Software testing.
https://en.wikipedia.org/wiki/Software_testing.
Accessed 2023.


Python pytest.
https://pytest.org.
Accessed 2023.


Python unittest.
https://docs.python.org/3/library/unittest.html.
Accessed 2023.


Python timeit.
https://docs.python.org/3/library/timeit.html.
Accessed 2023.


Sphinx documentation.
https://www.sphinx-doc.org/.
Accessed 2023.