

Why you should test your software

and how you can do it

FMRIB Analysis Group
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Overview

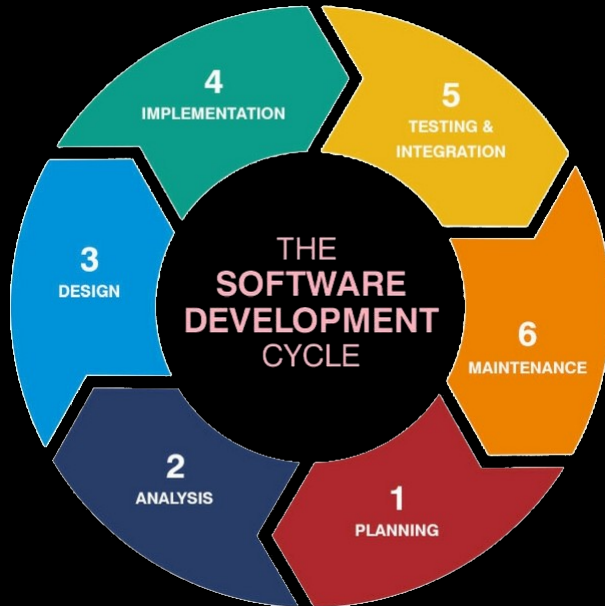
- Why testing is necessary
- Reducing the number of errors that you make when writing software
- Testing a Python application
- Automated testing using Github+CI

Science in 2020

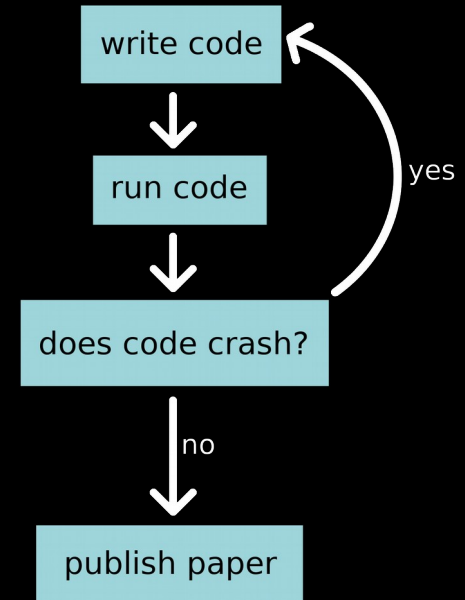
Research results == software outputs?

Software development practices

In industry



In research



Compiled vs interpreted languages

Compiled/strongly-typed
(e.g. C/C++/Java)

Interpreted/dynamically typed
(e.g. MATLAB/Python)

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- Write code 1.
- Run code 2.

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Run code 2.

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The compiler analyses every single line of code, and catches lots of errors for you.

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The interpreter only analyses the code that gets run, so errors may still be present in infrequently used branches/sections of code.

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1. We can depend on the compiler to catch many errors for us.
2. Compile code
3. (but it won't catch everything!)

The compiler analyses every single line of code, and catches lots of errors for you.

Write code 1.

Run code 2.

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3. (but it won't catch everything!)

The compiler analyses every single line of code, and catches lots of errors for you.

1. We have no compiler, so need to be much more careful during development, and rely on other tools and techniques to catch errors.
2. Run code

The interpreter only analyses the code that gets run, so errors may still be present in infrequently used branches/sections of code.

Compiled vs interpreted languages

It doesn't matter how smart you are – you will make mistakes

Compiled/strongly typed
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Interpreted/dynamically typed
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- 1. Use a good editor/IDE^{*}**
- 2. Organise your code sensibly**
- 3. Write code to test your code**
- 4. Use CI[†] to run your tests for you**

We can depend on the compiler to catch many errors for us.

We have no compiler, so we need to be much more careful during development, and rely on other tools and techniques to catch errors.

^{*}IDE: Integrated Development Environment

[†]CI: Continuous Integration

1. Use a good editor/IDE

- If you're using MATLAB, feel free to zone out for the next couple of minutes
- If you're using Notepad, TextEdit, Gedit, vanilla Emacs, etc, then you're doing it wrong
- You should be using an editor which provides (at least):
 - Syntax highlighting
 - Intelligent error detection
- Optional (but recommended) extras which will make life easier
 - Automatic code completion
 - Refactoring (e.g. rename a function in every place it is called)
 - (important for larger projects) Code navigation/file management

1. Use a good editor/IDE

- If you're using MATLAB, feel free to zone `import requests`

- If you

- You s

- Syn

- Inte

- Option

- Auto

- (imp

- You s

- environment

```
10 def get_episodes(episode_id: int):  
11     episode_id.
```

```
12     bit_length(self) int  
13     conjugate(self, args, kwargs) int  
14     denominator int  
15     from_bytes(cls, bytes, byteorder, args, ... int  
16     imag int  
17     numerator int  
18     real int  
19     to_bytes(self, length, byteorder, args, ... int  
20     __abs__(self, args, kwargs) int  
21     __add__(self, y) int  
22     __and__(self, y) int  
23     bool(self, args, kwargs) int
```

Press ^ to choose the selected (or first) suggestion and insert a dot afterwards >>

File Edit View Plugins Window Help

dev_mode = True

```
"http://talkpython.fm/api")
```

Response

(or first) suggestion and insert a dot afterwards >>

```
height = self.get_size()
```

```
glEnable(GL_DEPTH_TEST)
```

```
glViewport(0, 0, width, height)
```

```
glMatrixMode(GL_PROJECTION)
```

```
glLoadIdentity()
```

```
gluOrtho2D(0, width, 0, height, -1, 1)
```

```
glMatrixMode(GL_MODELVIEW)
```

```
glLoadIdentity()
```

1. Use a good editor/IDE

- PyCharm (everything included)
- Spyder (MATLAB-like)
- VS Code (needs some setup)
- Atom (needs some setup)
- Sublime Text (non-free, popular amongst hipsters)
- Emacs (only for the masochistic)

2. Organise your code sensibly

```
#!/usr/bin/env python
import numpy as np

# load data and model
data = np.loadtxt('input.txt')
model = np.loadtxt('design.txt')

# perform OLS regression
fit = np.linalg.inv(model.T @ model) @ model.T @ data
error = data - (model @ fit)

# save parameter estimates and residuals
np.savetxt('pes.txt', fit)
np.savetxt('residuals.txt', error)
```


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#!/usr/bin/env python
import numpy as np
import sys

def ols(data, model):
    """Perform ordinary-least-squares regression. """
    fit = np.linalg.inv(model.T @ model) @ model.T @ data
    error = data - (model @ fit)
    return fit, error

def main(args=None):
    """Fit a linear model to some data. """

    if args is None:
        args = sys.argv[1:]

    datafile = args[0]
    designfile = args[1]
    fitfile = args[2]
    errfile = args[3]

    # load data and model
    data = np.loadtxt(datafile)
    model = np.loadtxt(designfile)

    # perform OLS regression
    fit, error = ols(data, model)

    # save parameter estimates and residuals
    np.savetxt(fitfile, fit)
    np.savetxt(errfile, error)

if __name__ == '__main__':
    sys.exit(main())
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fit = np.linalg.pinv(model.T @ model) @ model.T @ data
error = data - (model @ fit)

# save parameter estimates and residuals
np.savetxt('pes.txt', fit)
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Harder to test

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if __name__ == '__main__':
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```

Easier to test

2. Organise your code sensibly

General advice

Wherever possible, strive to write functions which are:

- Small
- Simple
- Without side-effects

They will be easier to understand, easier to re-use, and easier to test.

2. Organise your code sensibly

General advice

Try to separate procedural operations (e.g. loading/saving data) from purely functional/numeric operations.

Doing so will make the critical parts of your code easier to test.

2. Organise your code sensibly

General advice

Use functions, modules, and packages to arrange your project in a sensible manner.

2. Organise your code sensibly

General advice

There is no correct answer to the question of how you should organise your code.

If it is easy to understand and navigate (and it does its job), then it is a good design.

2. Organise your code sensibly

General advice

Don't be afraid to refactor and rearrange your code as it evolves.

If you already have a test suite*, then you can use it to ensure that you are not breaking things when you rearrange them.

**Integration tests*, introduced later, are handy here.

3. Write code to test your code

```
test_model = np.array([[0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 1],  
                       [0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1]].T  
test_data  = (test_model[:, 0] * 5) + (test_model[:, 1] * 20)
```

```
def ols(data, model):  
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def main(args=None):  
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        args = sys.argv[1:]  
  
    datafile  = args[0]  
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    fitfile   = args[2]  
    errfile   = args[3]  
  
    # load data and model  
    data = np.loadtxt(datafile)  
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    # perform OLS regression  
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test_data  = (test_model[:, 0] * 5) + (test_model[:, 1] * 20)
```

```
def test_ols():  
    fit, err = ols(test_data, test_model)  
    assert np.isclose(fit, [5, 20]).all()  
    assert np.isclose(err, 0).all()
```

```
def ols(data, model):  
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    # perform OLS regression  
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```

```
def test_main():  
    np.savetxt('data.txt', test_data)  
    np.savetxt('model.txt', test_model)  
  
    main('data.txt', 'model.txt', 'pes.txt', 'residuals.txt')  
  
    fit = np.loadtxt('pes.txt')  
    err = np.loadtxt('residuals.txt')  
  
    assert np.isclose(fit, [5, 20]).all()  
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3. Write code to test your code

and run that code

- `pytest` <https://docs.pytest.org/en/latest/>
searches through your code for functions
beginning with `test_` and runs them for you.

```
(brc) → my_analysis pytest
===== test session starts =====
collected 2 items
```

```
tests/test_main.py::test_ols PASSED [ 50%]
tests/test_main.py::test_main PASSED [100%]
```

- `coverage` <https://github.com/nedbat/coveragepy>
tells you which lines of code were executed
during testing

```
----- coverage: platform linux, python 3.6.9-final-0 -----
```

Name	Stmts	Miss	Cover
analysis/__init__.py	0	0	100%
analysis/main.py	18	5	72%
TOTAL	18	5	72%

```
===== 2 passed in 0.13s =====
(brc) → my_analysis █
```

3. Write code to test your code

General advice

Write and run tests at the same time as you are writing the code.

Doing so will help you to better understand and trust your code.

3. Write code to test your code

General advice

Write tests for individual functions -
these are known as *unit tests*.

Write tests for the entire program -
these are known as *integration tests*.

3. Write code to test your code

General advice

Whenever you fix a bug in your code, write a test for it, so you'll know if it ever pops up again.

This is known as a *regression test*.

4. Use CI to run your tests for you

Continuous Integration (CI): Run code on somebody else's servers using magic

1. Push some changes to your remote repository (e.g. Github)
2. Github notifies the CI provider about the changes
3. The CI provider starts up a Docker container or a VM running somewhere in the cloud
4. A script, running in the container/VM, checks out your project, and runs your tests for you

4. Use CI to run your tests for you

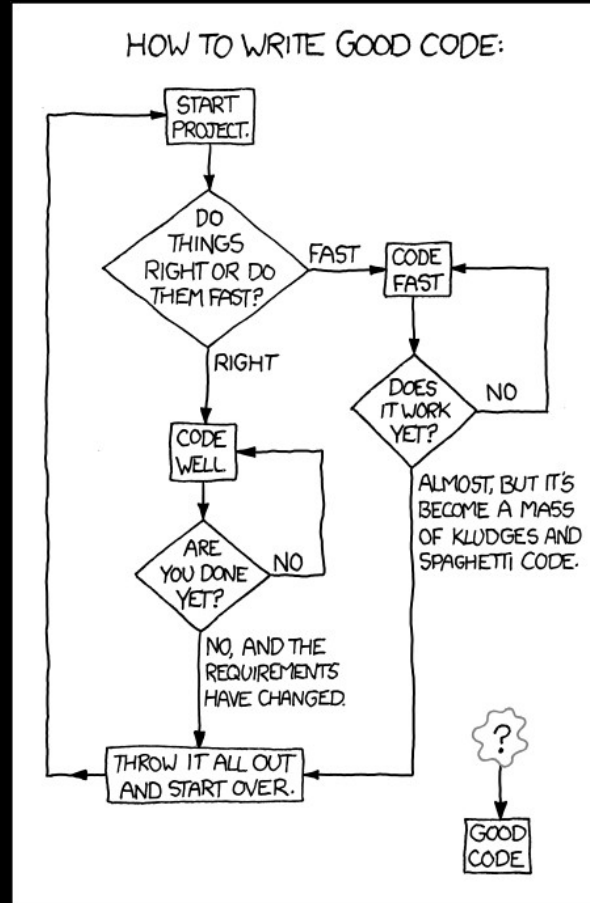
- Several CI providers work seamlessly with Github:
 - CircleCI (<https://circleci.com/>)
 - Travis (<https://travis-ci.org/>)
 - Azure (<https://azure.microsoft.com/en-us/services/devops/pipelines/>)
 - Appveyor (<https://www.appveyor.com/>)
- Free for open source projects
- If using Gitlab, you can install your own CI provider (running on your own hardware)

4. Use CI to run your tests for you

Example project:

<https://github.com/pauldmccarthy/win-brc-automated-testing>

Thanks for listening!



Bonus: mock for dependency injection

```
def load_parameters(cfgfile):  
    with open(cfgfile) as f:  
        p1 = int(f.read())  
        p2 = int(f.read())  
        p3 = int(f.read())  
    return p1, p2, p3  
  
def do_analysis(cfgfile):  
    p1, p2, p3 = load_parameters(cfgfile)  
    return p1 * p2 / p3
```

```
from unittest import mock
```

```
with mock.patch('mymodule.load_parameters', return_value=(10, 10, 10)):  
    assert mymodule.do_analysis('notafile') == 10
```