2.8 Testing Functions I: `doctest` and `pytest`

The last step of the Function Design Recipe is to test your code—but how? In this section, we'll discuss the different strategies for testing code that you'll use during the term, and beyond. As you write more and more complex programs in this course, it will be vital to maintain good habits to support you in your programming. One of these habits is developing good tests that will ensure your code is correct, and—often overlooked—using good *tools* to make those tests as easy to run as possible. You want to get in the habit of writing tests early in the process of programming, and running them as often as possible to detect coding errors as soon as you make them.

Doctests: basic examples in docstrings

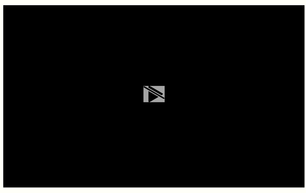
By following the Function Design Recipe, you naturally create a few tests for each function in the form of *doctest examples*, the examples you write in the function docstring. The simplest form of testing your function is import your function into the Python console, and then manually evaluate each doctest example one at a time and compare the output with the expected output in the docstring. This is a form of **manual testing**, as it requires human interaction to complete. Manual testing is often tedious and error-prone, so while it may be good for a quick check, we can certainly do better.

Our first improvement is to use the Python library `doctest`, which can automatically extract doctest examples from docstrings and convert them into runnable tests. To use `doctest`, you can add the following code to the very bottom of any Python file:[1]

[1] Don't worry about the `if __name__ == '__main__'` part for now; we will discuss this later on.

```
if __name__ == '__main__':
    import doctest     # import the doctest library
    doctest.testmod()  # run the tests
```

Then when you run the file, all of the doctest examples are automatically run, and you receive a report about which tests failed. If all tests passed, then by default nothing else is displayed, as you can see in the following demo.



The fact that nothing gets displayed when all tests pass can be a bit confusing when first using `doctest`. Luckily, we can modify how we call `doctest.testmod` to display all test results, pass or fail:

```
if __name__ == '__main__':
    import doctest                    # import the doctest library
    doctest.testmod(verbose=True)  # run the tests and display all results (pass or fail)
```

One final warning: in order to use `doctest`, your docstring examples must be correctly formatted and valid Python code. For more information about the `doctest` module, check out Appendix B.1 `doctest`.

Creating test suites with `pytest`

Though `doctest` is an extremely useful module, the examples we write in docstrings are only simple cases meant to illustrate typical uses of the function. As functions get more complex, we'll require more extensive tests to verify that they are correct. We could put all these tests into the function docstrings, but that would make the docstrings far too long.

So instead, we will use another Python library, `pytest`, to write our tests in a separate file, and so include an exhaustive set of tests without cluttering our code files. Let's illustrate this with an example. Suppose we have defined the following function in a files `trues.py`:[2]

[2] We've not included the body of this function, as we do not need to know how a function is implemented in order to write tests for it!

```
# In file trues.py

def has_more_trues(booleans: list) -> bool:
    """Return whether booleans contains more True values than False values.

    >>> has_more_trues([True, False, True])
    True
    >>> has_more_trues([True, False, False])
    False
    """
    # Function body omitted
```

Now, we'll see how to write tests for this function in a new file, which we'll call `test_trues.py`.[3] Now let us introduce some terminology. A **unit test** is a block of code that checks for the correct behaviour of a function for one specific input. A **test suite** is a collection of tests that check the behaviour of a function or (usually small) set of functions. Every test file contains a test suite.

[3] By convention, all Python modules which contain tests are named with the prefix `test_`.

In Python, we express a unit test as a function whose name starts with the prefix `test_`. The body of the function contains an `assert` statement, which is a new form of Python statement used to check whether some boolean expression is `True` or `False`. Here are two examples of unit tests we could write that are direct translations of the doctest examples from above:

```
# In file test_trues.py
import trues


def test_mixture_one_more_true() -> None:
    """Test has_more_trues on a list with a mixture of True and False,
    with one more True than False.
    """
    assert trues.has_more_trues([True, False, True])


def test_mixture_one_more_false() -> None:
    """Test has_more_trues on a list with a mixture of True and False,
    with one more False than True.
    """
    assert not trues.has_more_trues([True, False, False])
```

These unit test functions are similar to the functions we've defined previously, with a few differences:

- Each function name and docstring describes the purpose of the test (usually, what kind of input is being tested).
- The return type of the test function is `None`, which is a special type that indicates that no value at all is returned by the function.[4] In the body of the test function, there is indeed no `return` statement—instead, there's an `assert` statement.[5]

[4] Python's `None` is a bit special, and we'll see more of this later in the course.

[5] Another name for "`assert` statement" is *assertion*; we will use these terms interchangeably throughout these notes.

`assert` statements

So what exactly does an `assert` statement do? An `assert` statement has the form `assert <expression>`, and when one is executed the Python interpreter does the following:

1. First, it evaluates `<expression>`, which should produce a boolean value.
2. If the value is `True`, nothing else happens, and the program continues onto the next statement.

   But if the value is `False`, an `AssertionError` is raised. This signals to `pytest` that the test has failed.

So when `pytest` "runs" a unit test, what's actually going on is it calls a test function like `test_mixture_one_more_true`. If the function call ends without raising an `AssertionError`, the test *passes*; if the function call does raise an `AssertionError`, the test *fails*. A single unit test function can contain multiple `assert` statements; the test passes if all of the `assert` statements pass, and fails if any of the `assert` statements raise an error.

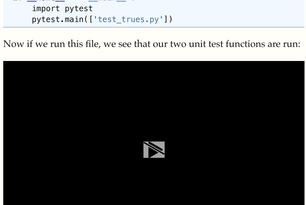
Running `pytest`

Finally, how do we use `pytest` to actually run our unit test functions? Similar to `doctest`, we need to first import `pytest` and then call a specific test function.

```
# At the bottom of test_trues.py

if __name__ == '__main__':
    import pytest
    pytest.main(['test_trues.py'])
```

Now if we run this file, we see that our two unit test functions are run:



References

- CSC108 videos: Doctest (Part 1, Part 2)
- CSC108 videos: Writing a '`__main__`' program (Part 1, Part 2)
- Appendix B.1 `doctest`
- Appendix B.2 `pytest`