Testing

BBM 101 - Introduction to Programming I

Hacettepe University
Fall 2016

Fuat Akal, Aykut Erdem, Erkut Erdem

Slides based on material prepared by Ruth Anderson, Michael Ernst and Bill Howe in the course CSE 140 University of Washington

Testing

- Programming to analyze data is powerful
- It is useless if the results are not correct
- **Correctness is far more important than speed**

Famous Examples

- Ariane 5 rocket
  - On June 4, 1996, the maiden flight of the European Ariane 5 launcher crashed about 40 seconds after takeoff.
  - Media reports indicated that the amount lost was half a billion dollars
  - The explosion was the result of a software error
- Therac-25 radiation therapy machine
  - In 1985 a Canadian-built radiation-treatment device began blasting holes through patients' bodies.

Testing does not *Prove* Correctness

- Edsger Dijkstra: “Program testing can be used to show the presence of bugs, but never to show their absence!”

Testing = Double-Checking Results

- How do you know your program is right?
  - Compare its output to a correct output
- How do you know a correct output?
  - Real data is big
  - You wrote a computer program because it is not convenient to compute it by hand
- Use small inputs so you can compute by hand
- Example: standard deviation
  - What are good tests for **`std_dev`**?

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2},$$

Testing ≠ Debugging

- **Testing**: Determining whether your program is correct
  - Doesn't say where or how your program is incorrect

- **Debugging**: Locating the specific defect in your program, and fixing it

  2 key ideas:
  - divide and conquer
  - the scientific method

What is a Test?

- A test consists of:
  - an input (sometimes called "test data")
  - an oracle (a predicate (boolean expression) of the output)
- Example test for sum:
  - input: [1, 2, 3]
  - oracle: result is 6
  - write the test as: `sum([1, 2, 3]) == 6`
- Example test for sqrt:
  - input: 3.14
  - oracle: result is within 0.00001 of 1.772
  - ways to write the test:
    - `sqrt(3.14) - 1.772 < 0.00001 and sqrt(3.14) - 1.772 > -0.00001`
    - `-0.00001 < sqrt(3.14) - 1.772 < 0.00001`
    - `math.abs(sqrt(3.14) - 1.772) < 0.00001`

Test Results

- The test passes if the boolean expression evaluates to **`True`**
- The test fails if the boolean expression evaluates to **`False`**
- Use the **`assert`** statement:
  - **`assert sum([1, 2, 3]) == 6`**
  - **`assert True`** does nothing
  - **`assert False`** crashes the program and prints a message

Where to Write Test Cases

- At the **top level**: is run every time you load your program

```
def hypotenuse(a, b):
    …
assert hypotenuse(3, 4) == 5
assert hypotenuse(5, 12) == 13
```

- In a **test function**: is run when you invoke the function

```
def hypotenuse(a, b):
    …
def test_hypotenuse():
    assert hypotenuse(3, 4) == 5
    assert hypotenuse(5, 12) == 13
```

Assertions are not Just for Test Cases

- Use assertions throughout your code
- Documents what you think is true about your algorithm
- Lets you know immediately when something goes wrong
  - The longer between a code mistake and the programmer noticing, the harder it is to debug

Assertions Make Debugging Easier

- Common, but unfortunate, course of events:
  - Code contains a mistake (incorrect assumption or algorithm)
  - Intermediate value (e.g., result of a function call) is incorrect
  - That value is used in other computations, or copied into other variables
  - Eventually, the user notices that the overall program produces a wrong result
  - Where is the mistake in the program? It could be anywhere.
- Suppose you had 10 assertions evenly distributed in your code
  - When one fails, you can localize the mistake to 1/10 of your code (the part between the last assertion that passes and the first one that fails)

Where to Write Assertions

- Function entry: Are arguments legal?
  - Place blame on the caller before the function fails
- Function exit: Is result correct?
- Places with tricky or interesting code
- Assertions are ordinary statements; e.g., can appear within a loop:

```
for n in myNumbers:
  assert type(n) == int or type(n) == float
```

Where *not* to Write Assertions

- Don’t clutter the code
  - Same rule as for comments
- Don’t write assertions that are certain to succeed
  - The existence of an assertion tells a programmer that it might possibly fail
- Don’t write an assertion if the following code would fail informatively

```
assert type(name) == str
print("Hello, " + name)
```

- Write assertions where they may be useful for debugging

What to Write Assertions About

- Results of computations

- Correctly-formed data structures

```
assert 0 <= index < len(mylist)
assert len(list1) == len(list2)
```

When to Write Tests

- Two possibilities:
  - Write code first, then write tests
  - Write tests first, then write code
- If you write the code first, you remember the implementation while writing the tests
  - You are likely to make the same mistakes in the implementation
- If you write the tests first, you will think more about the functionality than about a particular implementation
  - You might notice some aspect of behavior that you would have made a mistake about
  - This is the better choice

Write the Whole Test

- A common **mistake**:
  1. Write the function
  2. Make up test inputs
  3. Run the function
  4. Use the result as the oracle

- You didn't write a test, but only half of a test
  - Created the tests inputs, but not the oracle

- The test does not determine whether the function is correct
  - Only determines that it continues to be as correct (or incorrect) as it was before

Testing Approaches

- **Black box testing** - Choose test data ***without*** looking at implementation

- **Glass box** (white box, clear box) **testing** - Choose test data ***with*** knowledge of implementation

Inside Knowledge might be Nice

- Assume the code below:

```
c = a + b
if c > 100
        print("Tested")
print("Passed")
```

- Creating a test case with a=40 and b=70 is not enough
  - Although every line of the code will be executed

- Another test case with a=40 and b=30 would complete the test

Tests might not Reveal an Error Sometimes

```
def mean(numbers):
  """Returns the average of the argument list.
     The argument must be a non-empty list of numbers."""
  return sum(numbers)//len(numbers)

# Tests
assert mean([1, 2, 3, 4, 5]) == 3
assert mean([1, 2, 3]) == 2
```

This implementation is elegant, but wrong!

`mean([1,2,3,4])` → would return 2.5!!!

Last but not Least, Don't Write Meaningless Tests

```
def mean(numbers):
  """Returns the average of the argument list.
     The argument must be a non-empty list of numbers."""
  return sum(numbers)//len(numbers)
```

Unnecessary tests. Don't write these:

```
mean([1, 2, "hello"])
mean("hello")
mean([])
```