Testing

BBM 101 - Introduction to Programming I

Hacettepe University
Fall 2016

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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?

\[
s = \sqrt{\frac{1}{N - 1} \sum_{i=1}^{N} (x_i - \bar{x})^2},
\]
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: \texttt{sum([1, 2, 3]) == 6}

• Example test for \texttt{sqrt}:
  – input: 3.14
  – oracle: result is within 0.00001 of 1.772
  – ways to write the test:
    • \texttt{sqrt(3.14) - 1.772 < 0.00001 and sqrt(3.14) - 1.772 > -0.00001}
    • \texttt{-0.00001 < sqrt(3.14) - 1.772 < 0.00001}
    • \texttt{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

```python
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

```python
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

  ```python
  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

```python
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:

```python
    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([])