Testing

CSE 160 Summer 2026

Questions?

Sli.do #cse160

Announcements

- **Written Check-In 7 due tonight at 11:59 PM**
- **Homework Assignment 5 due Monday, August 17 at 11:59PM**
- **Programming Practice 6 due Sunday, August 9 at 11:59PM**
- **Resubmission Cycle 3 due Sunday, August 9th at 11:59PM**
  - Homeworks 1-3 eligible
  - Fill out the Google Form!
- **Final Exam information and Practice Finals** now available on course website!
  - Final Exam on Friday, August 21 at 9:40am in HRC 155

Today's Roadmap

1. How important is testing?
2. Testing programs vs. functions
3. Writing Test Suites
4. Testing Approaches
5. Testing Guidelines
6. Assertions for Debugging

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Why should we test our code?

- Programming to analyze data is powerful
- It's useless (or worse!) if the results are not correct
- Correctness is far more important than speed

Famous Examples of Software Failures

- Ariane 5 rocket (1996)
  - fault in the software in the inertial navigation system
- Therac-25 radiation therapy machine (1986/1987)
  - Fatal overdose due to software bugs and no external controls
- List of Software Failures

More Recent Software Failures

- Mars Rovers (1999)
  - Two systems were sharing information in different units
- Airplanes have a lot of software…
  - Airbus (2015) & Boeing (2019)
- WannaCry ransomware attack (2017)
  - Exploited a bug in software to demanding ransom payments
- CrowdStrike (2024)
  - “Routine” update by CrowdStrike crashed Windows devices: $5 Billion cost
- Tesla Autopilot Crashes (2016-present)

TECH | AMAZON

Prolonged AWS outage takes down a big chunk of the internet

AWS has been experiencing an outage for hours

By Jay Peters | @jaypeters | Updated Nov 25, 2020, 5:39pm EST

INSIDER

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Tesla's Full Self-Driving tech keeps getting fooled by the moon, billboards, and Burger King signs

Tim Levin Jul 26, 2021, 10:19 AM

Forbes

EDITORS' PICK | Oct 5, 2021, 09:09pm EDT | 3,285 views

Facebook Says A Bug In A Software Audit Tool Triggered Yesterday's Mega Outage

Testing does not prove correctness

"Program testing can be used to show the presence of bugs, but never to show their absence!"

- Edsger Dijkstra

- Testing can only increase our confidence in program correctness.
- Exhaustive testing (e.g. testing all possible inputs) is generally not possible
- Instead we have to be smart about testing

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

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Testing your program

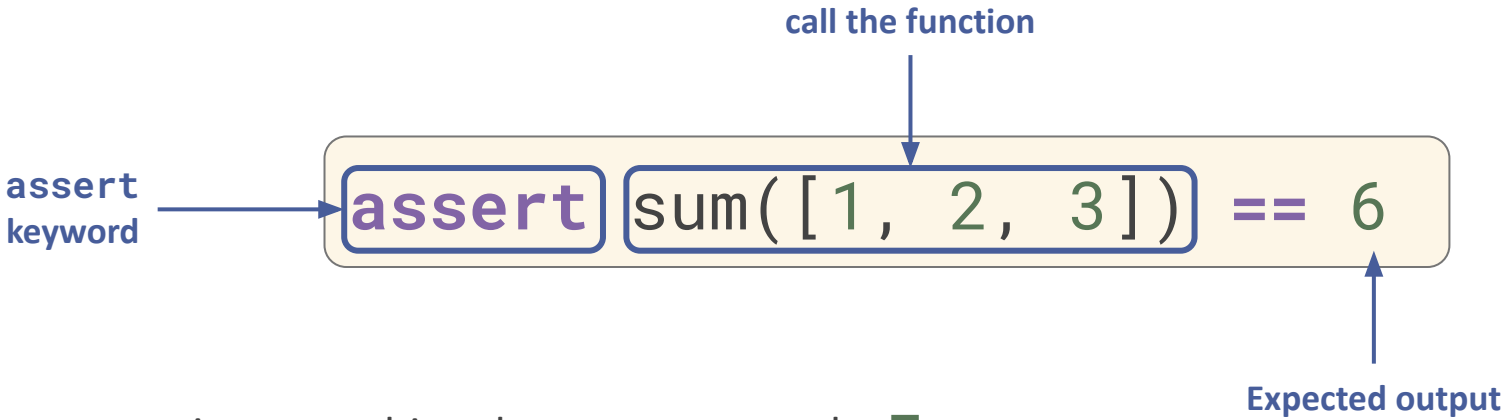
- How do you know your **program** is right?
  - Compare its output to a correct output
- How do you know a correct output?
  - Real data is big
  - You wrote a computer program because it is not convenient to compute it by hand
- Use small inputs so you can compute the expected output by hand
  - We did this in HW2, HW3, HW4 & HW5 with small data sets

Testing parts of your program

- Often called “unit testing”
- Testing that the output of individual functions is correct.
- One way: using `assert` statements
- We have also been doing this!
  - In Homeworks
  - In Programming Practices

Writing a test using an `assert` statement

- An example test for the `sum` function.
- We expect the function to return 6 when we pass in the list [1, 2, 3].



We are asserting something that we expect to be **`True`**

- If the assertion is **True**, then nothing will happen
- If the assertion is **False**, then the program halts and prints a message

Aside: Don't use == for comparing floats!

An example test in restaurants.py:

```
assert avg == 4.06
```

Don't do this! Do not test for equality with floats!

See `float_equality.py` on JupyterHub

Aside: Use `math.isclose()` for comparing floats!

An example test restaurants.py:

```
assert avg == 4.06
```

Don't do this! Do not test for equality with floats!

Instead:

```
assert math.isclose(avg, 4.06)
```

See `float_equality.py` on JupyterHub. Don't forget to `import math`.

How to write a good Test Suite

Test Suite: a collection of test cases used to test a program or function

A good Test Suite includes:

- Good coverage of the **input space**
  - What are the possible inputs to the function?
- Good coverage of **code**
  - What are the possible paths through the code?
  - Note: we do not always know what the code is before writing tests.
- Addresses **boundary cases**
  - What are cases at the edges of the input space

Example (input space coverage)

```
def abs(x):
    """
    Takes in an integer x and returns the absolute value of
    that integer.
    """
  if x > 0:
      return x
  else:
      return -x
```

What are the possible *categories* of values **x** can be?

Example (code coverage)

```
def abs(x):
    """
    Takes in an integer x and returns the absolute value of
    that integer.
    """
  if x > 0:
      return x
  else:
      return -x
```

What are the possible *paths through the code* in this function?

Example (code coverage): `assert abs(5) == 5`

```
def abs(x):
    """
    Takes in an integer x and returns the absolute value of
    that integer.
    """
    if x > 0:
        return x
    else:
        return -x
```

What are the possible *paths through the code* in this function?

Example (code coverage): `assert abs(-2) == 2`

```
def abs(x):
    """
    Takes in an integer x and returns the absolute value of
    that integer.
    """
    if x > 0:
        return x
    else:
        return -x
```

What are the possible *paths through the code* in this function?

Example (code coverage): Test Suite

```
def abs(x):
    """
    Takes in an integer x and returns the absolute value of
    that integer.
    """
   if x > 0:
       return x
   else:
       return -x
```

```
assert abs(5) == 5
assert abs(-2) == 2
```

Example (code coverage): Can still miss bugs

```
def abs(x):
    """
    Takes in an integer x and returns the absolute value of
    that integer.
    """
   if x > 1:
       return x
   else:
       return -x
```

```
assert abs(5) == 5
assert abs(-2) == 2
```

Example (boundary cases): `assert abs(0) == 0`

```
def abs(x):
    """
    Takes in an integer x and returns the absolute value of
    that integer.
    """
    if x > 0:
        return x
    else:
        return -x
```

```
assert abs(5) == 5
assert abs(-2) == 2
```

Another Example (Discuss!)

```
def find_max(lst):
    """
    Takes in a list of integers lst and returns the maximum
    value in the list. If the list is empty, return None.
    """
```

Come up with at least 4 assert statements including input and output that tests `find_max()`

Coming up with good test cases

Numbers:

- int vs. float values (Note: do not to test for equality with floats)
- Zero
- Negative values

Lists:

- Empty list, lists of different lengths
- Lists containing duplicate values (or including all the same value)
- Lists in ascending order/descending order
- Mix of types in list (if the function specification does not rule this out)

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Testing Approaches

- **Black box testing:** Choose test data ***without*** looking at the implementation, just test behavior mentioned in the specification (or doc-string)
- **Glass box** (white box, clear box) **testing:** Choose test data ***with*** knowledge of the implementation. Test that all paths through your code are exercised and correct. Examples:
  - If statement with several elifs, make sure your test cases will execute all branches
  - For loop, test if it is executed never, once, >1, max times

Don't Remove Tests!

Regression testing

- Whenever you find a bug (not from an existing test)
  - Add a **new** test case with the input that exposes the bug and the expected output to the test suite
  - Verify that the test suite fails
  - Fix the bug
  - Verify the fix worked
- Do NOT remove tests - protects against reintroducing the same bug later

When to write tests

- Two possibilities:
  - Write code first, then write tests
  - Write tests first, then write code
- It's best to write tests first
  - If you write the code first, you remember the implementation while writing the tests (confirmation bias!)
  - You are likely to make the same mistakes that you made in the implementation (e.g. assuming that negative values would never be present in a list of numbers)
- 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, some special case of input that you would have forgotten to handle

Where to write tests

- At the top level: tests are run every time you load your program

```
def hypotenuse(a, b):
  … body of hypotenuse …

assert hypotenuse(3, 4) == 5
assert hypotenuse(5, 12) == 13
```

As in HW2, programming practices

- In a test function: tests are run when you invoke the test function

```
def hypotenuse(a, b):
  … body of hypotenuse …

def test_hypotenuse():
  assert hypotenuse(3, 4) == 5
  assert hypotenuse(5, 12) == 13

test_hypotenuse()
```

As in HW3, HW4, HW5

What Not to Test: **Input types** not described in the specification

```
def abs(x):
    """
    Takes in an integer x and returns the absolute value of
    that integer.
    """
```

Examples of inputs that are unnecessary to test:

```
abs(0.01)
abs('hi')
abs([])
```

What Not to Test: **Behavior** not described in the specification

```
def roots(a, b, c):
    """
    Returns a list of the two roots of ax**2 + bx + c = 0.
    """
```

What is wrong with this test?

```
assert sorted(roots(1, 0, -1)) == [-1, 1]
```

Come up with a Test Suite!

```
def isBigger(x, y):
    """
    Assumes x and y are ints.
    Returns True if x is greater than y, False otherwise.
    """
```

Summary

- Testing doesn't prove correctness, only increases confidence in program correctness
- Writing a good test suite is hard, but can use heuristics including:
  - Good coverage of **input space**
  - Good coverage of **code execution** (not always known beforehand)
  - Address **boundary cases**
- Write tests before you write the code!
- Good tests help with debugging

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Assertions are not just for test cases

- You an use assertions throughout your code
- Documents what you think is true about your algorithm or data structure
  - E.g., `assert 0 <= index < len(my_list)`
- 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., in local variable, or 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 of expected type/size/value/shape?
  - 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 my_numbers:
    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 need to write an assertion if the following code would fail informatively:

```
a = 5
assert a == 5  # Not needed!
```

- Write assertions where they may be useful for debugging

```
assert type(name) == str
print("Hello, " + name)  # If this fails the exception will be useful
```