

CS1632, Lecture 9: Unit Testing, part 2

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How to test this method?

```
public class Example {  
    public static int doubleMe(int x) {  
        return x * 2;  
    }  
}
```

```
// Perhaps something like this...
```

```
@Test
```

```
public void zeroTest() {  
    assertEquals(Example.doubleMe(0), 0);  
}
```

```
@Test
```

```
public void positiveTest() {  
    assertEquals(Example.doubleMe(10), 20);  
}
```

```
@Test
```

```
public void negativeTest() {  
    assertEquals(Example.doubleMe(-4), -8);  
}
```

OK, how about this?

```
public class Example {  
    public void quackALot(Duck d, int num) {  
        for (int j=0; j < num; j++) {  
            d.quack();  
        }  
    }  
}
```

1. What is there to test to begin with? There are no values to test!
 - ☛ Test the behavior: somehow test `quack()` is called `num` times
2. How can we test `Example` class without `Duck` class?
 - `Duck` may not even be implemented yet
 - Even if it were, we don't want to test `Duck` code --- we want tests *localized*
 - ☛ Use a “body double” for `Duck` that fakes a real duck

Advance Unit Testing Techniques

- Removing Class Dependencies
 - Test Doubles
 - Stubs
- Behavior Verification
 - Mocks

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Test Doubles

- “Fake” objects you can use in your tests
- They can act in any way you want – they do not have to act exactly as their “real” counterparts

Test Double Examples

1. A doubled database connection

- Double doesn't actually connect to a database
- Double returns pre-determined database entries for testing

2. A doubled File object

- Double doesn't actually open a file
- Double emulates file read failures for the purposes of testing

3. A doubled RandomNumberGenerator

- Double doesn't actually generate random numbers
- Double returns pre-determined numbers for reproducible testing

Double Dependent Class (NOT the Tested Class)

- Remember, double objects of classes that the tested class depends on
 - That is because we don't want to test dependent classes
- Don't double the tested class!
- If you double the tested class, what are you testing? 😊

Test Double Example

```
@Test
public void testDeleteFrontOneItem() {
    LinkedList<Integer> ll = new LinkedList<Integer>();
    ll.addToFront(Mockito.mock(Node.class));
    ll.deleteFront();
    assertEquals(ll.getFront(), null);
}
```

- We want to test `LinkedList`; we don't want to test `Node`
- Test double `Node` with JUnit mock API

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Stubs

- Doubles are “fake objects”
- Stubs are “fake methods” for the “fake objects”

Stubs

- Stubbing a method says:
 - “Instead of calling that method, just do whatever I tell you.”
- "Whatever I tell you" is just return a value
 - Actual method is never executed

Stub Example

```
public int quackAlot(Duck d, int num) {  
    int numQuacks = 0;  
    for (int j=0; j < num; j++) {  
        numQuacks += d.quack();  
    }  
    return numQuacks;  
}
```

- We want to stub `quack()` to remove dependency on `Duck`

Create a test double, stub the method

```
@Test
public void testQuackAlot() {
    Duck mockDuck = mock(Duck.class);
    when(mockDuck.quack()).thenReturn(1);
    int val = quackAlot(mockDuck, 100);
    assertEquals(val, 100);
}
```

We have Localized the Test

- We only care about testing our quackAlot() method
 - We don't care about whether Duck.quack() works, or Duck works
 - Duck.quack() is tested separately in the unit tests for Duck class
- Unit tests should only test the unit being tested
 - Otherwise, test becomes BRITTLE (breaks easily due to external changes)
 - Otherwise, on failure, hard to pinpoint where defect occurred

What if you don't stub a method?

- What if you don't stub a method for a test double?
 - Still, original method is NOT executed
 - Returns a default value
 - E.g. If return type is boolean: false
 - E.g. if return type is int: 0
 - E.g. if return type is reference: null
- What if the method has return type `void`?
 - No need to stub since there is no return value

Advance Unit Testing Techniques

- Removing Class Dependencies
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Original Problematic Example

```
public class Example {  
    public void quackAlot(Duck d, int num) {  
        for (int j=0; j < num; j++) {  
            d.quack();  
        }  
    }  
}
```

1. What is there to test to begin with? There are no values to test!
 - ☛ Test the behavior: somehow test `quack()` is called `num` times
2. How can we test `Example` class without `Duck` class?

Behavior Verification

- No relation to "verification" in "verification and validation"
- Behavior Verification vs. State Verification
 - State Verification: Tests the state of the program
 - Whether state changes correctly as a result of method call(s)
 - Done through **assertions** on **postconditions** (what we've done so far)
 - Behavior Verification: Tests the behavior of code
 - Whether certain methods have been called a certain number of times
 - Whether methods have been called with the correct parameters
 - Done through **verify** in Mockito

Mock

- Mock: A test double which uses behavior verification
- Many frameworks (such as Mockito, the one we are using) don't differentiate between doubles and mocks
- Technically, a mock is a specific kind of test double.

Mock Example

```
@Test
public void testQuackAlot() {
    // Make a double of Duck, stub quack()
    Duck mockDuck = mock(Duck.class);
    mockDuck.when(mockDuck.quack()).thenReturn(1);
    // Call quackAlot, which calls mockDuck.quack() 5 times
    quackAlot(mockDuck, 5);
    // Make a true mock by verifying quack called 5 times
    Mockito.verify(mockDuck, times(5)).quack();
    // Note no assertions!  Assertions built in to verify.
}
```

What if Method is Too Complex to Stub?

```
public class Duck {
    boolean alive = true;
    public void shoot() {
        boolean hit = ...; /* complex trajectory calculation */
        if( hit ) alive = false;
    }
    public String toString() {
        return alive ? "alive" : "dead";
    }
}

public DuckHunt {
    public void shootDuck(Duck d) {
        System.out.println(d.toString()); // should return "alive"
        d.shoot();
        System.out.println(d.toString()); // should return "dead"
    }
}
```

- Why is stubbing `d.toString()` hard to do?

Create a Fake

```
public class FakeDuck extends Duck {  
    // Doesn't do complex trajectory calculation  
    public boolean shoot() { alive = false; }  
}  
  
@Test  
public void testShootDuck() {  
    // Make a fake Duck  
    Duck fakeDuck = new FakeDuck();  
    // Call shootDuck with fake Duck  
    shootDuck(fakeDuck);  
}
```

- Fake: a particular kind of double that is a simplified version of original object

What does a Good Unit Test Look Like?

- Reproducible on every run
- Independent of other tests
- Tests one test case at a time
- Localized (Tests only the unit)

Good Unit Test:

Reproducible on Every Run

- Test should either always pass or always fail. **Why?**
 - Otherwise, impossible to tell which build or version caused defect
 - The defect may have crept in long time ago but we were just lucky
- That means ...
 - All preconditions must be set up correctly before running each test
 - There can be no random factor while running test
 - No randomness in the test itself (e.g. passing a random input value)
 - No randomness internal to the program (e.g. game with a die roll)
- How do we remove randomness internal to the program?!
 - Don't worry, we will learn when we talk about Writing Testable Code 😊

Good Unit Test:

Independent of Other Tests

- Tests should not be impacted by other tests. **Why?**
- We may choose to run a subset of tests in a test suite
 - If a test that this test depends on is not chosen ...
- We may choose to run tests in a different order
 - We may even choose to run them in parallel!
 - Most unit testing frameworks allow parallel execution for faster completion
- Allows completion of test suite even in the event of failure
 - Even if a test fails, it does not impact any other tests

Good Unit Test:

Tests one thing at a time

- Do not test different test cases in a single test. **Why?**
 - If a test case fails (assertion fires), remaining test cases aren't tested
 - On test failure, hard to tell which test case failed
- Means you should call only one application method from test
 - The one that you are testing (unless it is unavoidable)
- If you use an “if..else” in a test, this is a code smell!
 - Value returned from a call used for something other than an assertion (for example, deciding which app method to call next, a no-no)

Good Unit Test:

Localized (Tests only the unit)

- Only test the code within the unit and nothing else. **Why?**
 - If test fails, you are sure the defect lies in the unit code
 - Otherwise, the defect may be in that “other” code you included
 - ☛ Defeats the entire purpose of unit testing!
- What if the unit (method) depends upon other methods?
 - Test double the object and stub the method

JUnit is not the only unit test framework out there!

- Not even for Java!
- But xUnit frameworks are common and easy to understand
 - C++: CPPunit
 - JavaScript: JSUnit
 - PHP: PHPUnit
 - Python: PyUnit
- Ideas should apply to other testing frameworks easily

My advice

- Try to add tests as soon as possible. DO NOT WRITE ALL OF YOUR CODE AND THEN TRY TO ADD TESTS.
- Ideally, write tests before coding (TDD).
- Develop in a way to make it easy for others to test.
- In legacy systems, add tests as you go. Don't fall into the morass!

Unit Testing != System Testing

- The manual testing that you've already done is a system test – it checks that the whole system works.
- This is not the goal of unit tests! Unit tests check that very small pieces of functionality work, not that the system as a whole works together.
- A proper testing process will include both –unit tests to pin down errors in particular pieces of code, system tests to check that all those supposedly-correct pieces of code work together.

Now Please Read Textbook Chapter 14

- In addition, look at code using Mockito in our JUnit example:
sample_code/junit_example/LinkedListTest.java

- Mockito User Manual:

<https://javadoc.io/static/org.mockito/mockito-core/3.2.4/org/mockito/Mockito.html>