

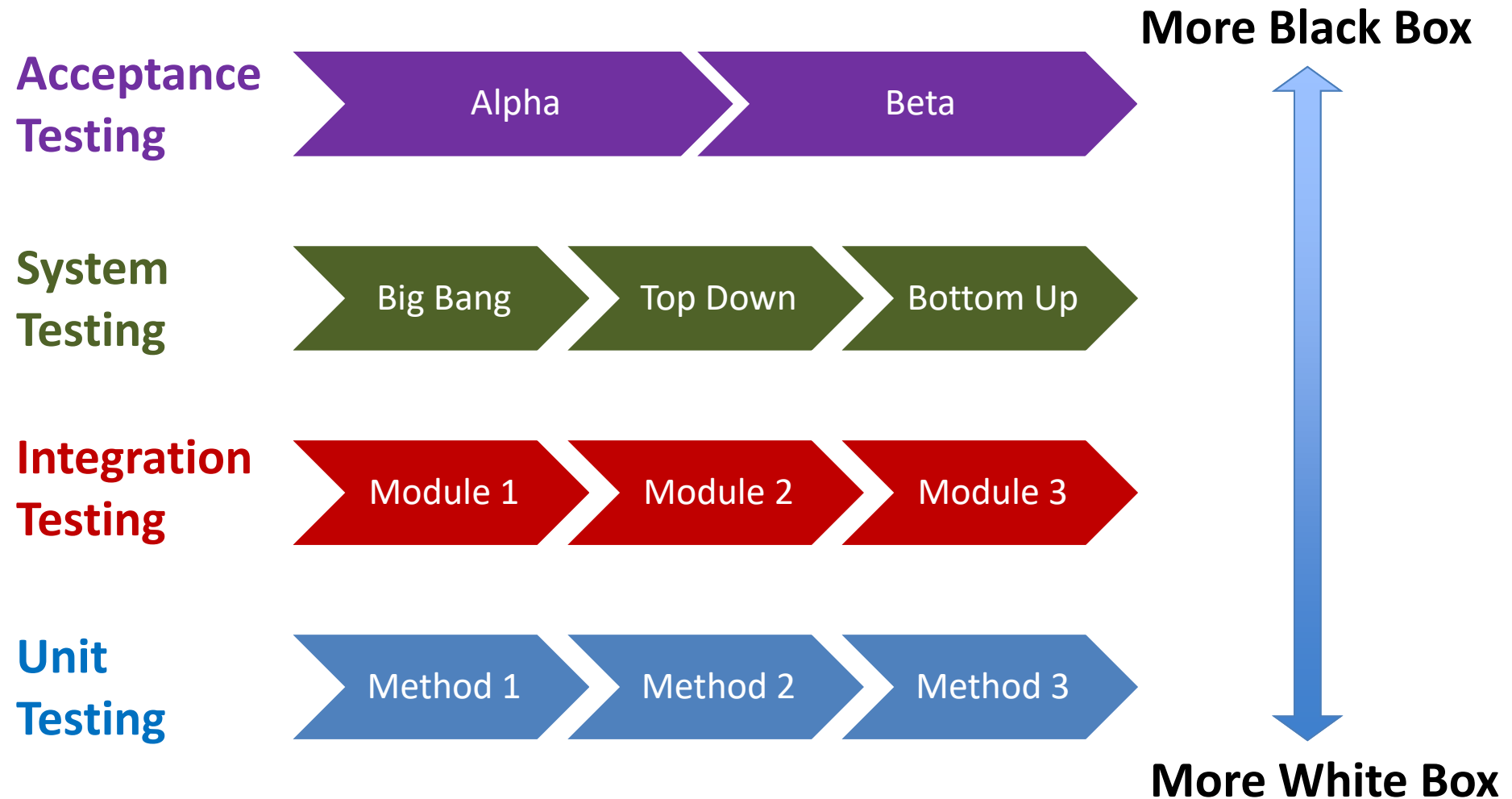
CS1632, Lecture 8: Unit Testing, part 1

Wonsun Ahn

What is unit testing?

- Unit testing: testing the smallest coherent "units" of code
 - Functions, methods, or classes
 - By directly invoking functions or methods
 - Necessarily white-box testing
- Goal: ensure the unit of code works correctly
 - Does NOT ensure the units taken together work correctly as a system
 - Very localized

The Four Levels of Software Testing



The Four Levels of Software Testing

- *Unit Testing*: Testing smallest unit of SW (typically a method)
- *Integration Testing*: Testing after integrating units into modules
 - A module in Java is analogous to a group of classes or package
- *System Testing*: End-to-end testing after integrating all modules
 - *Big Bang*: Testing at once after integrating all modules
 - *Top Down*: Testing incrementally by adding modules top-down
 - Uses *stubs* in place of not-yet-added leaf modules emulating those modules
 - *Bottom Up*: Testing incrementally by adding modules bottom-up
 - Uses a *driver* in place of not-yet-added root module calling the leaf modules
 - Why test incrementally? Easier to locate defect causing modules.

The Four Levels of Software Testing

- *(User) Acceptance Testing*: Checking SW is acceptable to user
 - Alpha Testing: Release to a select small group of users
 - Small group can be a select group of customers with high technical skill
 - Can be in-house, even the same development team (also called *dogfooding*)
 - Goal: To test and finalize the primary features of the SW
 - Beta Testing: Release to a broader set of users
 - *Closed Beta*: Also called *private beta*, only by invitation
 - *Open Beta*: Also called *public beta*, by anyone who wishes to participate
 - Goal: To ensure stability and security on various platforms and environments

Unit Testing Examples

- Testing that `sort()` method actually sorts elements
- Testing that `formatNumber()` method formats number properly
- Testing that passing in a null reference to a method which expects a valid object throws a `NullPointerException`
- Testing that passing in a string to a method which expects an integer throws a `NumberFormatException`

Who does Unit Testing?

- Usually done by the developer writing the code
- Another developer (esp. in pair programming)
- (Very occasionally), a white-box tester.

Why do Unit Testing?

1. Problems found earlier: no need to wait until system is built
2. Faster turnaround time: bug reporting overhead is not part of loop
 - Developer does the unit testing and can start debugging immediately
 - No need to wait for a tester to run test / file bug report / assign the bug
3. Developer understands issues with his/her code
 - Developer knows the code intimately and know where to find defects
4. “Living documentation”
 - Unit tests can be viewed as a documentation of expected behavior of the SW
 - Documentation is living because tests are verified regularly by running them against SW
5. Unit tests in sum total form a test suite
 - Test suite is run as regression test to find defects from changes with non-local impact
 - Unit test can discover defects due to changes in other units

What do Unit Tests Consist Of?

- A unit test is essentially a test case at the unit testing level
 - Same components: preconditions, execution steps, postconditions, ...
- Anatomy of a unit test when implemented (e.g. using JUnit):
 - Preconditions: set up code (inits variables / data structures, ...)
 - Execution Steps: one or more calls to unit tested method
 - Postconditions: assertions (checks postconditions are satisfied)
 - (Optional) tear down code (return to clean slate for next unit test)

A Unit Test Case for `LinkedList.equals()` method

- Preconditions:
 - Two linked lists with one node each
 - Nodes contain the integer value 1
- Execution Steps: Compare two lists with `equals()` method
- Postconditions: The `equals()` method SHOULD return true

A JUnit @Test Method is a Test Case

// Check that two LLs with one Node each with same val are equal

@Test

```
public void testEqualsOneNodeSameVals() {  
    LinkedList<Integer> list1 = new LinkedList<Integer>();  
    LinkedList<Integer> list2 = new LinkedList<Integer>();  
    list1.addToFront(new Node<Integer>(new Integer(1)));  
    list2.addToFront(new Node<Integer>(new Integer(1)));  
    assertEquals(list1, list2);  
}
```

- assertEquals: Invokes equals() method on arguments and asserts it returns true

A JUnit Class is a Test Plan

```
public class LinkedListTest {  
    @Test public void testZeroList() { ... }  
    @Test public void testClearedList() { ... }  
    @Test public void testMultiList() { ... }  
    ...  
}
```

- Each `@Test` JUnit method is a test case
- Each JUnit class is a test plan
- Collection of JUnit classes is a test suite

Running A Test Suite

```
public class TestRunner {
    public static void main(String[] args) {
        ArrayList<Class> classesToTest = new ArrayList<Class>();
        // Add any JUnit test classes here
        classesToTest.add(LinkedListTest.class);
        // For all test classes, use JUnit to run them
        for (Class c: classesToTest) {
            Result r = JUnitCore.runClasses(c);
            // Print out any failures for this class.
            for (Failure f : r.getFailures()) {
                System.out.println(f.toString());
            }
        }
    }
}
```

More Linked List Test Cases

`sample_code/ junit_example/LinkedListTest.java`

Assertions = Postconditions Check

- When you think something "should" or "must" happen ...
 - That is the EXPECTED BEHAVIOR or POSTCONDITION of the unit test
- When you execute the test by calling a method(s) ...
 - That is when you'll find out the OBSERVED BEHAVIOR of your method
 - Either by retrieving return value(s) or side-effects of method
- Should assert `EXPECTED BEHAVIOR == OBSERVED BEHAVIOR`

JUnit assertions

- Some possible assertions using JUnit:
 - `assertEquals`, `assertArrayEquals`, `assertSame`, `assertNotSame`, `assertTrue`, `assertFalse`, `assertNull`, `assertNotNull`, `assertThat(*something*)`, `fail()`, ...
- `assertSame(Object expected, Object actual)`: reference comparison
 - Compares two references with `==` operator rather than `equals()` method
- `assertThat(T actual, Matcher<T> matcher)`: a catch-all assertion
 - E.g. `assertThat("CS1632", anyOf(is("cs1632"), containsString("CS")))`;
- `fail()`: assertion that always fails
 - Why would you want an assertion that always results in test failure?
 - Maybe you shouldn't have even gotten to that part of code

fail() example

// Check addToFront(null) results in IllegalArgumentException

@Test

```
public void testAddNullToNoItemLL() {  
    LinkedList<Integer> ll = new LinkedList<Integer>();  
    try {  
        ll.addToFront(null);  
        fail("Adding a null node should throw an exception");  
    } catch (IllegalArgumentException e) {  
    }  
}
```

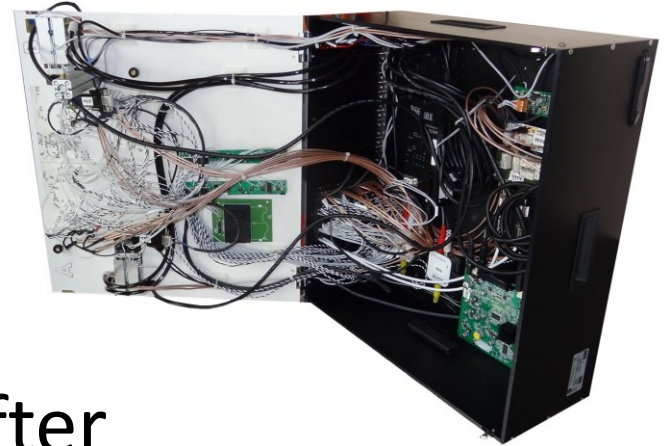
- Code execution never reaches fail() due to exception, as designed

Want more assertions?

- JUnit Javadoc reference:
 - <http://junit.sourceforge.net/javadoc/org/junit/Assert.html>

Test Fixture = Baseline Preconditions

- *Test fixture*: a fixed state used as a baseline precondition
 - Test cases in a test plan often need a common baseline precondition
 - Memory populated with a fixed set of objects
 - Database populated with a fixed set of entries
 - Hardware devices reinitialized to a fixed state
- In JUnit, implementable using @Before, @After
 - @Before annotation: Method executes before every @Test method
 - @After annotation: Method executes after every @Test method



Test Fixture Example

```
public class LinkedListTest {
    LinkedList<Integer> ll;
    Node<Integer>[] nodes;
    // Set up the test fixture before every @Test method
    @Before public void setUp() throws Exception {
        ll = new LinkedList<Integer>();
        nodes = new Node[10];
        for (int j = 0; j < 10; j++) {
            nodes[j] = new Node<Integer>(new Integer(j));
            ll.addToFront(nodes[j]);
        }
    }
    // Tear down the test fixture after every @Test method
    @After public void tearDown() throws Exception {}
    ...
}
```

Test Fixture Example

```
public class LinkedListTest {
    LinkedList<Integer> ll;
    Node<Integer>[] nodes;
    @Before public void setUp() throws Exception { /* see previous slide */ }
    @After public void tearDown() throws Exception { /* see previous slide */ }
    @Test public void testClearList() {
        ll.clear();
        assertNull(ll.getFront());
    }
    @Test public void testDeleteFront() {
        ll.deleteFront();
        assertSame(nodes[8], ll.getFront());
    }
}
```

- **Note:** ll is reset with node[9], node[8], node[7], ..., node[0] before testDeleteFront

What values to test on method arguments?

- Ideally...
 - Each equivalence class
 - Both internal and boundary values
- And also both success and failure cases
 - *Success case*: inputs which follow the “happy path”
 - *Failure case*: inputs where method is expected to fail
 - Failure cases, as well as success cases, must follow requirements

Success Cases and Failure Cases

```
public String quack(int n) throws Exception {  
    if (n > 0 && n < 10) {  
        return "quack!".repeat(n);  
    } else if (n >= 10) {  
        throw new Exception("too many quacks");  
    } else { // n <= 0  
        throw new Exception("too little quacks");  
    }  
}
```

- Equivalence classes: {..., -2, -1, 0}, {1, 2, ..., 9}, {10, 11, 12, ...}
- Success cases: {1, 2, ..., 9}
- Failure cases: {..., -2, -1, 0} + {10, 11, 12, ...}

Public vs. Private Methods

- Two philosophies:
 - Test only public methods
 - Test every method – public and private
- Test only public methods
 - Private methods are tested as part of public methods anyway
 - Private methods get added/removed/changed more often
 - Why? Because they are not part of the public object interface
 - If we test them, we need to modify the test code every time!
 - Private methods may be difficult to test due to language/framework

Public vs. Private Methods

- Test every method – public and private
 - Public/private distinction is arbitrary – they are all units in your code
 - Unit testing means testing at the lowest level;
Testing to the level of private methods adheres closer to the spirit
- Which philosophy to choose?
 - As everything in software QA, it depends 😊

Public Method Testing is Often Enough

```
class Bird {  
    public int fly(int n) {  
        return flapLeft(n) + flapRight(n);  
    }  
    // Tested as part of fly call.  
    private int flapLeft(int n) { ... }  
    private int flapRight(int n) { ... }  
    // Never called! So no need to test anyway.  
    private void urinate(double f) { ... }  
}
```

- A test of `fly` always tests `flapLeft` and `flapRight`
- Any private method not called in `fly` is in effect *dead code*

Where Public Method Testing is not Enough

// Assume all the called methods are private

```
public boolean foo(boolean n) {  
    if (bar(n) && baz(n) && beta(n)) {  
        return true;  
    } else if (baz(n) ^ (thud(n) || baa(n)) {  
        return false;  
    } else if (meow(n) || chew(n) || chirp(n)) {  
        return true;  
    } else {  
        return false;  
    }  
}
```

- It's a chore to even make sure each private method is tested
- If `foo` fails, hard to tell which private method has the defect

How can we test private methods?

- The programming language needs to allow it
- For Java, fortunately there is a way through something called *reflection*

```
class Duck {  
    private int quack(int n) { ... }  
}
```

```
// Get method quack which has one argument of int type.
```

```
Method m = Duck.class.getDeclaredMethod("quack", int.class);
```

```
// Set method to accessible.
```

```
m.setAccessible(true);
```

```
// Pass arguments to invoke. 1st argument is always the instance.
```

```
Object ret = m.invoke(new Duck(), 5);
```

- Read Chapter 24 in Textbook for details

Now Please Read Textbook Chapter 13

- Also see `sample_code/junit_example/LinkedListTest.java`
 - For Mac/Linux: you can run all JUnit tests by “`bash runTests.sh`”
 - For Windows: you can run all JUnit tests by “`runTests.bat`”
 - Above script will invoke TestRunner to run test suite
- User manual:
 - <https://junit.org/junit5/docs/current/user-guide/>
- Reference Javadoc:
 - <http://junit.sourceforge.net/javadoc/>