Unit Testing

Test First, Code Second

Understanding Why We Test First

- This seems backwards, if you test first there is nothing to test
- Testing first requires you to think differently
  - Some claim the most important piece of the agile development process
  - Can be difficult to embrace
  - How can this even be done with nothing to test?

Tests before Code

- Cooking recipes have been compared to software programs/algorithms
  - How do you know when the turkey is done?
  - Without a test you'll just be guessing at when you're done (and risk salmonella)
- Building inspector does the same thing
  - Set of criteria for the building to pass, even if the building doesn't exist yet
- Programming
  - Write the test case first
  - Forces you into a simple, bottom-up design as you test individual cases first and then later the integration of those cases

Writing a Test Case

- First, decide on subtask to accomplish
  - Should be small and require a simple test case (or cases)
- Simple example
  - Need to write code to find the largest of three integers
  - Write test case first to indicate success or failure of the code you will write

Simple Test Case

```
public void testMaxOfThreeInts()
{
        if (maxOfThreeInts(1,7,3) == 7)
        {
                System.out.println("Passed MaxOfThreeInts Test");
        }
        else
        {
                System.out.println("Failed maxOfThreeInts Test");
        }
}
```

Simple Test Case, Expanded

If desired, we can add more tests for the code, to test more conditions.

```
public void testMaxOfThreeInts()
{
        if (maxOfThreeInts(1,7,3) == 7)
        {
                if (maxOfThreeInts(6,1,4) == 6)
                {
                   System.out.println("Passed MaxOfThreeInts Test");
                }
                else
                {
                   System.out.println("Failed maxOfThreeInts Test");
                }
        }
        else
        {
                System.out.println("Failed maxOfThreeInts Test");
        }
}
```

Don’t add too many or the test case can become too complex. “Smoke test”.

Better Version

- Use assert which throws an exception if the expression in parenthesis is not true
  - Appropriate for internal invariants
  - NOT appropriate to take the place of argument checking, work your app would do for correct operation

  - For Java, must run with –ea flag

```
public void testMaxOfThreeInts()
{
        assert(maxOfThreeInts(1,7,3) == 7) : "Failed for 1,7,3";
        assert(maxOfThreeInts(7,1,3) == 7) : "Failed for 7,1,3";
}
```

Writing Code Being Tested

- Next we would fill in the code to be tested. If desired we could start with a stub to allow the test case to run:

```
public int maxOfThreeInts(int num1, int num2, int num3)
{
        return num1;
}
```

- Then we fill in the code and test it:

```
public int maxOfThreeInts(int num1, int num2, int num3)
{
        int max = num1;
        if ((num2 >= num1)) && (num2 >= num3)) max = num2;
        if ((num3 >= num1)) && (num3 >= num2)) max = num3;
        return max;
}
```

Slightly More Complex Example

- Test to see if entered password matches that of the stored password for a graphical password scheme

Graphical Password Test

Already defined:

```
class Point
{
  private int x,y;
  public Point(int x, int y) { ... }
  public double distance(Point otherPoint) { ... }
}
```

Header:

```
private boolean passwordMatch(ArrayList<Point> actual,
                              ArrayList<Point> entered)
```

What tests to write?

Graphical Password Test

```
private boolean passwordMatch(ArrayList<Point> actual,
                              ArrayList<Point> entered)
```

Next we write the code

```
private boolean passwordMatch(ArrayList<Point> actual,
                              ArrayList<Point> entered) {
       if (actual.size() != entered.size()) {
           return false;
       }
       for (int i=0; i<actual.size(); i++) {
           Point p1 = actual.get(i);
           Point p2 = entered.get(i);
           double d = p1.distance(p2);
           if (d > CIRCLEDIAMETER/2) {
               return false;
           }
       }
       return true;
   }
```

Tests can help drive the creation of the code;
e.g. if wrote test for different sized ArrayLists

Exhaustive Testing

- This would be if we wrote test cases to handle all input scenarios
  - Not feasible in most cases
  - Too many input combinations, tests become too complicated and difficult, too time consuming
- Practical alternative is representative testing
  - Pick cases that are representative of a segment of the code
  - Pick cases on the boundary conditions and outside boundary conditions (i.e. should cause errors)
  - We'll say more about choosing test conditions for good coverage later

Testing First is Hard!

- You may "reinterpret" the process by writing the code first and then immediately afterwards write the test
  - Not OK
- If you find code without a test, stop, write the test, and continue
  - Work harder to think of testing as the first step when tackling a subtask
  - The act of writing the test case will drive the design and force you to focus on the immediate subtask, eliminate ancillary issues, and give a different perspective on writing the code

Developing a Test Suite

- The collection of all tests is called the Test Suite
- Immediately provides a system status report
  - Use as a roadmap to locate problems
  - If testing is not done first, it is easy to have gaps in the system
- Test suite grows naturally and incrementally using the test-first methodology
- The test suite can grow to be quite large
  - Must be automated

Automated Testing

- Tests must be automated so they can be re-run in case new code breaks old code
- Must be
  - Fully automated (click a button to run them all)
  - Interpret Results (visual feedback)
  - Descriptive Error Messages (so you know where it failed)
  - Fast
- Testing frameworks like JUnit (Java), NUnit (.NET), or XUnit (C++) can help
- Will walk through JUnit briefly in class
- Can google for JUnit/NUnit tutorials online

Rationale Behind Testing First

- Forces programmers to think about code before writing it
  - By extension, guides design of the overall system
- If you wrote the code first and it seems to work, would you bother writing a test for it?
- Gives immediate, useful feedback
- Test suite becomes an invaluable, custom tool to gauge the health and progress of the system

Testing First Forces Simplicity

- Writing test phase
  - State test cases as simply as possible
  - Find enough representative test cases to cover the code
- Writing code
  - Goal becomes making the test pass
  - Perform least amount of work to reasonably make the test pass
    - Might be ugly code at first, but if it works it can be refactored later

Simplicity drives the Design

- Simple bottom-up development leads to a good high-level design
- Doesn’t dismiss system design, but promotes designing and building the system in tandem
- Argument: cumulative effect of making lots of good, small local decisions leads to a good overall, global design
  - Emergent behavior; we get an emergent design that can be robust

Testing First Clarifies the Task

- A test is a small, self-contained action
- It becomes an example to help understand what the code needs to do
- Also acts as a checkpoint; if you don’t understand the problem well enough to write a test case, you aren’t ready to write the code
- Might grapple on how to write the test, but the time also helps you write the code

Testing First Frees You from On-the-fly Editing

- On-the-fly editing: You’re coding along then see a different way of implementing the code.
  - Scrap approach or keep it?
  - Hit on productivity either way
- Testing first eliminates distraction
  - Aim for simplest, correct solution
  - Later, the code can be re-examined
  - No immediate worry about readability, efficiency, maintainability, speed, size, cleverness, etc. The focus is on making simple code to pass the test.
- After code is written it is fair game for change

Test Suites and Refactoring

- A major refactoring could involve changing code in lots of classes and methods
  - Potential for everything to horribly break
- Test Suite provides a safety net and provide confidence in large, complex changes
- Can experimentally probe the structure and dependencies by making tentative changes

Testing First Provides Documentation

- Test cases provide useful documentation
  - Encapsulates the developer’s intent while writing the code
- Future maintainers get chronology of the development and useful diagnostic tool to guide future changes

Fixing Broken Test Cases

- You modify code or introduce a bug and as a result, tests don’t run correctly. What now?
- Goal is to make the tests pass
  - Might require refactoring the test cases themselves to match new code signatures
  - Might require searching through the code to find out why the test case fails

Adding Missing Tests

- If you ever find a bug that the test suite doesn’t catch, then you must write a test that exposes the deficiency before fixing the code
  - Causes the tests to reflect the error condition
  - Prevents missing the problem in the future if it creeps back in somehow

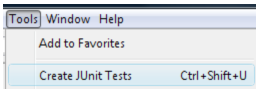
Tests Suites and Sanity

- Test suites psychologically help the team’s frame of mind
  - Successful passing of tests strokes your inner programmer
  - Stronger boost when you see a new/better/more efficient way to write your code, and can see that all of the tests still pass

JUnit and NetBeans Demo

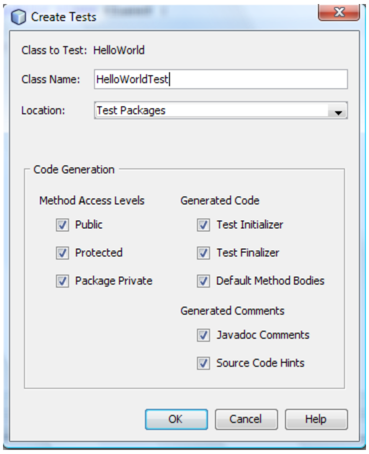
- Integrated into NetBeans
  - Slightly different process if not using an IDE; have to import Junit, make a test class, extend TestCase
  - Also integrated with Eclipse and other IDE's

1. Create project
2. Create class for code that will be tested
   - Can make a test case with no corresponding class, but I think it's a bit easier to make the class first
3. Select the class in the project view and under T)ools select Create JUnit Tests



JUnit

- Creating a JUnit Test
- Class has "Test" at end to distinguish it as a test
- Can leave default code generation
- If there are methods in the class, JUnit will create tests for each one
  - Can be useful to write an empty method to be tested first, with just the header, to make it easier to generate the test



Create Tests

Class to Test: HelloWorld

Class Name: HelloWorldTest

Location: Test Packages

Code Generation

Method Access Levels
☑ Public
☑ Protected
☑ Package Private

Generated Code
☑ Test Initializer
☑ Test Finalizer
☑ Default Method Bodies

Generated Comments
☑ Javadoc Comments
☑ Source Code Hints

Test Class

```
 @BeforeClass
 public static void setUpClass() throws Exception {
 }

 @AfterClass
 public static void tearDownClass() throws Exception {
 }

 @Before
 public void setUp() {
 }

 @After
 public void tearDown() {
 }

 /**
  * Test of main method, of class HelloWorld.
 */
 @Test
 public void testMain() {
     System.out.println("main");
     String[] args = null;
     HelloWorld.main(args);
     // TODO review the generated test code and remove the
default call to fail.
     fail("The test case is a prototype.");
 }
```

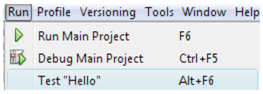
Run once for the test class

Run for every test

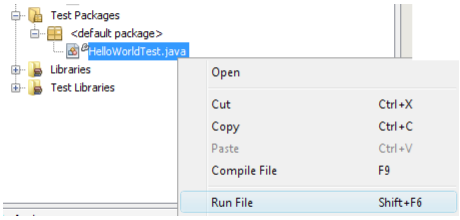
Test; Add multiple test methods with @Test

Running Tests

- Select "Test <project>" under the "R)un" menu



- Or right-click the test class and select "Run"

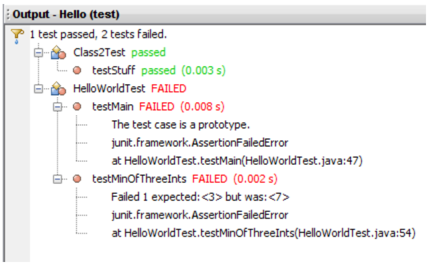


Determining Success or Failure

- The Assert class has the following methods:
  - assertEquals: Overloaded to test if an actual value matches the expected one. First parameter can be a String with a message.
    - assertEquals(“Number mismatch”, 3, 3);   // Passes if 3 == 3
  - assertFalse: Use this if you know the function will always return false (fails if it receives true)
  - assertNotNull: If your method return null in the event of failure use this to check to see if it succeeds
  - assertNotSame: If your method is supposed to return an element from a list you can use this to check if the element returned is the one from the actual list
  - assertNull: If your method return null in the event of failure use this to check to see if it fails
  - fail: Will fail the test, use this in conjunction with conditionals
  - failNotEquals: Essentially the same as assertEquals but will fail the test if they arent equal instead of causing an error
  - failNotSame: Essentially the same as assertNotSame except instead of causing an error it will cause a failure

Running Tests

- IDE displays results of each test; click on a test to get more details and jump straight to the failed case



```
Output - Hello (test)
1 test passed, 2 tests failed.
  Class2Test passed
    testStuff passed (0.003 s)
  HelloWorldTest FAILED
    testMain FAILED (0.008 s)
        The test case is a prototype.
        junit.framework.AssertionFailedError
        at HelloWorldTest.testMain(HelloWorldTest.java:47)
    testMinOfThreeInts FAILED (0.002 s)
        Failed 1 expected:<3> but was:<7>
        junit.framework.AssertionFailedError
        at HelloWorldTest.testMinOfThreeInts(HelloWorldTest.java:54)
```

Happy Testing!

- JUnit makes it easy to create, maintain, run tests
- Tests are kept separate from the actual project so they don’t interfere with the “real” code
- If you don’t want to use a test framework you could make your own with a little extra work
  - Separate class with a main() that invokes all the methods for the tests, outputs or asserts errors, etc.