CS 535 Object-Oriented Programming
Fall Semester, 2002
Doc 11 Testing
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References

JUnit Cookbook  http://junit.sourceforge.net/doc/cookbook/cookbook.htm

JUnit Test Infected: Programmers Love Writing Tests
http://junit.sourceforge.net/doc/testinfected/testing.htm

JUnit Javadoc:  http://www.junit.org/junit/javadoc/3.8/index.htm

Brian Marick's Testing Web Site:  http://www.testing.com/

Testing for Programmers, Brian Marick, Available at:  http://www.testing.com/writings.html

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Reading Assignment


Lecture Source Code

Java – CVS module testExamples

Smalltalk – Store package testExamples
Testing

Johnson's Law

If it is not tested it does not work

Types of tests

• Unit Tests
  Tests individual code segments

• Functional Tests
  Test functionality of an application
**Why Unit Testing**

If it is not tested it does not work

The more time between coding and testing

- More effort is needed to write tests
- More effort is needed to find bugs
- Fewer bugs are found
- Time is wasted working with buggy code
- Development time increases
- Quality decreases

Without unit tests

- Code integration is a nightmare
- Changing code is a nightmare
Why Automated Tests?

What wrong with:

- Using print statements
- Writing driver program in main
- Writing small sample programs to run code
- Running program and testing it be using it
Repeatability & Scalability

Need testing methods that:

• Work with N programmers working for K months (years)

• Help when modify code 6 months after it was written

• Check impact of code changes in rest of system

Practices that work in a school project may not be usable in industry

Standard industry practices may seem overkill in a school project

Work on building good habits and skills
We have a QA Team, so why should I write tests?

How long does it take QA to test your code?

How much time does your team spend working around bugs before QA tests?

How easy is it to find & correct the errors after QA finds them?

Most programmers have an informal testing process

With a little more work you can develop a useful test suite
When to Write Unit Tests

First write the tests

Then write the code to be tested

Writing tests first saves time

• Makes you clear of the interface & functionality of the code

• Removes temptation to skip tests
**SUnit & JUnit**

Free frameworks for Unit testing

SUnit originally written by Kent Beck 1994

- Built into VisualWorks 7.0

JUnit written by Kent Beck & Erich Gamma

- Available at: [http://www.junit.org/](http://www.junit.org/)

Already installed in JDK 1.2 on rohan and moria

Ports are available in

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<th>AppleScript</th>
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See [http://www.xprogramming.com/software.htm](http://www.xprogramming.com/software.htm) to download ports
How to Use SUnit

1. Make test class a subclass of TestCase

2. Make test methods
   The framework treats methods starting with 'test' as test methods

3. Run the tests
   You can run the test using TestRunner
   TestRunner open

   Use Browser SUnit Extensions
   Load parcel/RBSUnitExtensions.pcl to run the tests from the browser
**Browser SUnit Extensions**

```
**testIncrease**

self deny: counter isNil.
counter increase.
self assert: counter count = 1
```

Passed: 1 run, 0 failed, 0 errors
Sample TestClass

Smalltalk.CS535 defineClass: #TestCounter
    superclass: #{XProgramming.SUnit.TestCase}
    indexedType: #none
    private: false
    instanceVariableNames: 'counter'
    classInstanceVariableNames: ''
    imports: ''
    category: 'Course-Examples'

CS535.TestCounter methodsFor: 'testing'

setUp
    counter := Counter new.

tearDown
    counter := nil.

testDecrease
    counter decrease.
    self assert: counter count = -1.

testDecreaseWithShould
    "Just an example to show should: syntax"
    counter decrease.
    self should: [counter count = -1].

testIncrease
    self deny: counter isNil.
    counter increase.
    self assert: counter count = 1.

testZeroDivide
    "Just an example to show should:raise: syntax"
    self
        should: [1/0]
        raise: ZeroDivide.

    self
        shouldn't: [1/2]
        raise: ZeroDivide
**TestCase methods of interest**

Methods to assert conditions:

- `assert: aBooleanExpression`
- `deny: aBooleanExpression`
- `should: [aBooleanExpression]`
- `should: [aBooleanExpression] raise: AnExceptionClass`
- `shouldnt: [aBooleanExpression]`
- `shouldnt: [aBooleanExpression] raise: AnExceptionClass`
- `signalFailure: aString`

**setUp**

Called before running each test method in the class.

Used to:
- Open files
- Open database connections
- Create objects needed for test methods

**tearDown**

Called after running each test method in the class.

Used to:
- Close files
- Close database connections
- Nil out references to objects
Using JUnit Example

Goal: Implement a Stack containing integers.

Tests:

Subclass junit.framework.TestCase

Methods starting with 'test" are run by TestRunner

First tests for the constructors:

```java
public class TestStack extends TestCase {

    //required constructor
    public TestStack(String name) {
        super(name);
    }

    public void testDefaultConstructor() {
        Stack test = new Stack();
        assertTrue("Default constructor", test.isEmpty());
    }

    public void testSizeConstructor() {
        Stack test = new Stack(5);
        assertTrue(test.isEmpty());
    }
}
```
First part of the Stack

package example;

public class Stack {
    int[] elements;
    int topElement = -1;

    public Stack() {
        this(10);
    }

    public Stack(int size) {
        elements = new int[size];
    }

    public boolean isEmpty() {
        return topElement == -1;
    }
}

JUnit has three interfaces

- Text (junit.textui.*)

  Fastest to run

- AWT (junit.ui.*)

- Swing (junit.swingui.*)

  Can reload class files so you can

  Run TestRunner once

  Recompile program until it passes tests
Starting Swingui TestRunner

Make sure your classpath includes the code to tested

On Rohan use:

java  junit.swingui.TestRunner

You get a window similar to that on the next page

Enter the full name of the test class

Click on the Run button

If there are errors/failures select one

You will see a stack trace of the error

The “...” button will search for all test classes in your classpath
Swing version of JUnit TestRunner
Running the textui TestRunner

Sample Program using main

```java
public class Testing {
    public static void main (String args[]) {
        junit.textui.TestRunner.run( example.TestStack.class);
    }
}
```

Output

```
.. 
Time: 0.067
OK (2 tests)

java has exited with status 0.
```
assert Methods

assertTrue()
assertFalse()
assertEquals()
assertNotEquals()
assertSame()
assertNotSame()
assertNull()
assertNotNull()
assertNotNull()
fail()

For a complete list of the assert methods & arguments see

JUnit, Java 1.4 & assert

JUnit had a method called assert()

Java 1.4 makes assert a reserved word

JUnit starting 3.7 replaces assert() with assertTrue()

Use JUnit 3.7 or later with JDK 1.4

To use JDK 1.4 asserts:

• Compile with option -source 1.4

  java -source 1.4 programFile.java

• Run with the option -ea

  java -ea programFile
Testing the Tests

If can be useful to modify the code to break the tests

```java
package example;

public class Stack {
    int[] elements;
    int topElement = -1;

    etc.

    public boolean isEmpty() {
        return topElement == 1;
    }
}
```
Result of running Textui.TestRunner

F.F
Time: 0.113
There were 2 failures:
1) testDefaultConstructor(example.TestStack)junit.framework.AssertionFailedError: Default constructor
   at example.TestStack.testDefaultConstructor(TestStack.java:22)
   at Testing.main(Testing.java:14)
2) testSizeConstructor(example.TestStack)junit.framework.AssertionFailedError
   at example.TestStack.testSizeConstructor(TestStack.java:27)
   at Testing.main(Testing.java:14)

FAILURES!!!
Tests run: 2, Failures: 2, Errors: 0

java has exited with status 0.
Why Test the Tests?

One company had an automatic build and test cycle that ran at night. The daily build was created and all the tests were run at night. The test results were available first thing in the morning. One night the build process crashed, so the daily build was not made. Hence there was no code to test. Still 70% of the tests passed. If they had tested their tests, they would have discovered immediately that their tests were broken.
Test Fixtures

Before each test setUp() is run

After each test tearDown() is run

package example;

import junit.framework.TestCase;

public class StackTest extends TestCase {
    Stack test;

    public StackTest(String name) {
        super(name);
    }

    public void setUp() {
        test = new Stack(5);
        for (int k = 1; k <=5;k++)
            test.push( k);
    }

    public void testPushPop() {
        for (int k = 5; k >= 1; k--)
            assertEquals( "Pop fail on element " + k,  test.pop() , k);
    }
}

Suites – Multiple Test Classes

Multiple test classes can be run at the same time

Add Queue & TestQueue to Stack classes

```java
package example;

import junit.framework.TestCase;

public class TestQueue extends TestCase{
    public TestQueue ( String name){
        super(name);
    }

    public void testConstructor() {
        Queue test = new Queue();
        assert( test.isEmpty());
    }
}

package example;

import java.util.Vector;

public class Queue{
    Vector elements = new Vector();
    public boolean isEmpty() {
        return elements.isEmpty();
    }
}
```
Using a Suite to Run Multiple Test Classes

Running AllTests in TestRunner runs the test in

```java
StackTest
QueueTest
```

```java
package example;
import junit.framework.TestSuite;
import junit.textui.TestRunner;

public class AllTests {
    static public void main(String[] args) {
        TestRunner.run(example.AllTests.suite());
    }

    static public TestSuite suite() {
        TestSuite suite= new TestSuite();
        Try {
            suite.addTest(new TestSuite(StackTest.class));
            suite.addTest(new TestSuite(QueueTest.class));
        } catch (Exception e){
        }
        return suite;
    }
}
```
Using Main

We can use main to run the test via textui.TestRunner

The command:

    java example.AllTests

will run all the tests in StackTest & QueueTest

package example;

import junit.framework.TestSuite;
import junit.textui.TestRunner;

public class AllTests
{
    static public void main(String[] args)
    {
        TestRunner.run(AllTests.class);
    }

    static public TestSuite suite()
    {
        // same as last page
    }
}
How to Test Exceptions

At times you may wish to test input to methods that will cause an exception to be thrown.

Here is an example of a test that

- passes when an exception is thrown
- fails when the exception is not thrown

Example is from the JUnit FAQ

```java
public void testIndexOutOfBoundsException() {
    ArrayList list = new ArrayList(10);
    try {
        Object o = list.get(11);
        fail("Should raise an IndexOutOfBoundsException");
    } catch (IndexOutOfBoundsException success) {} 
}
```
Testing and Hidden Methods/State

Issues:

• How does one test hidden methods?

• Direct access to an object's state can reduce the time needed to write a test
Testing Hidden Methods One Position
Don't Do it

Pro:

• Can not test everything
• Clients of an object only care if public interface works correctly
• Testing public interface also tests hidden methods
• Hidden methods are more likely to change, requiring changes to the tests

The basic idea is to work smarter not harder. One cannot completely test each class, and one does not have infinite time to write tests one should write the most effective tests possible. Tests of the public interface of class will also test hidden methods of the class. Bugs in hidden methods that never affect the public methods are not a problem. Since the most important thing is that the public interface works correctly, concentrate your tests on the public interface.

Con:

• The closer the test is to the code it tests the easier the test
• Bugs in hidden methods can make it hard to debug public methods

My experience is that the more code I write without tests, the more time I spend on finding and correcting bugs. How many times have you spent hours (days?) tracking down a bug that turned out to be a simple bug in some simple untested method, which would have been easy to test? The argument that one cannot test everything and must make effective use of ones testing time is correct. Given the differences in programmer skill level, programmer experience, etc. everyone has to work out their own solution to this. The XP solution is to try to test everything that could possible break. Since most students are not used to testing, you have to fight the habit of not testing and testing after you have completely finished coding. Given the current state of affairs in commercial software, the industry has a lot to learn about testing.
How to Test Hidden Methods Directly?
Method 1: Relax the protection level

In Java one can

- Make the method package level access
- Place the test class in the same package as the tested code

Pro:

- Makes it possible to test the hidden method
- Clients outside the package can not access the method

Con:

- Clients in the package may then use the method
- Requires organizational discipline to avoid using the method

You should comment the method to inform the clients that the method is not to be used
How to Test Hidden Methods Directly?
Method 2: Use inner classes

import junit.framework.TestCase;

public class Foo {
    private int value;

    private void bar() {
        value = 10;
    }

    public static class FooTest extends TestCase {
        public FooTest(String name) {
            super(name);
        }

        public void testBar() {
            Foo a = new Foo();
            a.bar();
            assert(10 == a.value);
        }
    }
}

Pro:
• Provides access to all methods/fields
• Test does not have to be shipped with production code
• Test stays with tested class

Con:
• Source files are bit harder to read
• Must remove all inner $class files from production code
• Test not with other test classes
How to Test Hidden Methods Directly?
Method 3: Use reflection

Pro:
• Java reflection provides access to all methods/fields of a class
• Does not require any changes to tested class

Con:
• Reflection can be slow
• Reflection is cumbersome to use
• Requires setting permission files

See
http://www.eli.sdsu.edu/courses/fall98/cs596/notes/reflection/reflection.html for more information about reflection
What to Test

Everything that could possibly break

Test values

  Inside valid range

  Outside valid range

  On the boundary between valid/invalid

GUIs are very hard to test

  Keep GUI layer very thin

  Unit test program behind the GUI, not the GUI
Common Things that Programs Handle Incorrectly

Adapted with permission from “A Short Catalog of Test Ideas” by Brian Marick, http://www.testing.com/writings.html

Strings

Test using empty String

Collections

Test using:
• Empty Collection
• Collection with one element
• Collection with duplicate elements
• Collections with maximum possible size

Numbers

Test using:
• Zero
• The smallest number
• Just below the smallest number
• The largest number
• Just above the largest number
Testing Network Code

Writing automated tests for network code can be hard

Make the network code very thin

Write automated tests for the non-network code
Example – SimpleDateServer

The SimpleDateServer has two methods
  • One with network code
  • One for handling the request with no network code

Write tests for processRequestOn:

SimpleDateServer>>run
  | childSocket clientIOStream |
  [childSocket := serverSocket accept.
   clientIOStream := childSocket readAppendStream.
   clientIOStream lineEndTransparent.
   self processRequestOn: clientIOStream.] repeat

SimpleDateServer>>processRequestOn: anReadAppendStream
  | clientRequest |
  clientRequest := anReadAppendStream through: Character cr.
  (clientRequest startsWith: 'date')
  ifTrue:
    [anReadAppendStream
     nextPutAll: Time dateAndTimeNow printString;
     commit].
  anReadAppendStream close
Issues in Writing test for processRequestOn:

**processRequestOn: Input**

Need to create an ExternalAppendStream for input

Would be easier to test if arguments were:

- ReadStream
- WriteStream

**Server Output**

Initial sever was written without thought to parsing output

It will be hard for tests to parse current output

So it will be hard for a client to parse server response

Conclusion:

- Change server to make writing tests & client easier
Modified Server

SimpleDateServer>>run
  | childSocket |

  [childSocket := serverSocket accept.
  self
    processRequest: childSocket readStream lineEndTransparent
    response: childSocket writeStream lineEnd Transparent
  repeat

SimpleDateServer>>processRequest: aReadStream response: aWriteStream
  | clientRequest |
  clientRequest := aReadStream through: Character cr.
  (clientRequest startsWith: 'date')
    ifTrue:
      [aWriteStream
        nextPutAll: Date today printString;
        commit].
  (clientRequest startsWith: 'time')
    ifTrue:
      [aWriteStream
        nextPutAll: Time now printString;
        commit].
aWriteStream close.
Some Tests

TestSimpleDateServer is subclass of TestCase

TestSimpleDateServer>>testDate

| command response server serverDate serverDateString |
command := 'date \ withCRs readStream.
response := WriteStream on: String new.
server := SimpleDateServer new.
server processRequest: command response: response.
serverDateString := response contents.
serverDate := Date readFrom: serverDateString readStream.
self assert: serverDate = Date today.

TestSimpleDateServer>>testTime

| command response server serverTimeString serverTime |
command := 'time \ withCRs readStream.
response := WriteStream on: String new.
server := SimpleDateServer new.
server processRequest: command response: response.
serverTimeString := response contents.
serverTime := Time readFrom: serverTimeString readStream.
self assert: (Time now asSeconds - serverTime asSeconds) < 2.

TestSimpleDateServer>>testBadInput

| command response server |
command := 'fooBar \ withCRs readStream.
response := WriteStream on: String new.
server := SimpleDateServer new.
server processRequest: command response: response.
self assert: response contents trimBlanks isEmpty
Lessons

Keep the network layer thin

Server design may need to be modified to make it testable

See
Test networked code the easy way, Nelson Minar

for another example