CS 683 Emerging Technologies
Spring Semester, 2003
Doc 2 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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For more Information Read

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

JUnit FAQ, http://junit.sourceforge.net/doc/faq/faq.htm

Programming with Assertions, http://java.sun.com/j2se/1.4/docs/guide/lang/assert.html

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/

Already installed in JDK 1.2 on rohan and moria

Ports are available in

.NET	Ada	AppleScript	C
C#	C++	Curl	Delphi
Eiffel	Eiffel	Flash	Forte 4GL
Gemstone/S	Haskell	HTML	Jade
LISP	Objective-C	Oracle	Palm
Perl	Php	PowerBuilder	Python
Ruby	Scheme	Smalltalk	Visual Basic
XML	XSLT		

See 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

Broswer SUnit Extensions

Browser Edit Find View Category Class Protocol Method Tools Help

Find:

Category | Hierarchy

System-Depende
System-Name S
System-Override
System-Printing

Counter
TestCounter

Instance | Class | Shared Variable

setup teardown
testing

testDecrease
testDecrease
testIncrease
testZeroDivid

Source | Rewrite | Code Critic

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

Passed: 1 run, 0 failed, 0 errors

Profile | Debug | Run

Method: #testIncrease (testing) | **Parcel:** none | **Package:** TestExample

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
        shouldnt: [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:

```
import junit.framework.*;

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;
   }
}
```

Running JUnit

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

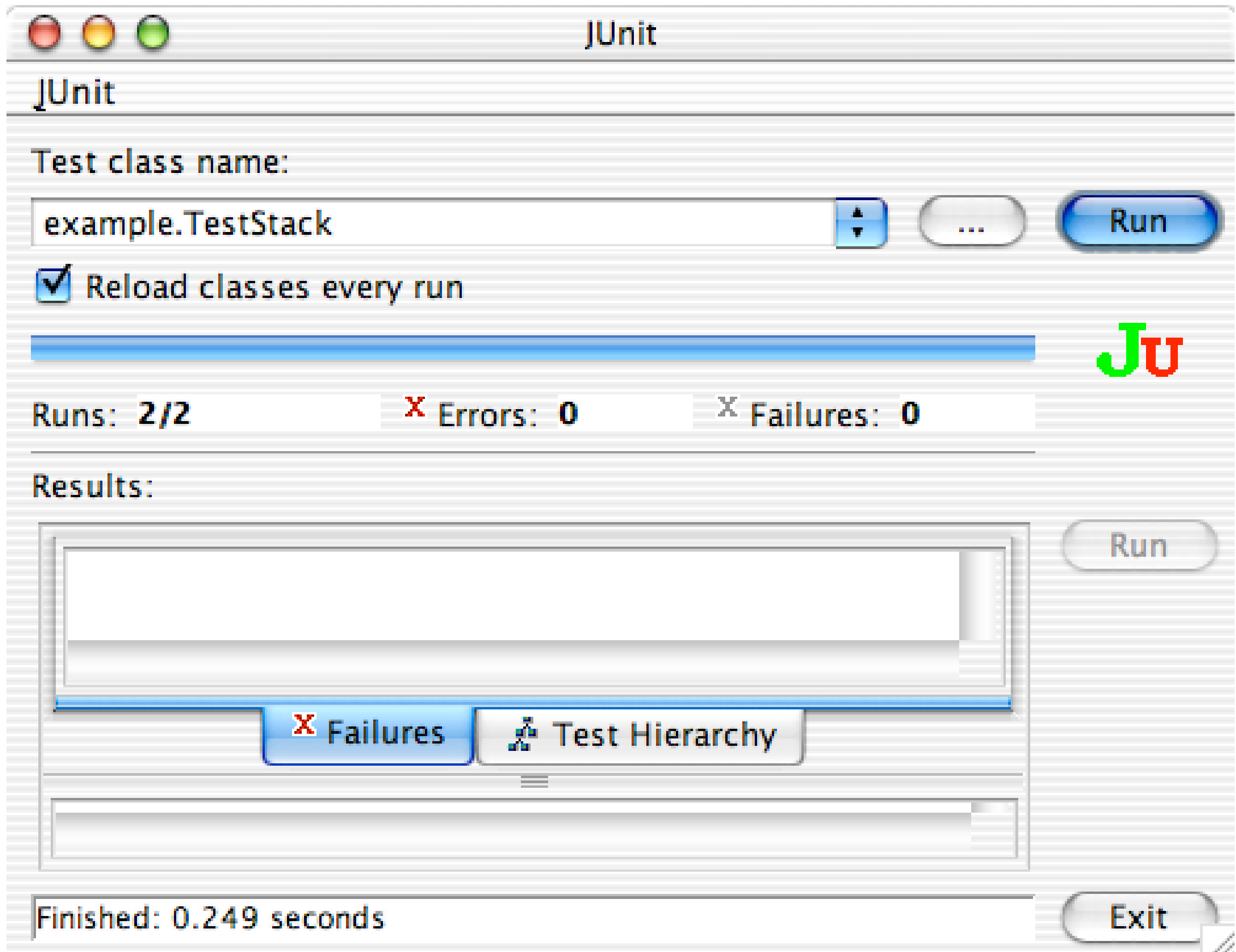
Click on the Run button

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

```
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()
fail()

For a complete list of the assert methods & arguments see

http://www.junit.org/junit/javadoc/3.8/index.htm/allclasses-frame.html/junit/junit/framework/Assert.html/Assert.html

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

```
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.AssertionFailedE
rror: Default constructor
	at example.TestStack.testDefaultConstructor(TestStack.java:22)
	at Testing.main(Testing.java:14)
2)
testSizeConstructor(example.TestStack)junit.framework.AssertionFailedErro
r
	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

```
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

StackTest
QueueTest

```
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

```
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 two 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 pubic 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 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