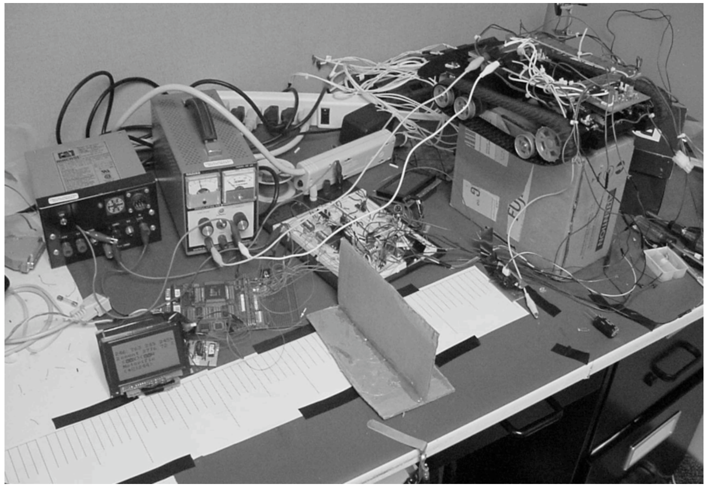
Unit Testing
JUnit and Coverage

Software Engineering



Chair of Programming Methodology

Eidgenössische Technische Hochschule Zürich
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Agenda for Today

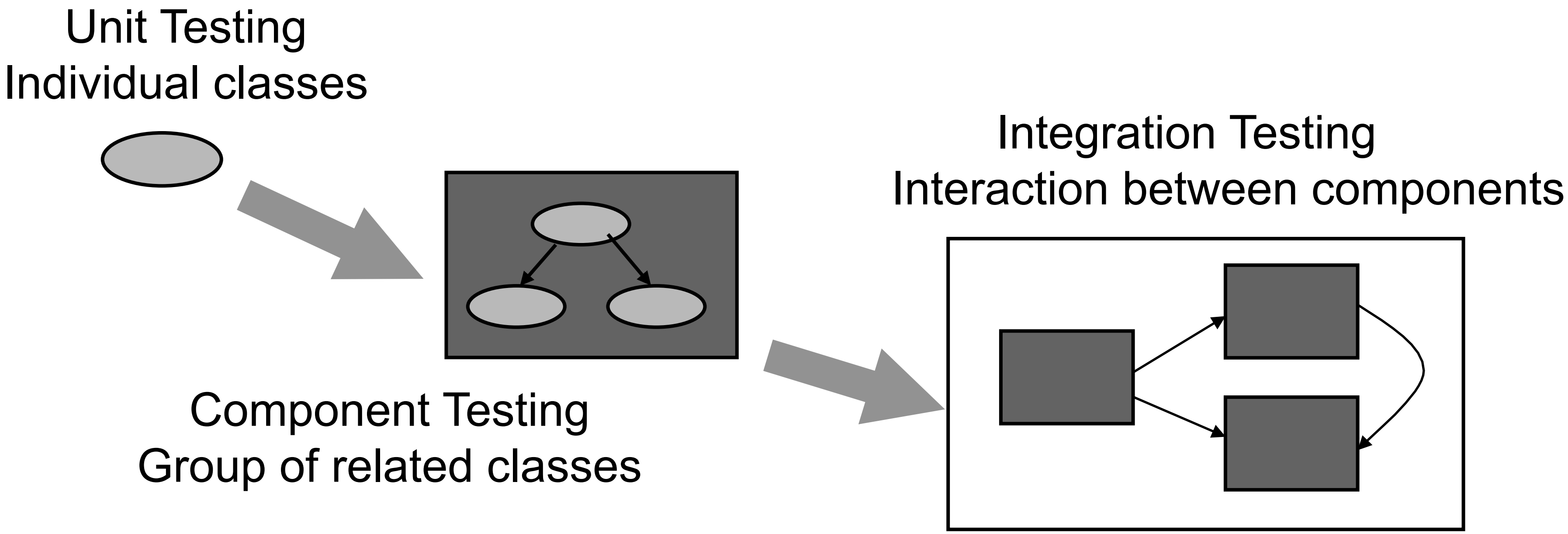
1. Testing
2. Main Concepts
3. Unit Testing – JUnit
4. Test Evaluation – Coverage
5. Reference

Software Testing

- Goal: find many errors before shipping software
  - Higher cost to fix errors after deployment
  - Higher acceptance and confidence of users
- Scientific approach
  - Proof correctness and completeness of code
- Pragmatic approach
  - Try out software in typical usage scenarios
- Fact
  - Testing does not guarantee the absence of errors

Testing Scope

- Testing in the small
  - Exercising the smallest executable units of the system
- Testing in the large
  - Putting the entire system to the test



Unit Testing
Individual classes

Integration Testing
Interaction between components

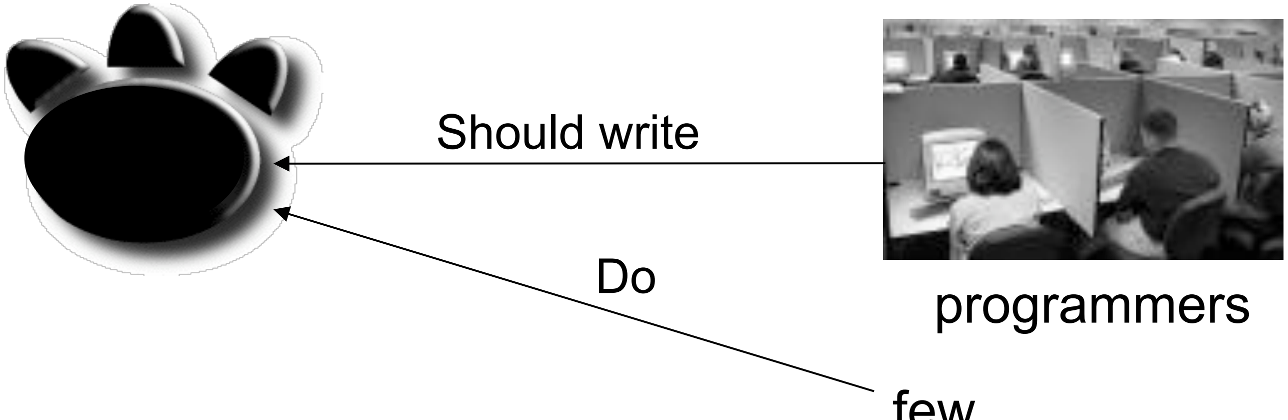
Component Testing
Group of related classes

Unit Testing

- Exercising the smallest individually executable units
- Objectives: find faults in the units, assure correct functional behavior of units
- Usually performed by programmers

- The Typical Test Cycle
  - Develop a suite of test cases
  - Create test fixtures to support each test case
  - Clean-up fixtures, if necessary
  - Run the test and capture test results
  - Report and analyze the test results

Testing Problem



Should write

Do

programmers

few

Why?

I am so busy…

It is difficult…

- Programmers need a tool to:

  "Write a few lines of code, then a test that should run; or even better, write a test that won't run, then write the code that will make it run."

JUnit

- Almost indisputably the single most important third-party Java library ever developed
- Fueled the testing explosion
  - Inspired a whole family of xUnit tools:
    NUnit(.net), PyUnit(Python), CppUnit(c++), DUnit(delphi), …
  - increasing number of extensions: JMLUnit, SQLUnit, XMLUnit
- IDE integration
  - NetBeans, BlueJ, IntelliJ, JBuilder, Eclipse, …
- open source

"Never in the field of software development was so much owed by so many to so few lines of code."
Martin Fowler

Detailed Look

- Written by Erich Gamma (of Design Patterns fame) and Kent Beck (creator of XP methodology)
- A simple framework to write and run repeatable tests
- JUnit features include:
  - Assertions for testing expected results
  - Test fixtures for sharing common test data
  - Test suites for easily organizing and running tests
  - Graphical and textual test runners

- JUnit 3.8.2: old stable version
  - Naming conventions and reflection
- JUnit 4.5: new stable version
  - Using Java 5 annotations

Terminology

- Test Case
  - defines a method to run a set of tests
- Test Suite
  - a collection of related test cases
- Test Fixture
  - a common set of test data and collaborating objects shared by many tests
  - Generally are implemented as instance variables in the test class
- Test Runner
  - runs tests and reports results
- Errors and failures
  - An error is some unanticipated failure (e.g., an exception thrown inside the tested code)
  - A failure is anticipated, and is produced by a call of an assertXXX method

JUnit 3.x Testing Steps

1. Create a test class
    - Import junit.framework.*
    - Declared as a subclass of TestCase
- Create Test Case
    - Name the test method as testXXX
    - Asserts the expected results on the object under test
- Use Test Fixture when necessary

1. Check for expected exceptions
2. Run the tests in the console or IDE

Example: Money class

```
import org.junit.*;
import static org.junit.Assert.*;
import java.util.*;

public class Money {
	private int fAmount;
  private String fCurrency;

	public Money(int amount, String currency) {
    fAmount=amount; fCurrency=currency; }

	public int amount() { return fAmount; }

	public String currency() { return fCurrency; }

	public Money add(Money m) {
    return new Money(  amount()+m.amount(),
                         currency()); }
}
```

Test method

```
public class MoneyTest extends TestCase {// test class
  public void testadd() {                    // test method
    // create the test fixture
     Money m12CHF = new Money(12, "CHF");
     Money m14CHF = new Money(14, "CHF");
    Money expected = new Money(26, "CHF");
    Money result = m12CHF.add(m14CHF);
    // verify the result, use assertEquals in this example
     Assert.assertEquals(expected,result);
  }
}
```

JUnit Assertions

- Within a test
  - Call the method being tested and get the actual result
  - Assert what the correct result should be with one of the provided assert methods
  - These steps can be repeated as many times as necessary

- An assert method
  - Is a JUnit method that performs a test
  - Throws an AssertionFailedError if the test fails
  - JUnit catches these Errors and shows you the result

JUnit Assertions (Cont’d)

- assertTrue(boolean test)
  assertFalse(boolean test)
  assertEquals(Object expected, Object actual)
  assertSame(Object expected, Object actual)
  assertNotSame(Object expected, Object actual)
  assertNull(Object object)
  assertNotNull(Object object)
  fail()
- assertXXX(**String** ***message***, …)
  - Throws an AssertionFailedError if the test fails
  - The optional *message* is included in the Error

Use of Fixtures

- Some test cases act on similar sets of objects
  - Create a fixture instead of declaring them in all methods
  - Write as many Test Cases as you like
  - Add as many test methods as you like

- Use in detail
  - Add fields for each part of the fixture
  - Define setUp to initialize the fields
  - Define tearDown to release any permanent resources

Test Runners

- Run the tests and collect the results
- Make sure that the **`junit.jar`** file is on classpath
- Textual/graphical user interface
  - Command line:

```
java junit.textui.TestRunner  <test class name>
java junit.swingui.TestRunner  <test class name>
```

  - Ant task (See `<junit>` tag)
- May use a main() method:

```
 public static void void
main(String
a
rgs
[]) {          junit.textui.TestRunner.run(suite());}
java junitfaq.SimpleTest
```

JUnit 4

- Forward and backward compatibility
  - JUnit4 can run JUnit 3 tests without any changes
  - To enable JUnit 4 tests to run in JUnit 3 environments, use JUnit4TestAdapter (see next slide)
- Java 5 annotations instead of naming conventions
- Free to use any superclass for tests
- Identify fixture methods with annotations, possible to have multiple fixture methods
- More annotations to simplify tests

Making a test class for Money

```
public class MoneyTest {
  @Test public void SimpleAdd() {
     Money m12CHF= new Money(12, "CHF");
     Money m14CHF= new Money(14, "CHF");
     Money expected= new Money(26, "CHF");
     Money result= m12CHF.add(m14CHF);

     Assert.assertTrue(expected.equals(result));
  }
}
```

Use of Fixtures

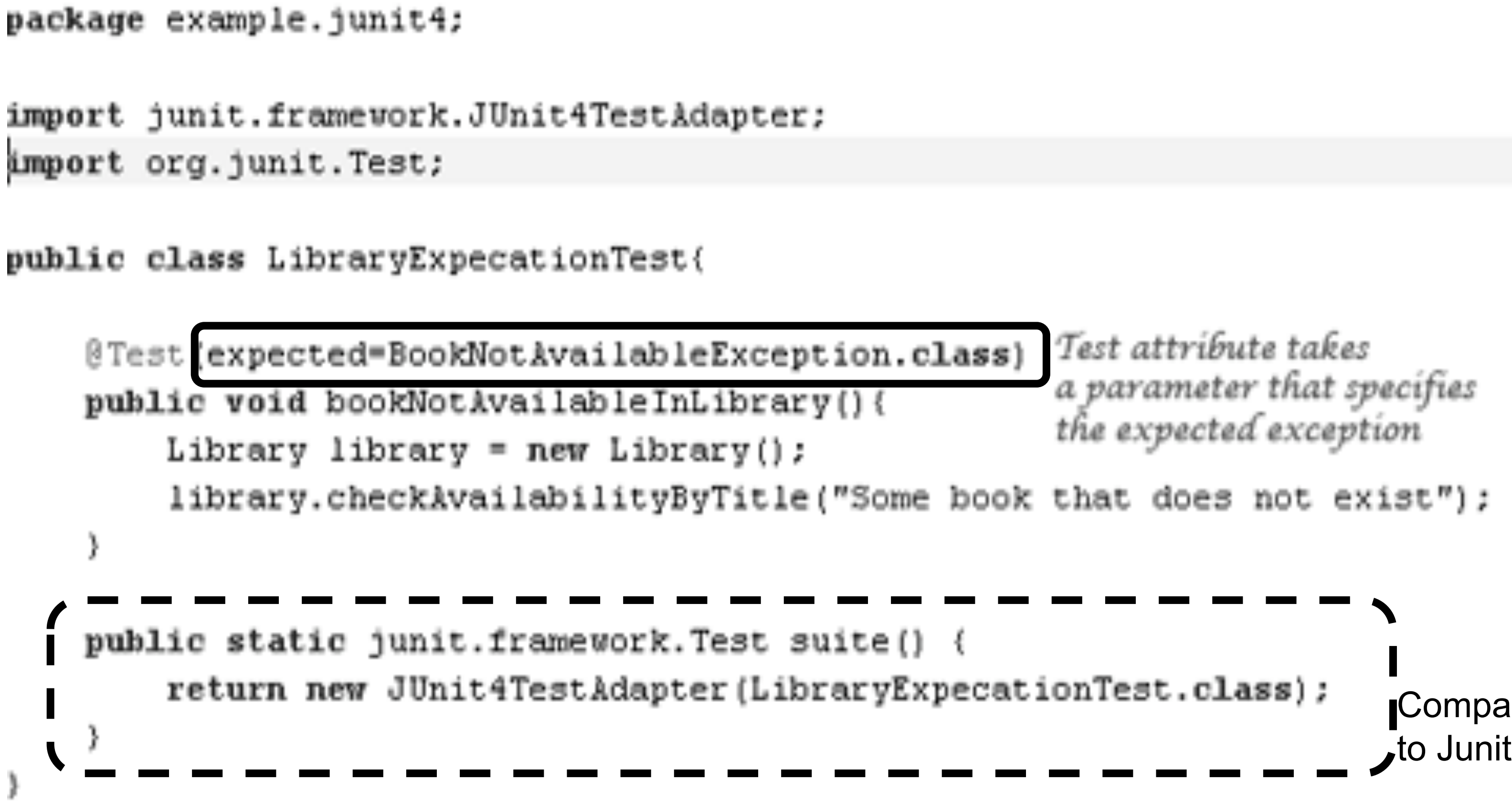
- when some test cases act on similar sets of objects
  - creating a fixture instead of declaring in all methods
  - write as many Test Cases as you'd like
  - add as many test methods as you'd like
- How to do
  - Add fields for each part of the fixture
  - Annotate a method with @Before and initialize the variables in that method
  - Annotate a method with @After to release any permanent resources you allocated in setUp
  - One-time setup and teardown for all classes: @_Class

Example: Use of Fixtures

```
public class MoneyTest {
  private Money m12CHF;  // fixture data
  private Money m14CHF;
  @Before public void setUp() {    // setting up fixture
     m12CHF= new Money(12, "CHF");
     m14CHF= new Money(14, "CHF");
  }
  @Test public void SimpleAdd() { // [12 CHF] + [14 CHF] = [26 CHF]
     Money expected= new Money(26, "CHF");
     Money result= m12CHF.add(m14CHF);
     Assert.assertTrue(expected.equals(result));
  }
}
```

JUnit 4: Expecting Exceptions

- @Test annotation takes a parameter declaring the type of Exception thrown (test fails if no exception is thrown) .



```java
package example.junit4;

import junit.framework.JUnit4TestAdapter;
import org.junit.Test;

public class LibraryExpecationTest{

    @Test(expected=BookNotAvailableException.class)
    public void bookNotAvailableInLibrary(){
        Library library = new Library();
        library.checkAvailabilityByTitle("Some book that does not exist");
    }

    public static junit.framework.Test suite() {
        return new JUnit4TestAdapter(LibraryExpecationTest.class);
    }
}
```

Test attribute takes a parameter that specifies the expected exception

Compatible to Junit 3.x

JUnit 4: Other Annotations

- Ignoring a test
  - @Ignore annotation tells the runner to ignore the test
  - @Ignore(“reason of why to ignore the test”) to pass in a string message to the runner and report it

- Timing out a test
  - @Test (timeout=10)
  - pass in a timeout parameter to the test annotation to specify the timeout period in milliseconds
  - If the test takes more, it fails

More Unit Testing Issues

- How do I test database dependent code?
  - dbUnit
- Should I test my web application? How?
  - HttpUnit
    - Parses HTML results into DOM
    - Easy link navigation and form population
    - Useful for automated acceptance tests
  - Canoo WebTest
    - HttpUnit inside Ant

A partial List of xUnit framworks:

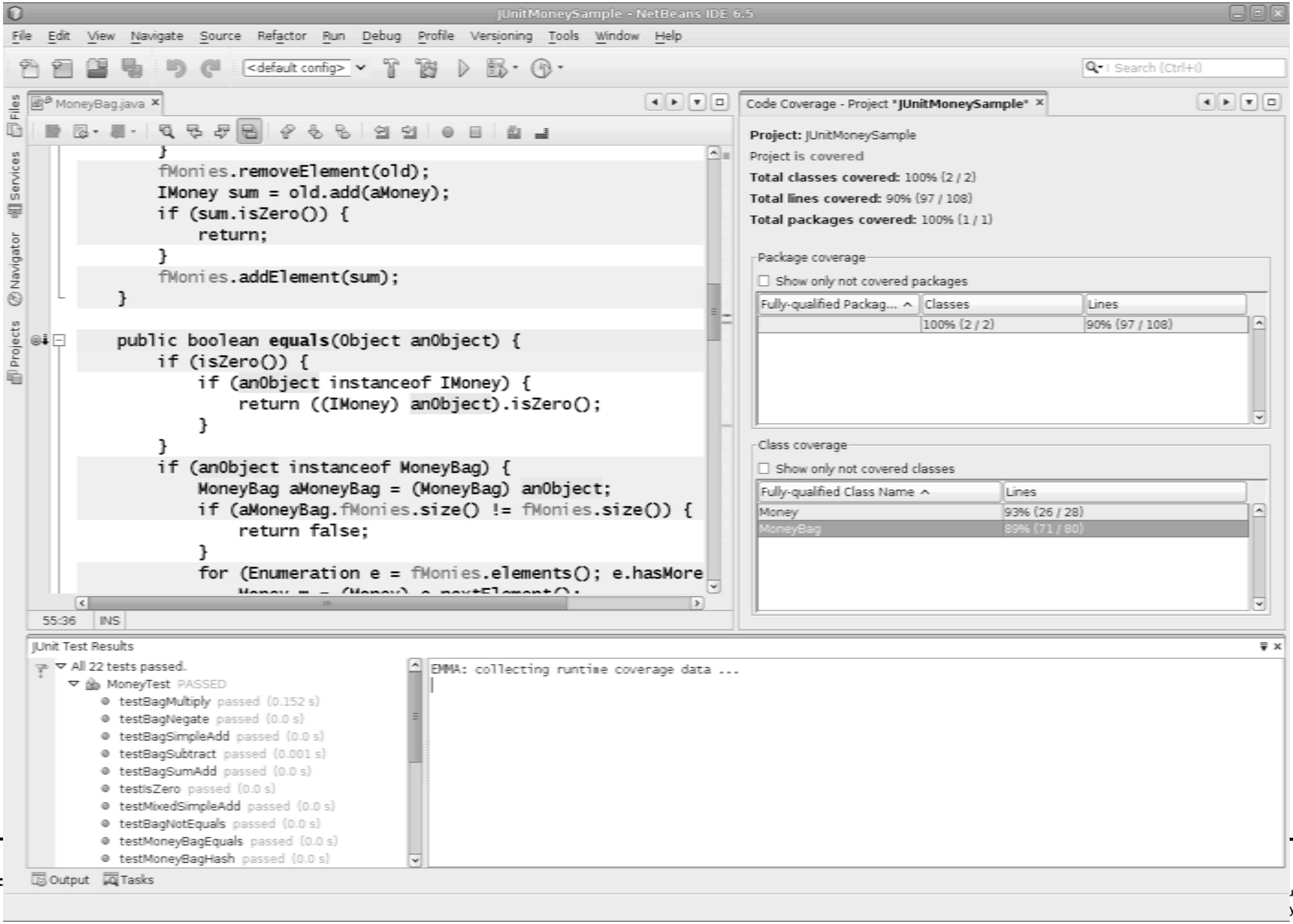
http://en.wikipedia.org/wiki/XUnit

Test Evaluation: Code Coverage

- How good is a test?
- Do we have enough test cases?
- Testing is inherently incomplete
  - Coverage metrics: quantitative evaluation of test suite
  - A test evaluation tool helps in assessing whether the test cases achieve good coverage or not

- Tools
  - Clover, Quilt, Emma, Coverlipse, JDepend, Cobertura, Java Test Coverage, …

Coverage Netbeans Plugin



```
        }
        fMonies.removeElement(old);
        IMoney sum = old.add(aMoney);
        if (sum.isZero()) {
            return;
        }
        fMonies.addElement(sum);
    }

    public boolean equals(Object anObject) {
        if (isZero()) {
            if (anObject instanceof IMoney) {
                return ((IMoney) anObject).isZero();
            }
        }
        if (anObject instanceof MoneyBag) {
            MoneyBag aMoneyBag = (MoneyBag) anObject;
            if (aMoneyBag.fMonies.size() != fMonies.size()) {
                return false;
            }
            for (Enumeration e = fMonies.elements(); e.hasMore
                Money m = (Money) e.nextElement();
```

55:36 INS

Code Coverage - Project "**JUnitMoneySample**"

Project: JUnitMoneySample

Project is covered

Total classes covered: 100% (2 / 2)

Total lines covered: 90% (97 / 108)

Total packages covered: 100% (1 / 1)

Package coverage

☐ Show only not covered packages

Fully-qualified Packag... ^	Classes	Lines
	100% (2 / 2)	90% (97 / 108)

Class coverage

☐ Show only not covered classes

Fully-qualified Class Name ^	Lines
Money	93% (26 / 28)
MoneyBag	89% (71 / 80)

JUnit Test Results

- All 22 tests passed.
  - MoneyTest PASSED
    - testBagMultiply passed (0.152 s)
    - testBagNegate passed (0.0 s)
    - testBagSimpleAdd passed (0.0 s)
    - testBagSubtract passed (0.001 s)
    - testBagSumAdd passed (0.0 s)
    - testIsZero passed (0.0 s)
    - testMixedSimpleAdd passed (0.0 s)
    - testBagNotEquals passed (0.0 s)
    - testMoneyBagEquals passed (0.0 s)
    - testMoneyBagHash passed (0.0 s)

```
EMMA: collecting runtime coverage data ...
```

JMLUnit

- A model-driven test generation tool, from Iowa State University
- One of a suite of tools based on the JML behavioral interface specification language
- Automatic generation of test oracles using
  - Formal specifications and
  - Runtime assertion checker
- License: open source

Summary

- “Any program feature without an automated test simply doesn’t exist”
- Testable code improves confidence and design
- Programmers can sleep better
- “Keep the bar green to keep the code clean!”

Reference

- JUnit http://www.junit.org
  http://junit.sourceforge.net/doc/cookbook/cookbook.htm
- Extreme programming

  http://www.xprogramming.com
- Coverage http://codecoverage.netbeans.org
- dbUnit http://www.dbunit.org
- HttpUnit http://www.httpunit.org
- Canoo WebTest http://webtest.canoo.com
- Software QA and Testing Resource Center http://www.softwareqatest.com
- JMLUnit http://jmlspecs.org