Software Engineering 2004

Testing Tools and Techniques

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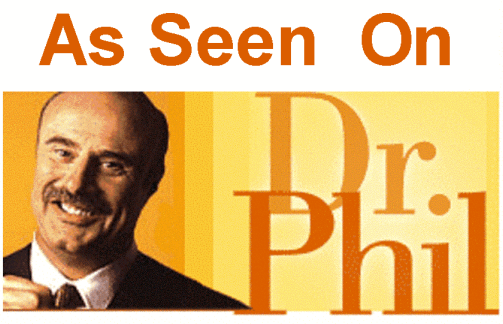
Testing Automation

"Design your world so that you can't help but succeed"

Creating a **no-fail environment**

- Version Control
- Testing
- Automation



Testing from *"Coding in Fear"* to *"Coding with Confidence"*

Testing Tools and Techniques

1. Unit Testing with JUnit
2. Mock Techniques
3. Domain Specific JUnit Extensions
4. Code Coverage Analyzers
5. Continuous Integration Tools
6. Design for Testing

Categories of Tools (1)

- General purpose test frameworks
  - JUnit
  - NUnit
- Support libraries
  - Mock Objects
- Domain-specific test frameworks
  - HttpUnit
  - XmlUnit
  - JfcUnit
- Memory management analyzers
  - Valgrind

Categories of Tools (2)

- Code coverage analysers
  - Clover
  - Quilt
- Test generators
  - jTest
- Stress Testing Tools
  - LoadSim, JUnitPerf
- Static analysis
  - Lint
  - FindBugs

JUnit

xUnit

- **xUnit** Family
  - Simplicity
  - Define, run, and check
- Instance: **JUnit**
  - Very simple: 5 classes in `junit.framework`
  - Many extensions
  - `http://www.junit.org`
- Instance: **NUnit**
  - .NET Attributes
  - `http://nunit.sf.net`

JUnit: Example

```
import junit.framework.TestCase;

public class TestSimple extends TestCase {

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

  public void testSplitEmpty() {
    String[] result = "  ".split("\\s+");
    assertEquals("Should not produce a token", 0, result.length);
  }

  public void testSplit2() {
    String[] result = "a   bc  ".split("\\s+");
    assertEquals("Should be 2 tokens", 2, result.length);
  }
}
```

JUnit: Grouping Tests

TestSuite

- `addTest(Test)`
- `addTestSuite(Class)`

How to construct a Test?

```
new MyTest("testFoo")
```

or

```
new MyTest("Some text") {
  public void runTest() {
    testFoo();
  }
}
```

JUnit: Grouping Tests

```
public class TestFoo extends TestCase {

  public TestFoo(String method) { ... }

  public void testFoo() { ... }
  public void testBar() { ... }

  public static Test suite() {
    TestSuite result = new TestSuite();
    result.addTest(new TestFoo("testFoo"));
    result.addTest(new TestFoo("testBar"));
    return result;
  }
}
```

or:

```
    return new TestSuite(TestFoo.class);
```

JUnit: Grouping Tests

Typical composition class:

```
public class TestAll {
  public static Test suite() {
    TestSuite result = new TestSuite("All tests");
    result.addTestSuite(TestFoo.class);
    result.addTestSuite(TestBar.class);
    return result;
  }
}
```

JUnit: Running a Test

TestRunner

- invokes `suite` method
- or constructs `TestSuite`

Graphical

```
$ java junit.swingui.TestRunner
```

Textual

```
$ java junit.textui.TestRunner
```

JUnit: Assertions

"Real testing checks results"

- `assertTrue`, `assertFalse`
- `assertEquals`
- `assertSame`
- `assertNotNull`
- `fail`

Advice: Use `assert*` with a failure message.

JUnit: Fixture per Test

```
private XMLReader _reader;

protected void setUp() throws Exception {
  SAXParserFactory factory = SAXParserFactory.newInstance();
  factory.setNamespaceAware(true);
  factory.setValidating(false);
  _reader = factory.newSAXParser().getXMLReader();
}

protected void tearDown() {
  _reader = null;
}

public void testFoo () throws Exception {
  _reader.parse(new InputSource(new StringReader("<Foo/>")));
  // I want to assert something :(
}
```

Fixture `setUp` and `tearDown` is performed for every test.

JUnit: Fixture per Suite

```
TestSetup wrapper = new TestSetup(suite) {
  protected void setUp() {
    oneTimeSetUp();
  }

  protected void tearDown() {
    oneTimeTearDown();
  }
};
```

Don't use static initializers.

Must be in static variables.

JUnit: (Excepted) Exceptions

Not expected: don't catch, just throw!

```
public void testRead () throws IOException {
  StringReader reader = new StringReader("SWE!");
  assertEquals("First char must be S", reader.read(), 'S');
}
```

Expected: try-fail-catch

```
public void testList () {
  List<String> list = new ArrayList<String>();
  list.add("Foo");

  try {
    String reuslt = list.get(1);
    fail("Not a valid index.");
  } catch(IndexOutOfBoundsException exc) {
    assertTrue(true);
  }
}
```

JUnit: Best Practices (1)

- Make a test fail now and then
  "Spring the Trap"
- Keep tests **independent**
  - No order guarantee
  - Separate instances for every test
- Custom, domain-specific **asserts**
- **Design** test code.
  - Production/Test : 50/50
  - Tests are not a list of statements.

JUnit: Best Practices (2)

- Test just **one** object
  - Mock up related objects
- Write test back (asserts) first.
- Don't use the same value twice $(1 + 1)$
- Don't break **encapsulation** for testing.
  - Test code in same package
  - Use parallel source trees
- Testing is not an end in itself

JUnit: More Automation

Why not build in IDE?

- Poor automation, building from source, deployment

$\Rightarrow$ Integrate in automated build process.

```
<junit printsummary="yes" haltonfailure="yes">
  <classpath>
    <path refid="project.cp"/>
    <pathelement location="${build.tests}"/>
  </classpath>
  <formatter type="plain"/>
  <test name="org.foo.TestAll" />
</junit>
```

`batchtest`: compose tests in Ant

JUnit: Fancy Reports

Formatter

```
<junit ...>
  ...
  <formatter type="xml"/>
  <test todir="$builddir/reports" ... >
</junit>
```

Report Generation

```
<junitreport>
  <fileset dir="$builddir/reports">
    <include name="TEST-*.xml"/>
  </fileset>

  <report todir="$builddir/reports/html"/>
</junitreport>
```

JUnit: Further Reading

- *"Pragmatic Unit Testing in Java and JUnit"*
- *"JUnit in Action"*
- *"Java Open Source Programming with XDoclet, JUnit, WebWork, Hibernate"*
- `http://www.junit.org`

Mock Techniques

Mock Objects: Rationale

- Test just one thing
- Tests should focus. Be Independent.
- Faulty code $\Leftrightarrow$ Test

But ... What if code is not just 'one thing'?

$\Rightarrow$ **Fake** the other 'things'!

$\Rightarrow$ **Mock objects**

Use Mock Objects If ...

- Behaviour that is beyond your control.
- Exceptional situations (difficult to reproduce)
- External resources (server, database)
- Lot of code to setup.
- Expensive, poor performance
- Reflection and interaction: How was code used?
- Non-existing code.

Solution: Test the Interactions

- More difficult with state
  - Is the content type set?
  - Is the 'temp directory' method not invoked twice in a session?
  - Is a topic scheduled for indexing?
  - Is a stream closed?
- Almost impossible with state
  - Is the request's pathinfo requested when ShowFile is invoked?
  - Are the access flags checked when a topic is requested?
  - Is the log function invoked with an error?

Mock Object Generators

At compile-time

- MockMaker – `http://mockmaker.sf.net`
- MockCreator – `http://mockcreator.sf.net`

At runtime

- DynaMock – `http://www.mockobjects.com`
- jMock – `http://www.jmock.org`
- EasyMock – `http://www.easymock.org`

Features

- Define Expectations
- Mock-ready implementations of standard libraries

Mock Objects: EasyMock

Expectations as actual method calls!

Mock Control

- Record and replay mode.
- Control, StrictControl, NiceControl

MockControl methods

- `getMock()`
- `replay()`, `verify()`
- `setReturnValue`, `setThrowable(...)`

`http://www.easymock.org`

EasyMock: Example 1

```
private XMLReader _reader;
private MockControl _control;
private ContentHandler _handler;

protected void setUp() throws Exception {
  ...

  _control = MockControl.createNiceControl(ContentHandler.class);
  _handler = (ContentHandler) _control.getMock();
  _reader.setContentHandler(_handler);
}

public void testFoo () throws Exception {
  _handler.endElement("", "Foo", "Foo");
  _control.replay();

  _reader.parse(new InputSource(new StringReader("<Foo/>")));
  _control.verify();
}
```

EasyMock: Example 2

```
protected void setUp() throws Exception {
  ...
  _control = MockControl.createStrictControl(ErrorHandler.class);
  _handler = (ErrorHandler) _control.getMock();
  _reader.setErrorHandler(_handler);
}

public void testIllegalFoo() throws Exception {
  _handler.fatalError(null);
  _control.setMatcher(MockControl.ALWAYS_MATCHER);
  _control.replay();

  try {
    _reader.parse(new InputSource(new StringReader("<Bar></Bar>")));
  } catch(SAXParseException exc) {
    assertTrue(true);
  }
  _control.verify();
}
```

Mock Objects: Limitations

- Requires an interface: implementation must be substitutable.
  - Design for Testing
  - Example: test if a `strong` element is created.
    Use `JDOMFactory`
- Requires 'mock-ready' libraries. Many libraries do not allow this kind of configuration.
- DynaMock: no type checking by compiler.
- DynaMock: verbose constraints and return values.
- Easy to break the real code: what does it use?

Mock Objects: Further Reading

- *"Endo Testing: Unit Testing with Mock Objects"* (XP2000)
- *"Mock Objects"* in *"Pragmatic Unit Testing"*
  Sample chapter available online
- `www.mockobjects.com`

Domain specific extensions

Some Popular Extensions

- Web Applications
  e.g. HttpUnit
- Performance
  e.g. JUnitPerf
- Integration
  e.g. Cactus (J2EE)
- GUI Applications
  e.g. JfcUnit
- XML Processing
  e.g. XML Unit

JUnitPerf: Test Decorators

TimedTest

```
Test testCase = ... ;
Test timedTest = new TimedTest(testCase, 2000);
```

LoadTest

```
Test testCase = ... ;
Test loadTest = new LoadTest(testCase, 25);
```

RepeatedTest

```
Test testCase = ...;
Test repeatedTest = new RepeatedTest(testCase, 10);
Timer timer = new ConstantTimer(1000)
Test loadTest = new LoadTest(repeatedTest, 25, timer);
```

http://www.clarkware.com/software/JUnitPerf.html

XML Processing: XMLUnit

Handy utils for XML, XPath, XSLT.

`XMLTestCase`: `assertXMLEqual`

- Identical / similar
- Meaningful diff messages

`Transform`

- Easy to use in XSLT tests

`Validator`

- Tools for DTD and Schema validation

`http://xmlunit.sf.net`

Testing Web Applications

Some Issues

- Security
  - Resources protected?
  - Unexpected input?
  - ... not generated by a browser?
- Validation of XHTML, CSS, JavaScript
- Check broken links
- Are files served correctly? (type)
- Does my caching mechanism work?
- Can you handle loads of users?

Unit Testing of Java Web Applications

- **Servlet Unit Testing**
  - Mock objects for servlets container
  - Servlet container: difficult to mock
  - Mock Objects Framework implements servlet mocks
- **In-Container Integration Testing**
  - Cactus (J2EE integration tests)
  - Rather heavy-weight
- **Functional Testing**
  - Simulate browser
  - HttpUnit

Servlet Testing with Mock Objects

Approach

- Mock the objects on which a servlet depends.
- Mock the servlet container.

Implementation (mockobjects.com)

- `MockHttpServletRequest`
  - Supports expectations
    e.g. `request.setExpectedError(SC_NOT_FOUND)`
  - Verify: request.verify();
- `MockServletConfig`
- `MockServletInputStream`
- ...

Servlet Container Mock: (Dis)advantages

- Possible to mock the dependencies of servlets
- Tends to be close to functional testing
- Why not test at the client-side?

In general: Leave servlet specific environment as soon as possible.

HttpUnit: Functional Testing

- Automated functional tests ⇒ No need for checking the site by hand.
- Targets programmers
- Simplicity. Just code.
- Well-designed web applications:
  - Request/response is unit
  - Possible to test

Supports frames, forms, JavaScript, basic HTTP authentication, cookies and redirection.

`http://httpunit.sf.net`

HttpUnit: Hello World

- WebClient / WebConversation
- WebRequest
- WebResponse

```
WebClient client = new WebConversation();
WebResponse response = client.getResponse("http://www.cs.uu.nl/groups/ST/Gw");
WebLink link = response.getLinkWith("Vision");
WebRequest request = link.getRequest();
```

Links:

- `WebLink[] getLinks`
- `WebLink getLinkWith`
- `WebLink getLinkWithID`
- `WebLink getLinkWithImageText`

HttpUnit: Working with Forms

Retrieving values from a form:

```
WebForm form = response.getForms()[0];
assertEquals("Martin Bravenboer", form.getParameterValue("name"));
assertEquals("", form.getParameterValue("password"));
assertEquals("", form.getParameterValue("password2"));
```

Submitting a form:

```
form.setParameter("name", "Martin Bravenboer");
form.setParameter("password", "foobar");
form.setParameter("password2", "foobar");
form.sumbit();
```

Testing Web Applications: Further Reading

- `http://www.c2.com/cgi/wiki?ServletTesting`
- *"Testing a Servlet"* in *"Mock Objects"* in *"Pragmatic Unit Testing"*
- *"Unit Testing Servlets and Filters"* in *"JUnit in Action"*
- *"In-container Testing with Cactus"* in *"JUnit in Action"*
- *"Functional Testing with HttpUnit"* in *"Java Tools for Extreme Programming"*

Code Coverage Analyzers

Code Coverage Analysis

- How well is the code exercised?
- Improving Coverage
  - Write more tests
  - Refactoring
    - Eliminate duplication
    - More reuse

Implementations

- Clover – Closed Source. Free for non commercial use
  `http://www.cenqua.com/clover/index.html`
- JCoverage – GPL/Closed Source `http://www.jcoverage.com`
- Quilt – Open Source `http://quilt.sf.net`
- NoUnit – Open Source `http://nounit.sf.net`

Clover coverage report - Checkstyle Project
Coverage timestamp: Thu Aug 26 2004 12:35:30 EST
Overview **Package** File
FRAMES NO FRAMES

package stats: LOC: 4,649 Methods: 213
NCLOC: 2,974 Classes: 34
Files: 26

Package	Conditionals	Statements	Methods	TOTAL
com.puppycrawl.tools.checkstyle	67.6%	79.7%	87.8%	**78.8%**

Classes	Conditionals	Statements	Methods	TOTAL
AllTests	-	0%	0%	**0%**
Main	0%	0%	0%	**0%**
PropertyCacheFile	21.4%	14%	66.7%	**19.5%**
TreeWalker.SilentJava14Recognizer	-	100%	50%	**60%**
DefaultLogger	58.3%	80.6%	55.6%	**71.2%**
PropertiesExpander	50%	75%	100%	**75%**
Checker	63.2%	83.4%	87.5%	**78.1%**
Checker.ErrorCounter	50%	80%	85.7%	**78.6%**
TreeWalker	87.5%	80.3%	90%	**82.8%**
DebugAuditAdapter	-	87.5%	87.5%	**87.5%**
PackageNamesLoader	80%	88.6%	100%	**88.7%**
DefaultConfiguration	50%	90%	100%	**89.5%**
PackageNamesLoaderTest	-	86.7%	100%	**89.5%**
ConfigurationLoader	87.5%	91.3%	100%	**91%**
ConfigurationLoaderTest	100%	91.8%	100%	**93.5%**
ConfigurationLoader.InternalLoader	90%	95%	100%	**93.9%**
PackageObjectFactoryTest	-	91.7%	100%	**94.1%**
UtilsTest	-	94.4%	100%	**95%**
XMLLogger	90%	98.7%	100%	**97.1%**
StringArrayReaderTest	-	98.1%	100%	**98.2%**
CheckerTest	50%	100%	100%	**99.2%**
BaseCheckTestCase	100%	100%	100%	**100%**
BaseCheckTestCase.BriefLogger	-	100%	100%	**100%**
DebugChecker	-	100%	100%	**100%**
DebugFilter	-	100%	100%	**100%**
DefaultContext	-	100%	100%	**100%**
OptionTest	-	100%	100%	**100%**
PackageObjectFactory	100%	100%	100%	**100%**
StringArrayReader	100%	100%	100%	**100%**
XMLLoggerTest	100%	100%	100%	**100%**
XMLLoggerTest.TestThrowable	-	100%	100%	**100%**

Clover: Example

```
120   0     public void addException(AuditEvent aEvt, Throwable aThrowable)
121         {
122   0         synchronized (mErrorWriter) {
123   0             mErrorWriter.println("Error auditing " + aEvt.getFileName());
124   0             aThrowable.printStackTrace(mErrorWriter);
125         }
126     }
```

```
154   347     protected void closeStreams()
155           {
156   347         mInfoWriter.flush();
157   347         if (mCloseInfo) {
158   347             mInfoWriter.close();
159           }
160
161   347         mErrorWriter.flush();
162   347         if (mCloseError) {
163     0             mErrorWriter.close();
164           }
165       }
```

Continuous Integration Tools

- Types of Automation
  - Commanded Automation
  - Scheduled Automation
  - Triggered Automation
- Integrate components as early and often as possible.
- Server monitors repository
- Avoid big bang integration
- Requires
  - Automated build process
  - Automated distribution process
  - Automated deploy process

Continuous Integration: Implementations

- CruiseControl (for Java)
- AntHill
  - Handle multiple projects and their dependencies
  - Separate checkouts
  - Time-based build scheduler (instead of commit push)
  - Bad experience with time-based scheduling.
  - `http://www.urbancode.com/projects/anthill/`
- Daily Build System
  - **continuous** stresses that a daily build is not enough
  - StrategoXT: Daily builds -¿ Nix Buildfarm
  - `http://www.program-transformation.org/Tools/DailyBuildSystem`
- Nix Buildfarm

Continuous Integration: CruiseControl

- Repeated builds
- Builds jobs implemented in Ant
- Trigger: modification checks
  CVS, Subversion, VSS, file system, HTTP and more.
- Publishers
  Status, Email, SCP, FTP

Limitations

- SCM logic in build files
- No managing of dependencies (Maven is supported)

`http://cruisecontrol.sf.net`

Nix Continuous Integration System

- Nix: dependencies and their configuration
- Nix: caching for free
- Functional abstraction: variants
- Distributed builds
- Building RPMs in User-Mode Linux

Prototype limitations

- Supports Subversion only
- Lack of status interface
- Abstractions targeted at GNU packages.

Eelco Dolstra will tell more about this.

`http://www.cs.uu.nl/groups/ST/Buildfarm`

Continuous Integration: Further Reading

- *"Pragmatic Project Automation: How to Build, Deploy, and Monitor Java Applications"*

  Excerpts available

- *"Continuous Integration"* (Martin Fowler)

  `http://www.martinfowler.com/articles/continuousIntegration.html`

Design for Testing

Design for Testing

"Your code sucks if it isn't testable"

Dave Astels, an Artima Blogger

- Separation of concerns
  $\Rightarrow$ Separate, independent tests
  $\Rightarrow$ Faulty code easier to identify
- Design for flexibility.
  - Testing requires different implementations
- Unit testing improves the design of code
  - Small methods
  - Reduction of side effects
  - More explicit arguments

Design for Testing: 'Inversion of Control'

- aka 'Dependency Injection', 'Tell, Don't Ask'
- Connecting stuff
- Don't let objects collect their own stuff
- Push versus pull
- Container/Context: the container sets everything an object needs
- Allows replacement with a Mock.

Design for Testing: 'Reduce Coupling'

- No static singletons
  - Cannot be replaced
  - Might not be cleared while running several tests
- Use factories instead of explicit instantiation
  For example "Registry"
  - Scope: process, thread, session
  - Static method can hide a 'thread-scoped' data
- **Law of Demeter**
  Method target restricted to 'local' or 'global' objects

Design for Testing: 'Gateway'

"Encapsulate access to external systems and resources"

- Libraries
- Services
- Databases

Implementation

- Create an API for your usage
- Translate into external resource invocation

Use *"Separated Interface"*

- Real Implementation
- *"Service Stub"* implementation (Mock)

Design for Testing: Further Reading

- *"Patterns of Enterprise Application Architecture"*

  `http://c2.com/cgi/wiki?PatternsOfEnterpriseApplicationArchitecture`

- *"Tell, Don't Ask"*

  `http://www.pragmaticprogrammer.com/ppllc/papers/1998_05.html`

  `http://c2.com/cgi/wiki?TellDontAsk`

- *"Law of Demeter"*

  `http://c2.com/cgi/wiki?LawOfDemeter`

- *"Design Patterns: Elements of Reusable Object-Oriented Software"*

  http://c2.com/cgi/wiki?DesignPatternsBook