An Introduction into JUnit

Praxis der Software-Entwicklung 2010/11
Daniel Bruns  Erik Burger | January 18, 2011
Program testing can be used to show the presence of bugs, but never to show their absence!

Dijkstra, 1972
Classification of Tests

Functional Tests
- Correctness according to specification
- Concurrency/Thread safeness

Non-Functional
- Performance
- Security
- Usability
- Interoperability
- Reliability
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**Knowledge**
- black-box tests
- white-box tests

**Structure**
- Unit
- Integration
- System
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- Object oriented classes often have dependencies on other classes
- A lot of classes cannot be tested independently
- → micro integration tests
- Starting from a certain degree of dependencies, test effort rises disproportionately high
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- Test represent typical usage scenarios
- Less dependencies → easier to use
- High degree of dependencies
  - Lack of modularisation?
  - Bad design?
  - Bad code dependency management
- → Refactoring
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Test Coverage

Types of coverage

- Statement coverage (Anweisungsüberdeckung)
- Branch coverage (Zweigüberdeckung)
- Path coverage (Pfadüberdeckung)
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public int foo (int x, int y) {
    int z = 0;
    if (y != 0) {
        while (x != 0) {
            if (x > 0) {
                z += y;
                x--;
            } else {
                z -= y;
                x++;
            }
        }
    }
    return z;
}
Control Flow Graph

z = 0

y != 0

x != 0

return z

x > 0

z += y; x--

z -= y; x++
Control Flow Graph

\[ z = 0 \]

\[ y \neq 0 \]

\[ x \neq 0 \]

\[ x > 0 \]

\[ z += y; x-- \]

\[ z -= y; x++ \]

return z
z = 0

y != 0

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x != 0

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Testing
Daniel Bruns, Erik Burger – JUnit

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\[ y \neq 0 \]

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return \( z \)

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Test Design

Equivalence classes

- Assumption: similar control flow for similar values
- Last example: 3 test needed for full branch coverage
- Equivalence classes:

Extreme values

- Variant of equivalence classes approach
- “Off-by-one” most prominent error
- Extreme values for integers: MIN_VALUE, -1, 0, 1, MAX_VALUE, someArray.length
- Extreme values for objects: null, empty strings, empty collections
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  \[
  \{(x, y) \mid y = 0\}, \{(x, y) \mid y \neq 0 \land x > 0\}, \{(x, y) \mid y \neq 0 \land x \leq 0\}\]

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JUnit

2 Overview

3 Assertions

4 Fixtures
   • Definition
   • Example
   • Parameterised Tests
   • Test Suites

5 Eclipse Integration
   • Test Runners
JUnit is a framework for writing tests

- JUnit uses Java’s reflection capabilities (Java programs can examine their own code)
- JUnit helps the programmer:
  - define and execute tests and test suites
  - formalize requirements and clarify architecture
  - write and debug code
  - integrate code and always be ready to release a working version
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JUnit inspired various other unit testing frameworks for other programming languages, like NUnit (.NET), CppUnit(C++)

JUnit is the de facto standard for test driven Java development.
JUnit

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JUnit 3 vs JUnit 4

JUnit4

- JUnit4 was a complete redevelopment
- includes ideas from other frameworks and uses features of Java 1.5
- uses Java annotations (like @Test)
- This lecture is based on JUnit 4

Be careful

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A test case tests (insofar as possible) a single method
You can have multiple test cases for a single method
A test suite combines unit tests
The test fixture provides software support for all this
The test runner runs unit tests or an entire test suite
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Test Case Verdicts

- **A verdict** is the declared result of executing a single test.
- **Pass**: the test case achieved its intended purpose, and the software under test performed as expected.
- **Fail**: the test case achieved its intended purpose, but the software under test did not perform as expected.
- **Error**: the test case did not achieve its intended purpose.

Potential reasons:
- An unexpected event occurred during the test case.
- The test case could not be set up properly.
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What is a JUnit Test?

A test “script” is just a collection of Java methods.
General idea is to create a few Java objects, do something interesting with them, and then determine if the objects have the correct properties.

What is added? Assertions.

- A package of methods that checks for various properties:
  - “equality” of objects
  - identical object references
  - null / non-null object references

- The assertions are used to determine the test case verdict.
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Organisation of JUnit Tests

- Each method represents a single test case that can independently have a verdict (pass, error, fail).
- Normally, all the tests for one Java class are grouped together into a separate class.
- Naming convention:
  - Class to be tested: Value
  - Class containing tests: ValueTest
Writing a JUnit test class

Start by importing these JUnit 4 classes

```java
import org.junit.*;
import static org.junit.Assert.*; // note static import
```

Declare your test class in the usual way

```java
public class MyProgramTest {
}
```

Declare an instance of the class being tested

```java
public class MyProgramTest {
    MyProgram program;
    int someVariable;
}
```
import org.junit.*;
import static org.junit.Assert.*;

public class ArithmeticTest {
    @Test
    public void testMultiply() {
        assertEquals(4, Arithmetic.multiply(2, 2));
        assertEquals(-15, Arithmetic.multiply(3, -5));
    }

    @Test
    public void testIsPositive() {
        assertTrue(Arithmetic.isPositive(5));
        assertFalse(Arithmetic.isPositive(-5));
        assertFalse(Arithmetic.isPositive(0));
    }
}
Assertions

Assertions are defined in the JUnit class Assert

- If an assertion is true, the method continues executing.
- If any assertion is false, the method stops executing at that point, and the result for the test case will be fail.
- If any other exception is thrown during the method, the result for the test case will be error.
- If no assertions were violated for the entire method, the test case will pass.

All assertion methods are static methods.
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Assertion Methods

Boolean conditions are true or false

assertTrue(condition)
assertFalse(condition)

Objects are null or non-null

assertNull(object)
assertNotNull(object)

Objects are identical (i.e. two references to the same object), or not identical.

assertSame(expected, actual)
assertNotSame(expected, actual)
Assertion Methods

“Equality” of objects

`assertEquals(expected, actual)`
valid if: `expected.equals(actual)`

“Equality” of arrays

`assertArrayEquals(expected, actual)`
- arrays must have same length
- for each valid value for i, check as appropriate:
  `assertEquals(expected[i], actual[i])`
  `assertArrayEquals(expected[i], actual[i])`

There is also an unconditional failure assertion `fail()` that always results in a fail verdict.
Assertion Methods

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A test fixture is the context in which a test case runs.

- Typically, test fixtures include:
  - Objects or resources that are available for use by any test case.
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- Allows multiple tests of the same or similar objects
- Share fixture code for multiple tests
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@Before: Methods annotated with @Before are executed before every test.

@After: Methods annotated with @After are executed after every test.

If there are e.g. 10 test, every @Before method is executed 10 times.

More than one @Before or @After is allowed.

Names of these methods are irrelevant, but must be public void
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- **@After**: Methods annotated with `@After` are executed after every test.
- If there are e.g. 10 tests, every `@Before` method is executed 10 times
- More than one `@Before` or `@After` is allowed
- Names of these methods are irrelevant, but must be `public void`
@Before: Methods annotated with @Before are executed before every test.

@After: Methods annotated with @After are executed after every test.

If there are e.g. 10 test, every @Before method is executed 10 times.

More than one @Before or @After is allowed.

Names of these methods are irrelevant, but must be public void.
public class MoneyTest {
    private Money f12CHF;
    private Money f14CHF;
    private Money f28USD;

    @Before
    public void setUp() {
        f12CHF = new Money(12, "CHF");
        f14CHF = new Money(14, "CHF");
        f28USD = new Money(28, "USD");
    }
}
Setup and Teardown

Setup

Use the @Before annotation on a method containing code to run before each test case.

Teardown (regardless of the verdict)

Use the @After annotation on a method containing code to run after each test case. These methods will run even if exceptions are thrown in the test case or an assertion fails.

It is allowed to have any number of these annotations

All methods annotated with @Before will be run before each test case, but they may be run in any order.
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@BeforeClass: executed once before a test suite
@AfterClass: executed once after a test suite
Only one @BeforeClass and @AfterClass allowed
Methods must be static
public class MoneyTest {
    private static string currency;

    @BeforeClass
    public static void setGlobalCurrency() {
        this.currency = "CHF";
    }

    @Before
    public void setUp() {
        m12 = new Money(12, this.currency);
        m14 = new Money(14, this.currency);
    }
}
Expected Exception

- Exceptions that are expected on test executing
- Annotation using @Test
- @Test(expected=MyException.class)
- If no exception is thrown, or an unexpected exception occurs, the test will fail.
- That is, reaching the end of the method with no exception will cause a test case failure.
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Expected Exceptions – example

```java
new ArrayList<>().get(0);

- Should throw an IndexOutOfBoundsException

@Test(expected = IndexOutOfBoundsException.class)
public void empty() {
    new ArrayList<>().get(0);
}
```
Ignore

- Tests annotated using `@Ignore` are not executed
- Test runner reports that test was not run
- `@Ignore("Reason")` allows to specify a reason why a test was not run

Timeout

- Test allows to specify a timeout parameter
- `@Test(timeout=10)` fails if the test takes more than 10 milliseconds
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Parameterised Tests

Motivation

If you want a test to run with several parameter values, you’d have to

- loop over a collection of values
- which means if there was a failure, the loop wouldn’t terminate
- write unique test cases for each test data combination
- which could prove to be a lot of coding

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With JUnit, you can create highly flexible testing scenarios easily
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Creating a parameterised test

1. Create a generic test and decorate it with the `@Test` annotation
2. Create a static feeder method that returns a Collection type and decorate it with the `@Parameters` annotation
3. Create class members for the parameter types required in the generic method defined in Step 1
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5. Specify the test case be run with the Parameterized class via the @RunWith annotation
@RunWith(Parameterized.class)
public class ParameterizedTest {
    private int numberToTest;
    private int rest;
    public ParameterizedTest(Integer pValue, Integer rValue) {
        numberToTest = pValue.intValue();
        rest = rValue.intValue();
    }
    @Parameters
    public static List<Integer[]> testValues() {
        return Arrays.asList(new Integer[][]{
            {1, 1}, {3, 1}, {6, 0}, {7, 1}, {9, 1}
        });
    }
    @Test
    public void isOdd() {
        assertTrue(numberToTest % 2 == rest);
    }
}
Creating a test suite

- Tests can be combined to test suites
- Suites can contain other suites
- Useful for partitioning your test scenarios
- Well supported by Test Runners (see example)
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Test Suite – Example

```java
testSuiteExample
import org.junit.runner.RunWith;
import org.junit.runners.Suite;

@RunWith(Suite.class)
@Suite.SuiteClasses(
    MyTest1.class,
    MyTest2.class,
    MyTest3.class
)
public class AllTests {
}
```

Overview

Assertions

Fixtures

Eclipse Integration

Daniel Bruns, Erik Burger – JUnit

January 18, 2011

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The JUnit framework does not provide a graphical test runner. Instead, it provides an API that can be used by IDEs to run test cases and a textual runner than can be used from a command line.

Eclipse and Netbeans each provide a graphical test runner that is integrated into their respective environments.
Test Runners

With the runner provided by JUnit:

- When a class is selected for execution, all the test case methods in the class will be run.
- The order in which the methods in the class are called (i.e. the order of test case execution) is not predictable.

Other Runners

- Test runners provided by IDEs may allow the user to select particular methods, or to set the order of execution.
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Test Case Generation

- Hand-writing test cases is a tedious job...
- ...and may be another source of error.

Test case generation (TCG) does all the dirty work.

- Input: parameters to test and oracle of some sort
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Testing with JMLUnitNG

JMLUnitNG

- By Dan Zimmerman (U Washington—Tacoma), 2010
- Complete rewrite of JMLUnit (now support for Java 1.5)
- Based on TestNG (instead of JUnit)
- Current version 1.0a2, released 25 December 2010
- Builds (input and) oracle from JML specifications

Classification of Tests

- Pass: Result matches post-condition
- Fail: Result does not match post-condition (or unexpected exception)
- Meaningless: Test input does not match pre-condition
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Classification of Tests
- **Pass**: Result matches post-condition
- **Fail**: Result does not match post-condition (or unexpected exception)
- **Meaningless**: Test input does not match pre-condition
Example

```java
//@ requires x >= 0;
//@ ensures \result == x + y;
int add (int x, int y) {
    while (0 < --x) y++;
    return y;
}
```

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Table: Values for x and y, with corresponding verdicts.
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How to Use JMLUnitNG

Starting point: Java classes with JML specifications

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2. Provide data: enter specific test data and fixtures
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3. Test generation
4. Test running

Live Demo
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Live Demo
Conclusion

Disclaimer

- JMLUnitNG is still in alpha stage!
- Does not provide much automation / Eclipse integration yet
- May have bugs itself
- Contact Dan Zimmerman <dmz@acm.org> in doubt