Karlsruhe Institute of Technology

An Introduction into JUnit

Praxis der Software-Entwicklung 2010/11

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INSTITUT FÜR THEORETISCHE INFORMATIK – INSTITUT FÜR PROGRAMMSTRUKTUREN UND DATENORGANISATION

Foreword

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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- black-box tests
- white-box tests

Structure

- Unit
- Integration
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- $\rightarrow$ micro integration tests
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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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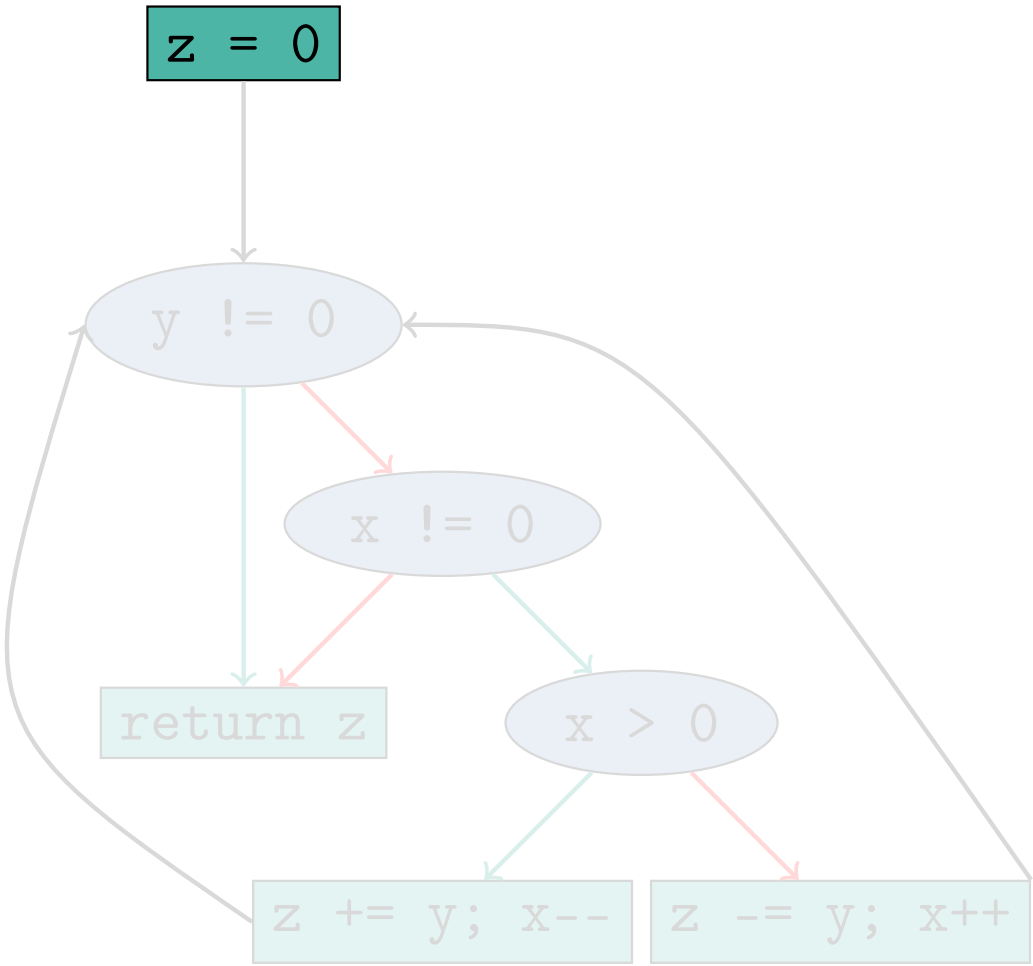
Example Method

```
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



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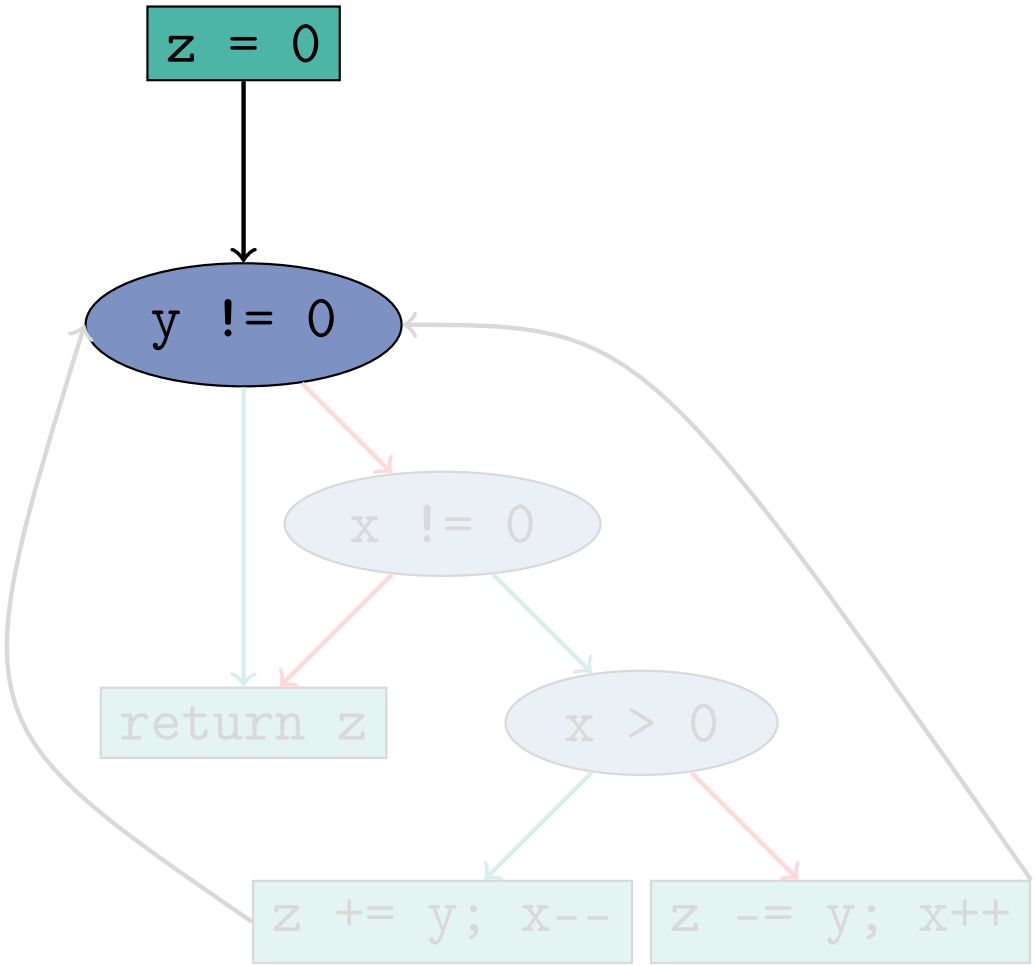

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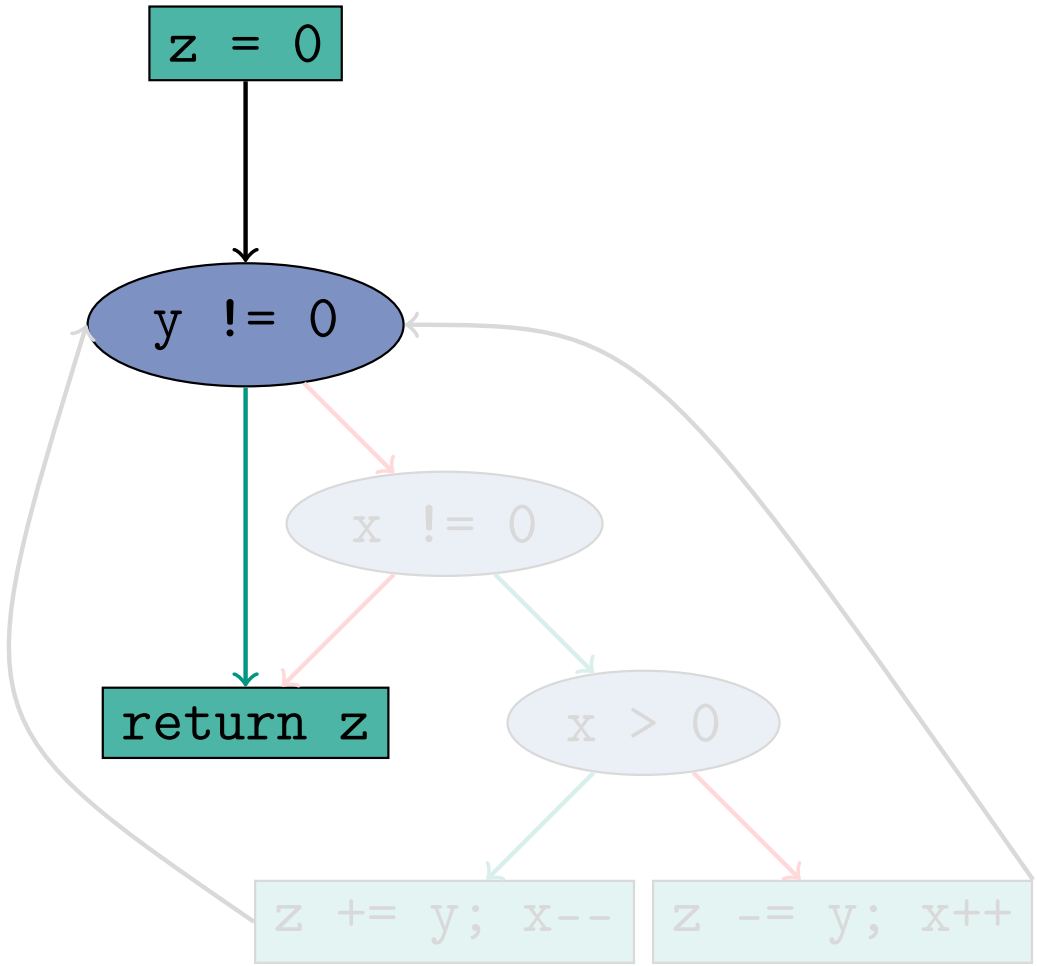

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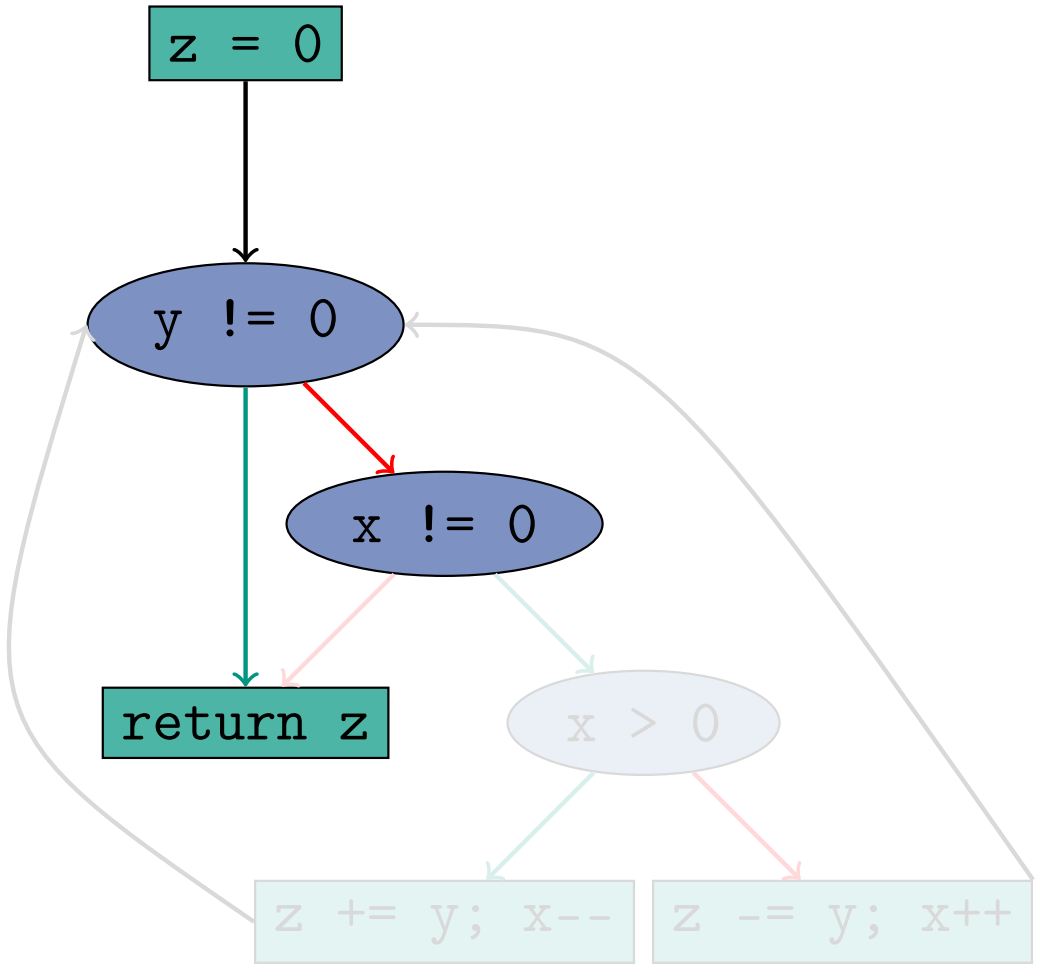

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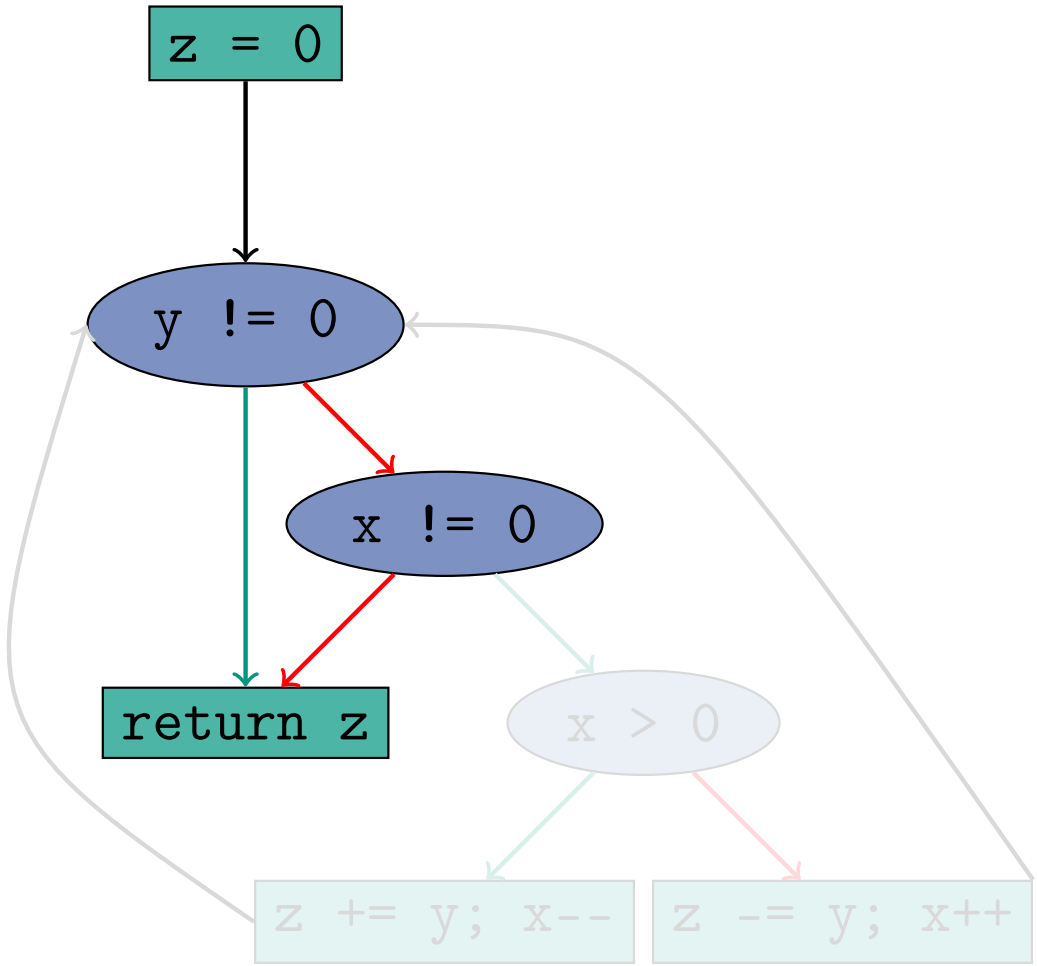

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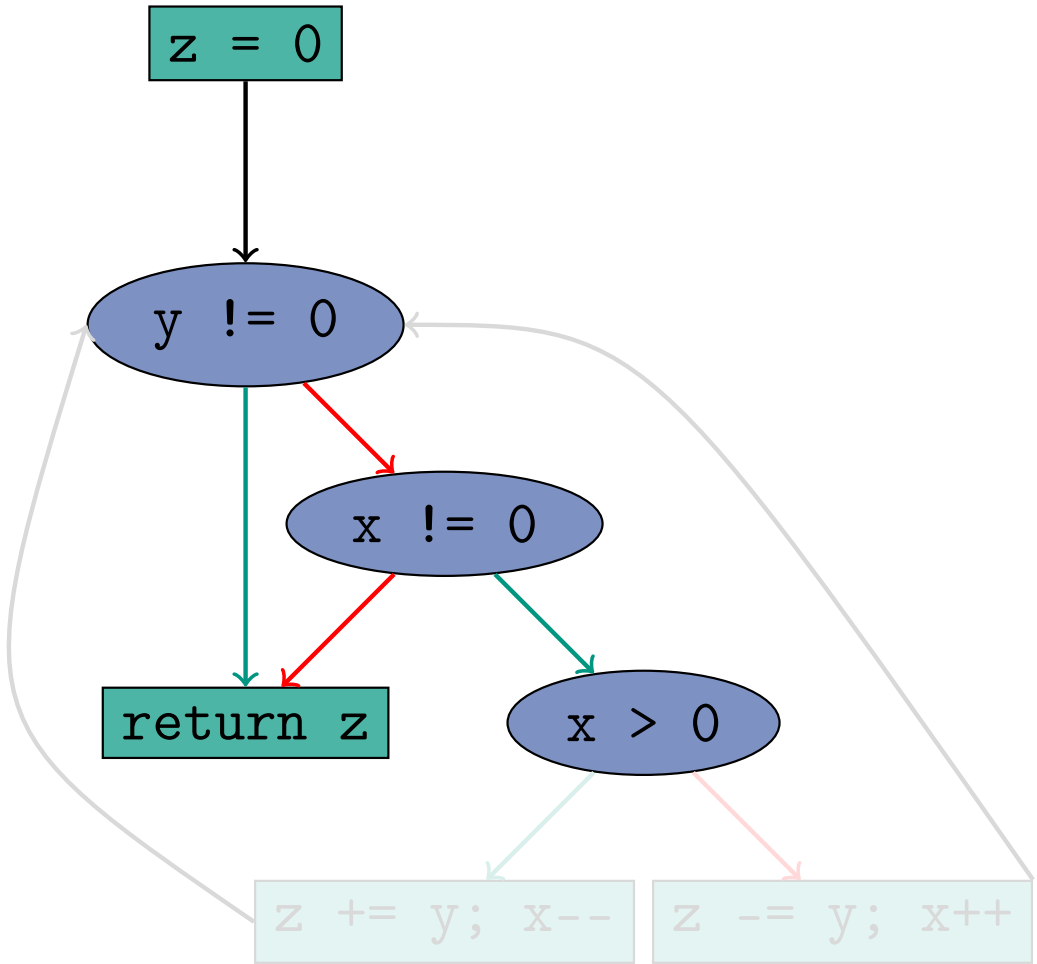

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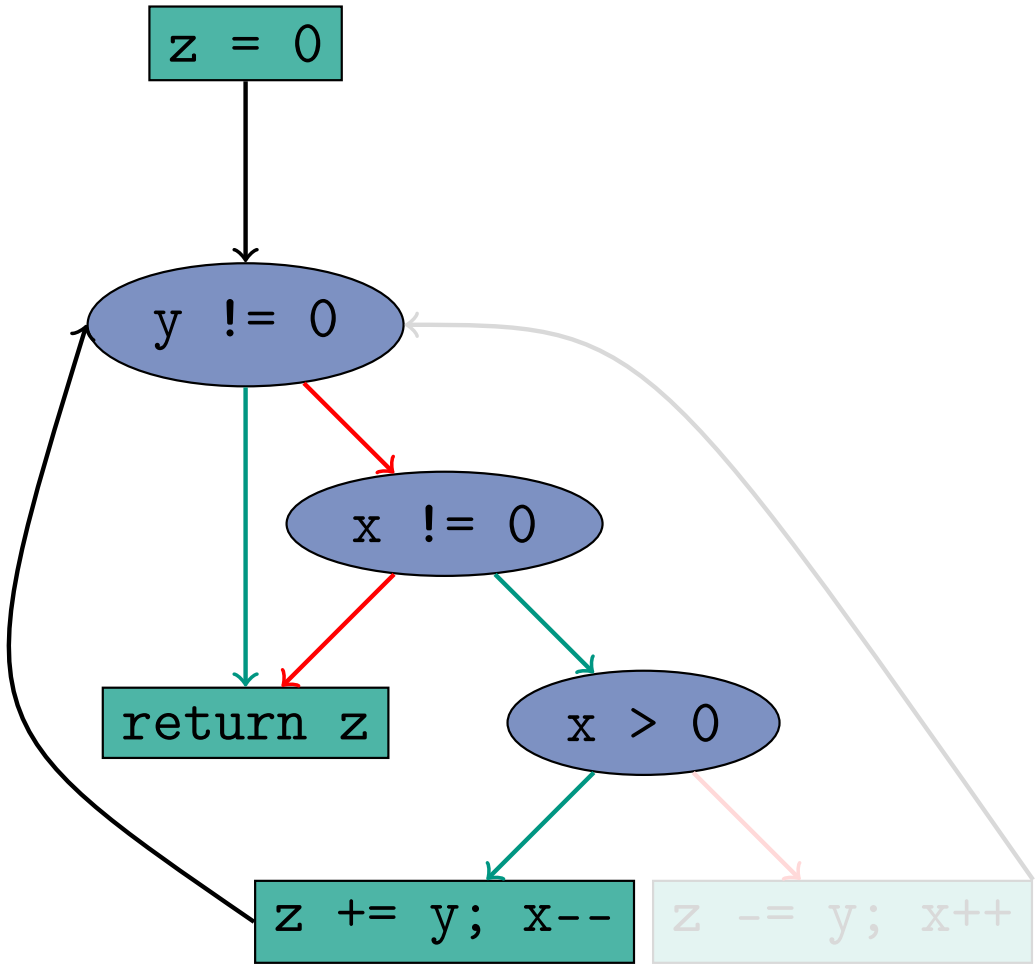

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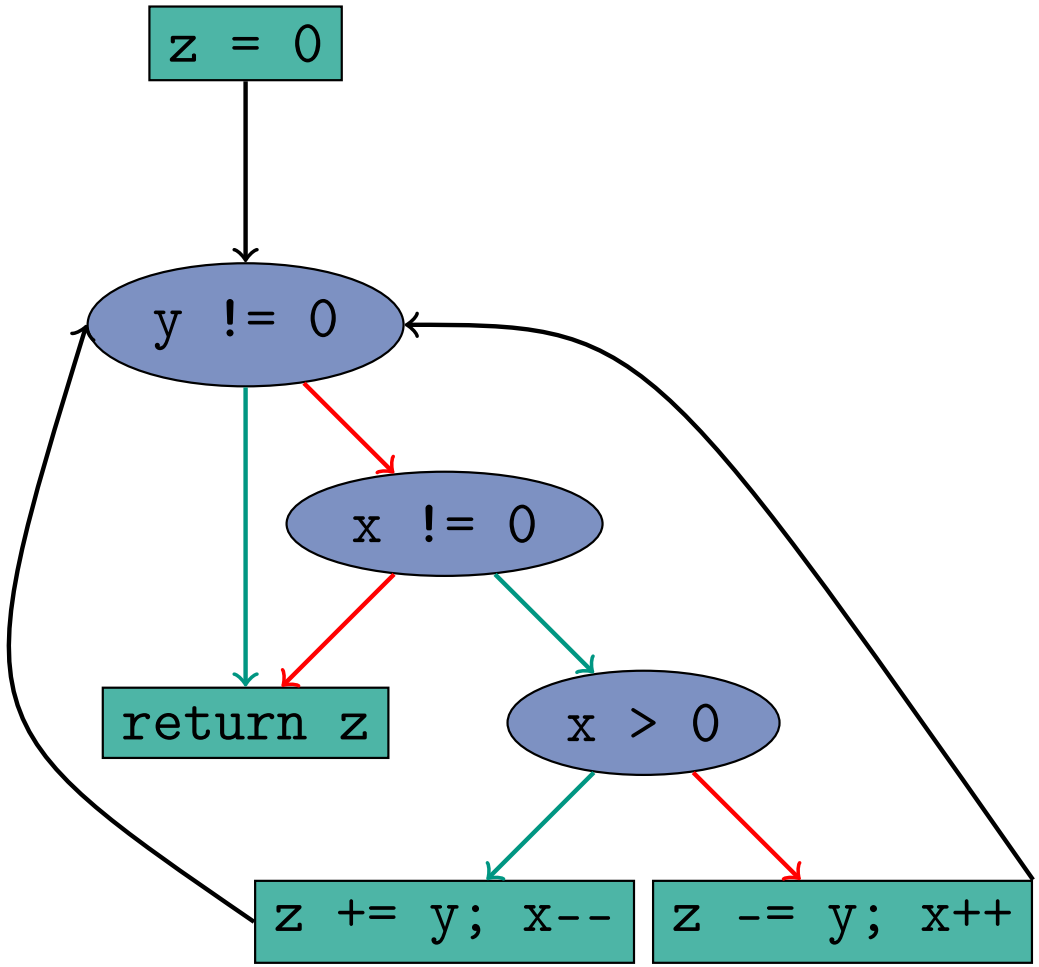

Test Design

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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  $\{\{(x, y) \mid y = 0\}, \{(x, y) \mid y \neq 0 \wedge x > 0\}, \{(x, y) \mid y \neq 0 \wedge x \leq 0\}\}$

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JUnit

JUnit – Overview

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++)
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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

- Many (web) tutorials are still based on JUnit 3
- JUnit 4 is backwards compatible to version 3
- but JUnit 4 is much cleaner

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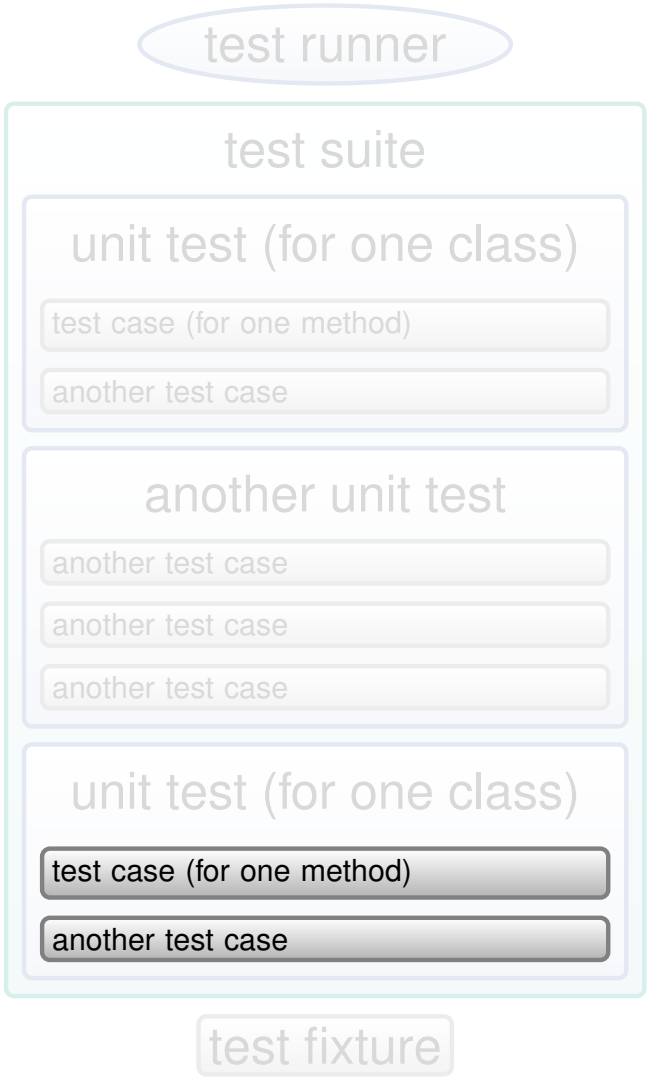

- A unit test tests the methods in a single class
- A test case tests (insofar as possible) a single method
- You can have multiple test cases for a single method
- A test suite combines unit tests
- The test fixture provides software support for all this
- The test runner runs unit tests or an entire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

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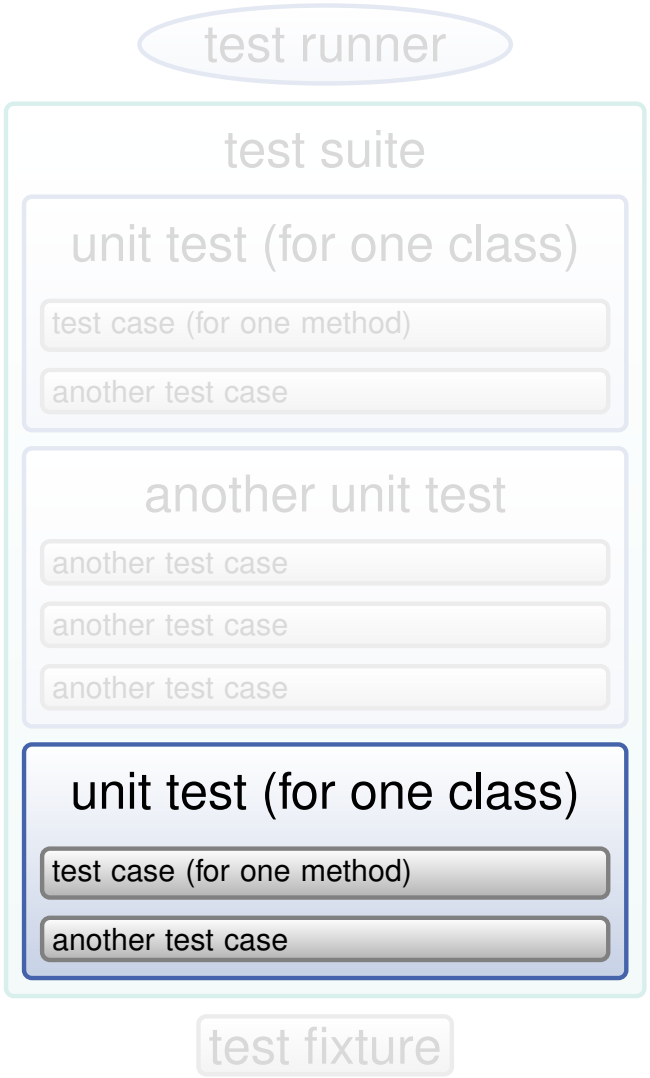

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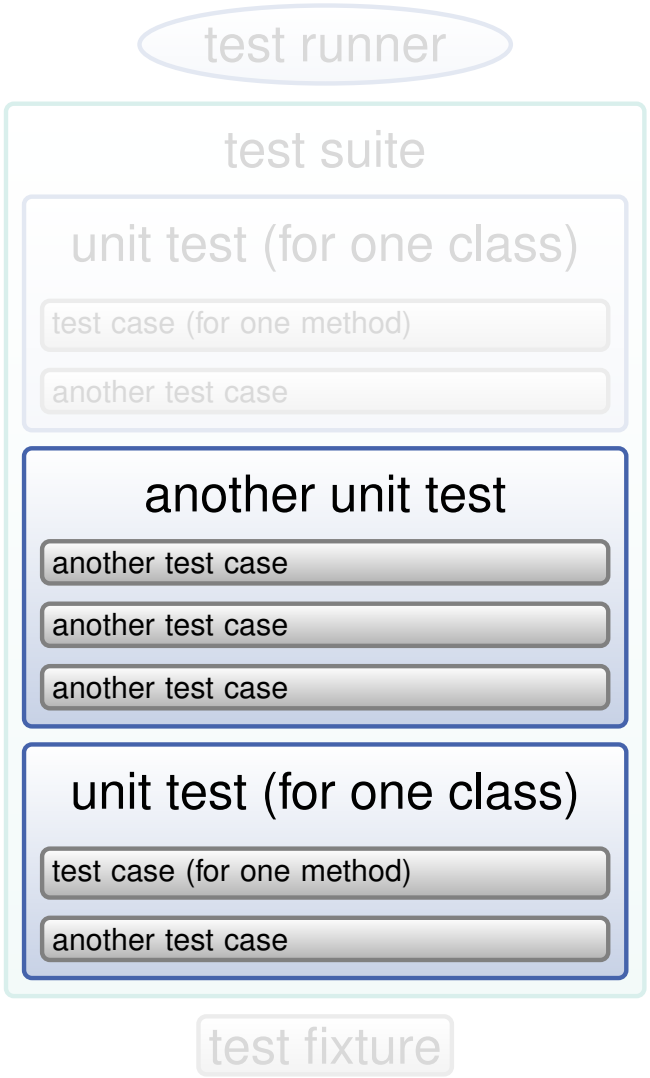

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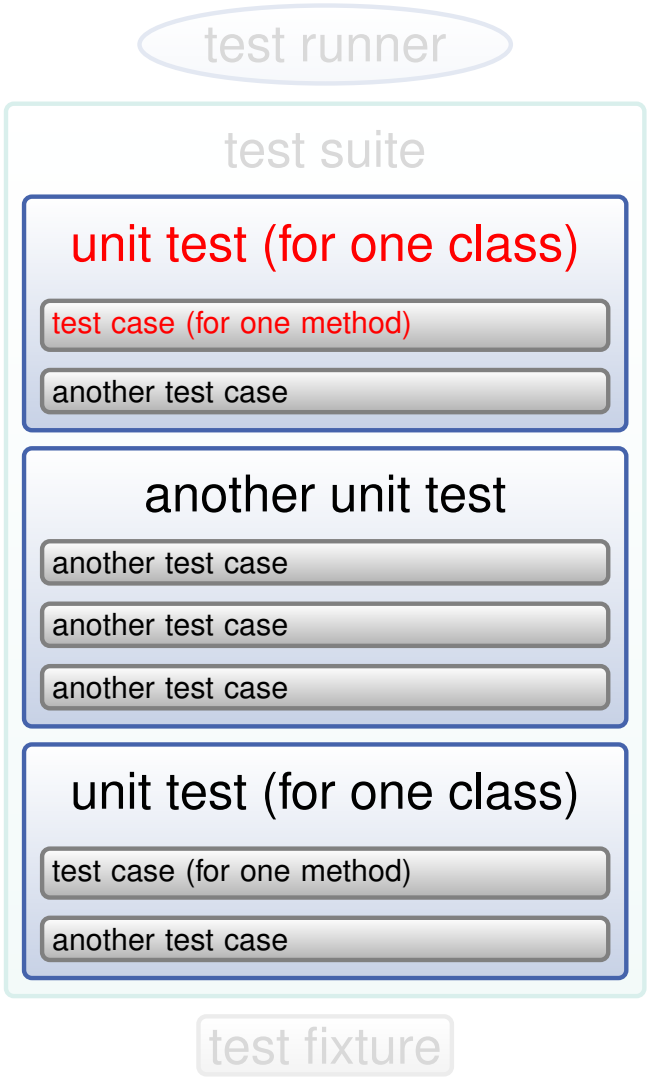

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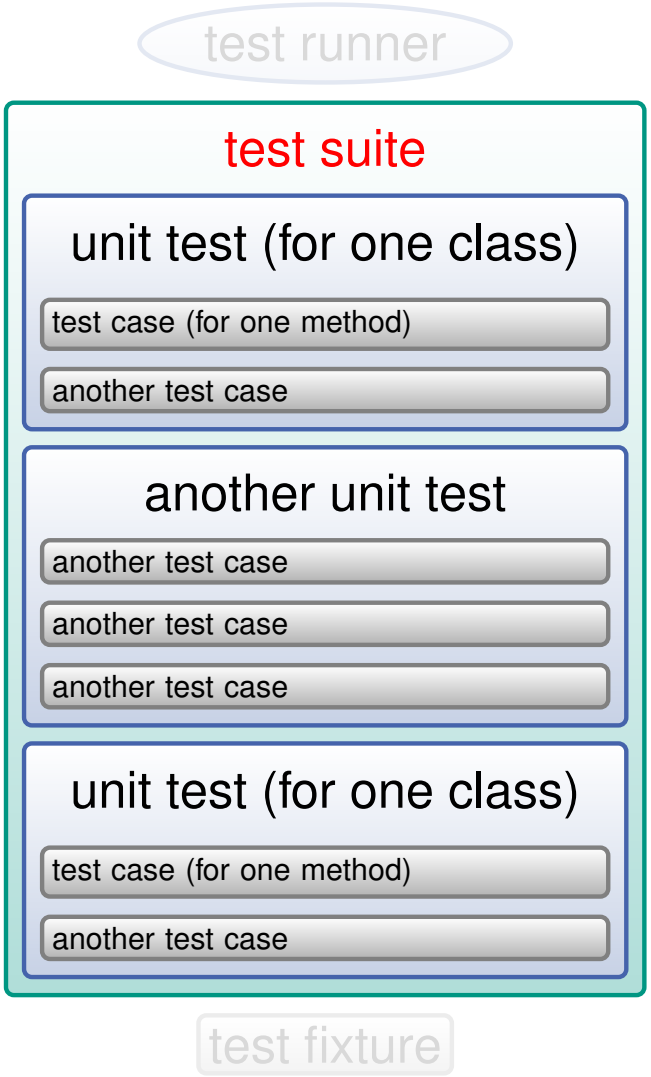

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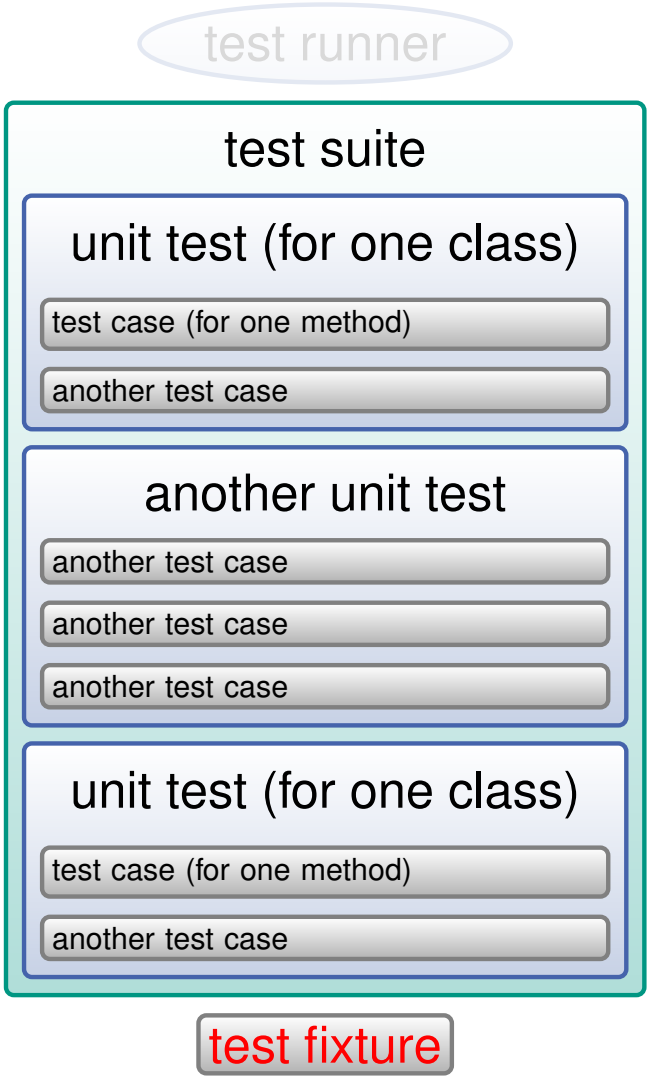

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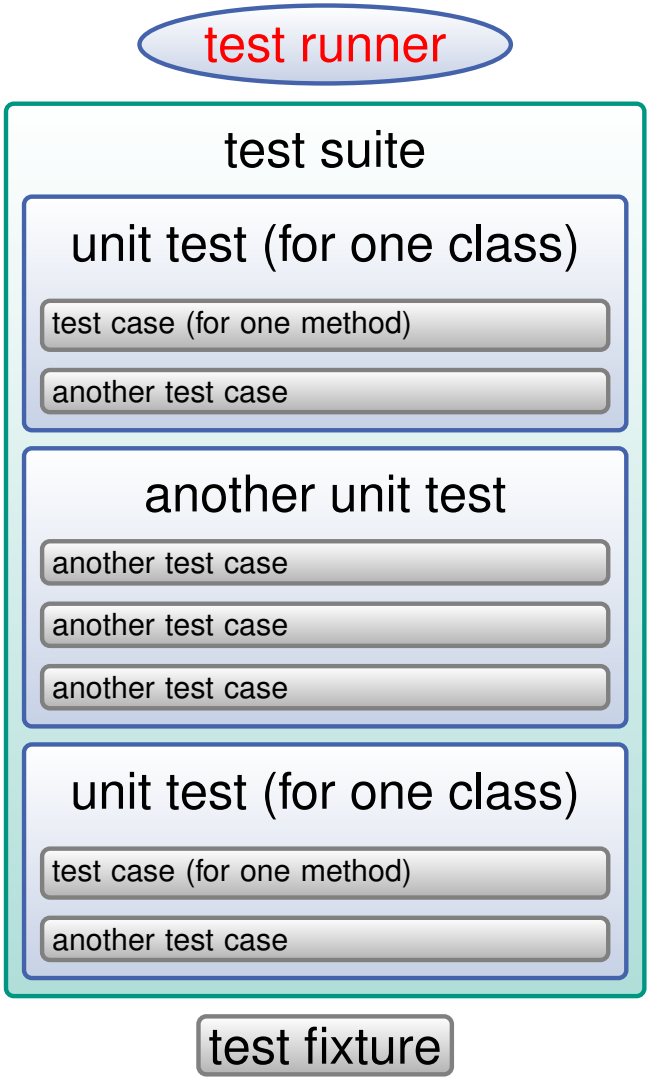

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Test Case Verdicts

- 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

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

Declare your test class in the usual way

```
public class MyProgramTest {
}
```

Declare an instance of the class being tested

```
public class MyProgramTest {
    MyProgram program;
    int someVariable;
}
```

A simple example

```
1  import org.junit.*;
2  import static org.junit.Assert.*;
3  public class ArithmeticTest {
4      @Test
5      public void testMultiply() {
6          assertEquals(4, Arithmetic.multiply(2, 2));
7          assertEquals(-15, Arithmetic.multiply(3, -5));
8      }
9
10     @Test
11     public void testIsPositive() {
12         assertTrue(Arithmetic.isPositive(5));
13         assertFalse(Arithmetic.isPositive(-5));
14         assertFalse(Arithmetic.isPositive(0));
15     }
16 }
```

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**.
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- If no assertions were violated for the entire method, the test case will **pass**.

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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:

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

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- Typically, test fixtures include:
  - Objects or resources that are available for use by any test case.
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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
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Fixture – Example

```
1  public class MoneyTest {
2      private Money f12CHF;
3      private Money f14CHF;
4      private Money f28USD;
5
6      @Before
7      public void setUp() {
8          f12CHF= new Money(12, "CHF");
9          f14CHF= new Money(14, "CHF");
10         f28USD= new Money(28, "USD");
11     }
12 }
```

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.

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BeforeClass/AfterClass

- `@BeforeClass`: executed once before a test suite
- `@AfterClass`: executed once after a test suite
- Only one `@BeforeClass` and `@AfterClass` allowed
- Methods must be *`static`*

Fixture – Example

```
1  public class MoneyTest {
2      private static string currency;
3
4      @BeforeClass
5      public static void setGlobalCurrency() {
6          this.currency = "CHF";
7      }
8
9      @Before
10     public void setUp() {
11         m12= new Money(12, this.currency);
12         m14= new Money(14, this.currency);
13     }
14 }
```

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

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

- Should throw an `IndexOutOfBoundsException`

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

Ignore/Timeout

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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Parameterised Tests

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
4. Create a constructor that takes these parameter types and correspondingly links them to the class members defined in Step 3
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Parameterised Test – Example

```
1  @RunWith(Parameterized.class)
2  public class ParameterizedTest {
3      private int numberToTest;
4      private int rest;
5      public ParameterizedTest(Integer pValue, Integer rValu
6          numberToTest = pValue.intValue();
7          rest = rValue.intValue();
8      }
9      @Parameters
10     public static List<Integer[]> testValues() {
11         return Arrays.asList(new Integer[][] {
12             {1,1}, {3,1}, {6,0}, {7,1}, {9,1}
13             });
14     }
15     @Test
16     public void isOdd() {
17         assertTrue(numberToTest % 2 == rest);
18     }
19 }
```

Test Suites

Creating a test suite

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- suites can contain other suites
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Test Suite – Example

```
1  import org.junit.runner.RunWith;
2  import org.junit.runners.Suite;
3
4  @RunWith(Suite.class)
5
6  @Suite.SuiteClasses({
7       MyTest1.class,
8       MyTest2.class,
9       MyTest3.class
10      }
11 )
12 public class AllTests {
13 }
```

Running JUnit Tests

- 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.
- It is good practice to write tests with are independent of execution order, and that are without dependencies on the state any previous test(s).

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

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

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

x	*y*	*res*	verdict
-1	-1	-1	meaningless
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How to Use JMLUnitNG

Starting point: Java classes with JML specifications

Phases

1. Preparation: create necessary test classes
2. Provide data: enter specific test data and fixtures
   - Global data: used in every test
   - Local data: used in this test
3. Test generation
4. Test running

Live Demo

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2. Provide data: enter specific test data and fixtures — manual
   - Global data: used in every test
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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