

Object Oriented Testing

Junit, Mockito

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2012-2013

<http://deptinfo.unice.fr/twiki/bin/view/Minfo/SoftEng1213>

Agenda

- Back to V&V
- JUnit 4
- Differences with JUnit 3
- Alternatives to Junit
- Mockito
- Alternatives to Mockito

V&V Principles (reminder?)

- Two aspects of the concept of quality:
 - Conformance to the specification: VALIDATION
 - Answering: **do we build the right product?**
 - Checks during realization, most often with the client
 - **Defect** w.r.t to requirements the product must meet
 - Correctness of a stage or of the whole: VERIFICATION
 - Answering: **do we build the product correctly?**
 - Testing
 - **Errors** w.r.t to precise definitions established during the preceding development stages

Test: definition...

- An execution experiment, to emphasize a defect or an error
 - Diagnosis: what is the problem
 - Need of an **oracle**, which indicates whether the experiment result is conformed to the intentions
 - Location (if possible) : where is the cause of the problem?
- ☞ *Tests should find errors!*
- ☞ *One should not aim at demonstrating that a program works using tests!*
- Oftent neglected as:
 - Project leaders do not invest in negative results
 - Developers do not consider testing as a destructive process

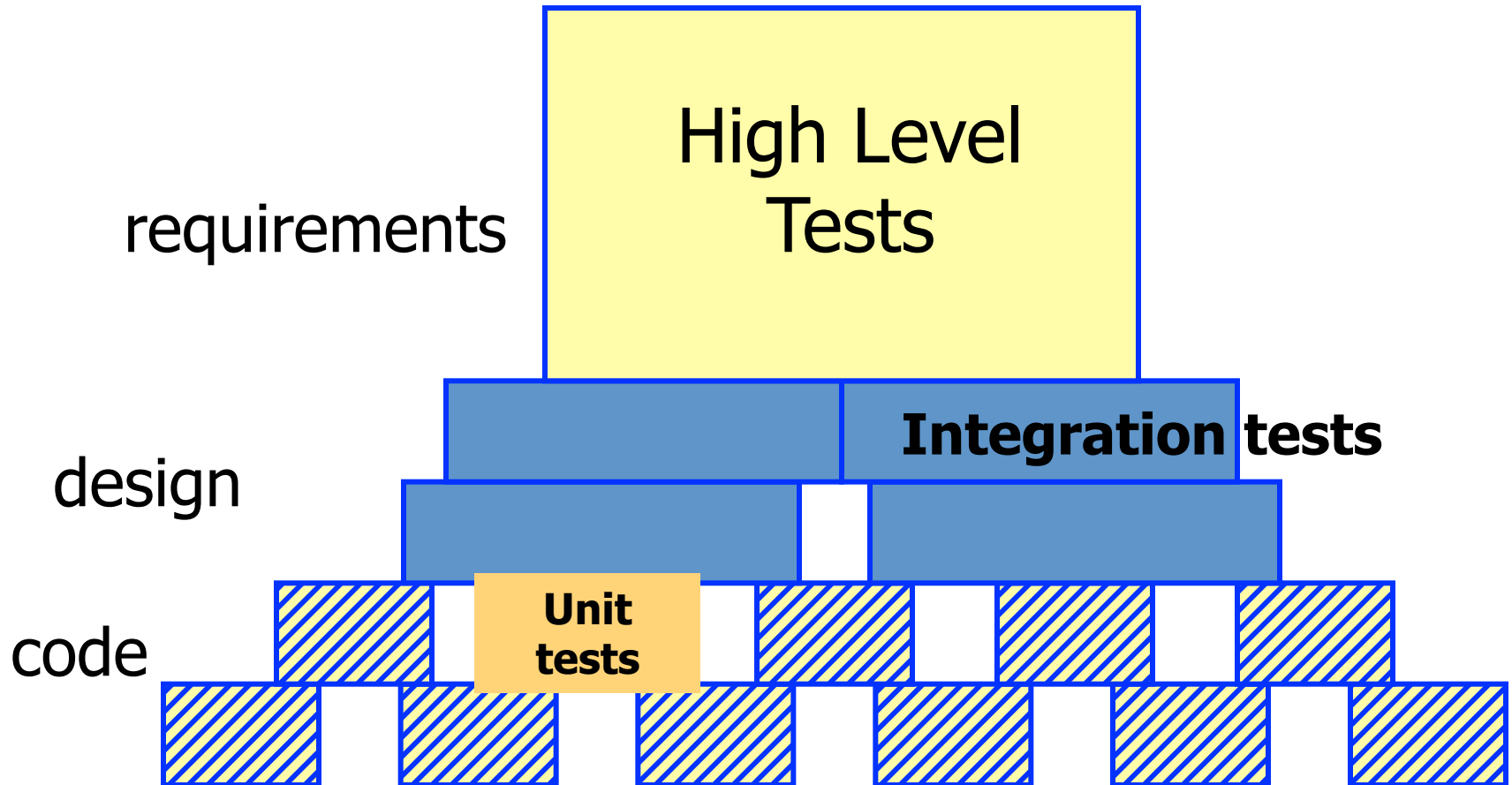
Elements of a test

- Name, objective, comments, author
 - Data: test set
 - Some code that call methods: test case
 - Oracles (checking of properties)
 - Traces, observable results
 - Reporting, a summary...
-
- Average cost: as much as the tested program

Test vs. Attempt vs. Debugging

- Testing data are kept
 - The cost of testing is recouped
 - Because a test must be **reproducible**
- A test is different from code adjustment or debugging
- Debugging is an investigation
 - Hard to reproduce
 - Which aims at explaining an issue

Testing Strategies



Black box functional testing

- Principles
 - Rely on external specification
 - Partition data to test in **equivalence classes**
 - An expected value in 1..10 gives [1..10], < 1 et > 10
 - Add « relevant » values:
 - Bound testing: on bounds for acceptance, just beyond bounds for denial

JUnit

JUnit v4

www.junit.org

JUnit

- The reference for unit testing in Java
- 3 of the advantages of eXtreme Programming applied to testing:
 - As unit testing use the interface of the class under test, it leads the developer to think of the usage of this interface, early in the development
 - They enable developers to detect early outlier cases
 - **Providing a documented correctness level, they enable developers to modify the code architecture with confidence**

Example

```
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;
    }
}
```

First test before the implementation of **simpleAdd**

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

public class MoneyTest {
    //...
    @Test public void simpleAdd() {
        Money m12CHF= new Money(12, "CHF");           // (1)
        Money m14CHF= new Money(14, "CHF");
        Money expected= new Money(26, "CHF");
        Money result= m12CHF.add(m14CHF);             // (2)
        assertTrue(expected.equals(result));         // (3)
    }
}
```

1. Code to set up the context of the test (*fixture*)
2. Experiment on objects in the context
3. Result checking, oracle...

Test Cases

- Write normal classes
- Define inside some methods annotated with `@Test`
- To check the expected results (write oracles...) one has to call one of the numerous variants of provided `assertXXX()` methods:
 - `assertTrue(String message, boolean test), assertFalse(...)`
 - `assertEquals(...)` : test with equals
 - `assertSame(...), assertNotSame(...)` : test using object references
 - `assertNull(...), assertNotNull(...)`
 - `Fail(...)` : to directly raise an `AssertionFailedError`
 - *Overloading of some methods for the different base types (int...)*
 - **Add « `import static org.junit.Assert.*` » to make everything available**

Application to equals in Money

```
@Test public void testEquals() {  
    Money m12CHF= new Money(12, "CHF");  
    Money m14CHF= new Money(14, "CHF");  
  
    assertTrue(!m12CHF.equals(null));  
    assertEquals(m12CHF, m12CHF);  
    assertEquals(m12CHF, new Money(12, "CHF"));  
    assertTrue(!m12CHF.equals(m14CHF));  
}
```

```
public boolean equals(Object anObject) {  
    if (anObject instanceof Money) {  
        Money aMoney= (Money)anObject;  
        return aMoney.currency().equals(currency())  
            && amount() == aMoney.amount();  
    }  
    return false;  
}
```

Fixture: common context

- Duplicated setup code:

```
Money m12CHF= new Money(12, "CHF");  
Money m14CHF= new Money(14, "CHF");
```

- Classes that have several test methods can use annotations `@Before` and `@After` on methods to initialize, resp. clean, the context common to all tests (= *fixture*)
 - Each test is executed in its own context, by calling the `@Before` method before and the `@After` method... after (for each test method):
 - For 2 methods, the execution is equivalent to:
 - `@Before-method ; @Test1-method(); @After-method();`
 - `@Before-method ; @Test2-method(); @After-method();`
 - This should ensure that no side effect occurs between tests' execution
 - The context is defined by attributed in the testing class

Fixture : application

```
public class MoneyTest {
    private Money f12CHF;
    private Money f14CHF;

    @Before public void setUp() {
        f12CHF= new Money(12, "CHF");
        f14CHF= new Money(14, "CHF");
    }

    @Test public void testEquals() {
        assertTrue(!f12CHF.equals(null));
        assertEquals(f12CHF, f12CHF);
        assertEquals(f12CHF, new Money(12, "CHF"));
        assertTrue(!f12CHF.equals(f14CHF));
    }

    @Test public void testSimpleAdd() {
        Money expected= new Money(26, "CHF");
        Money result= f12CHF.add(f14CHF);
        assertTrue(expected.equals(result));
    }
}
```


Test Execution

- By introspection of classes
 - Class as method parameter

```
org.junit.runner.JUnitCore.runClasses(TestClass1.class, ...);
```

- Runtime introspection of the class
 - Analyzing annotations @Before, @After, @Test
 - Test execution following the defined semantics (cf. previous slides)
 - Generation of an object representing the result
 - NOK: detail of the error (Stack Trace, etc.)
 - OK: only counting what's OK
- Further details on the result of a test execution
 - Failure = error of the test (detection of an error in the code under test)
 - Error = error/exception in the testing environment (detection of an error in the testing code)

Test execution with the command line

- Using the class
 - org.junit.runner.JUnitCore

```
java org.junit.runner.JUnitCore com.acme.LoadTester  
com.acme.PushTester
```

- Installing JUnit
 - Put junit-4.5.jar in the CLASSPATH (compilation and execution)
 - That's all...

Other features

- Testing exception raising
 - `@Test(expected= ExceptionClass.class)`

```
@Test(expected = ArithmeticException.class)
public void divideByZero() {
    calculator.divide(0);
}
```

- Testing an execution with a limited time
 - Spécified in milliseconds

```
@Test(timeout=100)
...
```

- *No equivalent in JUnit 3*

Other features

- Ignore (temporarily) some tests
 - Additional Annotation `@Ignore`

```
@Ignore("not ready yet")
@Test
public void multiply() {
    calculator.add(10);
    calculator.multiply(10);
    assertEquals(calculator.getResult(), 100);
}
}
```

- *No equivalent in JUnit 3*

Test Parametrization

```
@RunWith(value=Parameterized.class)
public class FactorialTest {

    private long expected;
    private int value;

    @Parameters
    public static Collection data() {
        return Arrays.asList( new Object[][] {
            { 1, 0 }, // expected, value
            { 1, 1 },
            { 2, 2 },
            { 24, 4 },
            { 5040, 7 },
        });
    }

    public FactorialTest(long expected, int value) {
        this.expected = expected;
        this.value = value;
    }

    @Test
    public void factorial() {
        Calculator calculator = new Calculator();
        assertEquals(expected, calculator.factorial(value));
    }
}
```

Test Parametrization

- `@RunWith(value=Parameterized.class)`
 - Executes all tests of the class with data provided in the method annotated with `@Parameters`
- `@Parameters`
 - 5 elements in the example list
 - Each element is an array used as arguments for the testing class constructor
 - In the example, data are used in `assertEquals`
- Equivalent to:

```
factorial#0: assertEquals( 1, calculator.factorial( 0 ) );  
factorial#1: assertEquals( 1, calculator.factorial( 1 ) );  
factorial#2: assertEquals( 2, calculator.factorial( 2 ) );  
factorial#3: assertEquals( 24, calculator.factorial( 4 ) );  
factorial#4: assertEquals( 5040, calculator.factorial( 7 ) );
```

- *No Equivalent in JUnit 3*

Fixture at the class level

- **@BeforeClass**
 - A single annotation per class
 - Evaluated once for the testing class, before any other initialization
`@Before`
 - Looks like a constructor...

- **@AfterClass**
 - A single annotation per class too
 - Evaluated once after all the executed tests, after the last `@After`
 - Useful to really clean the testing environment (file closing, side effect...)

Suite: test organisation

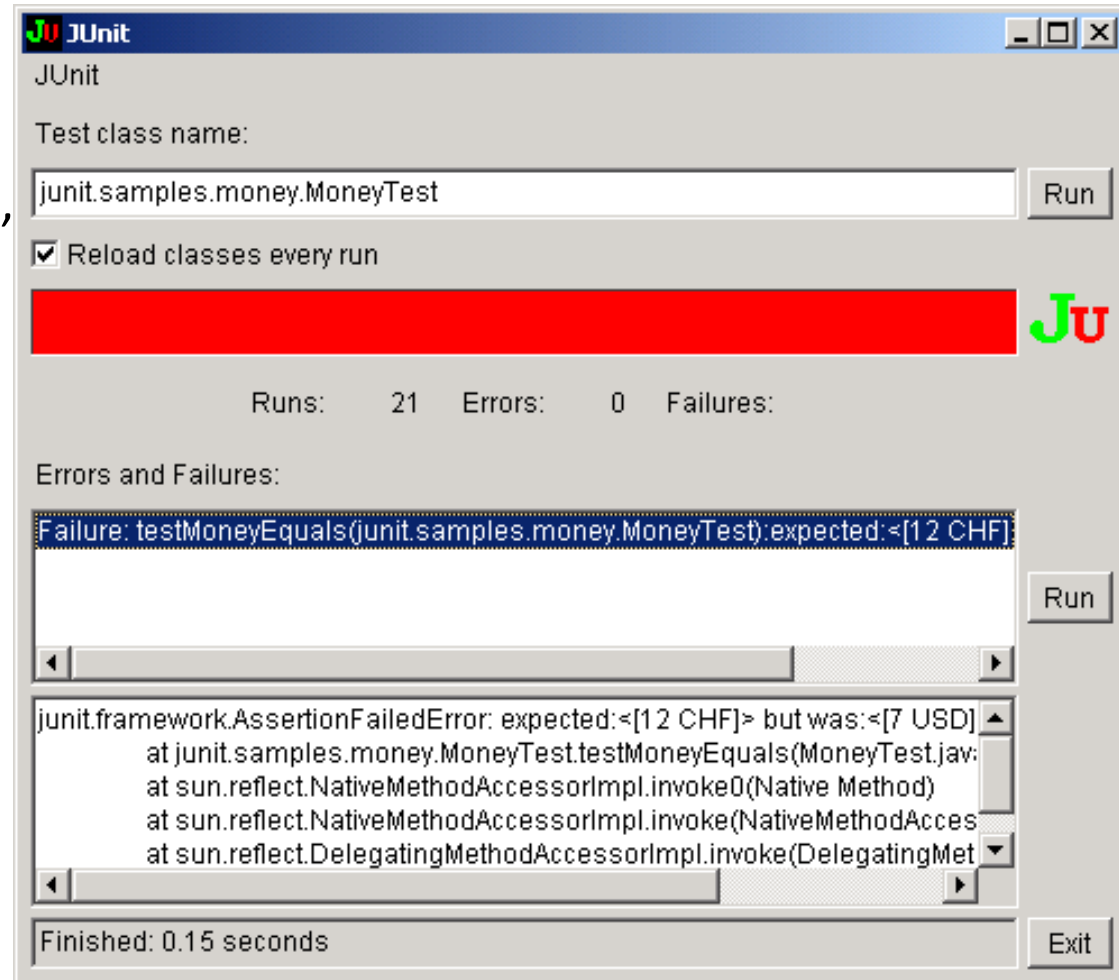
- Some test classes can be organized in hierarchies of « suite »
 - They automatically call all `@Test` methods in each testing class
 - A « suite » is made of testing classes or suites
 - Tests can be assembled in a hierarchy at any level, all tests are always automatically executed in one pass

```
@RunWith (value=Suite.class)
@SuiteClasses (value={CalculatorTest.class,
AnotherTest.class})
public class AllTests {
    ...
}
```

- A suite can have several `@BeforeClass` and `@AfterClass` methods, which will be called one before and after the suite execution

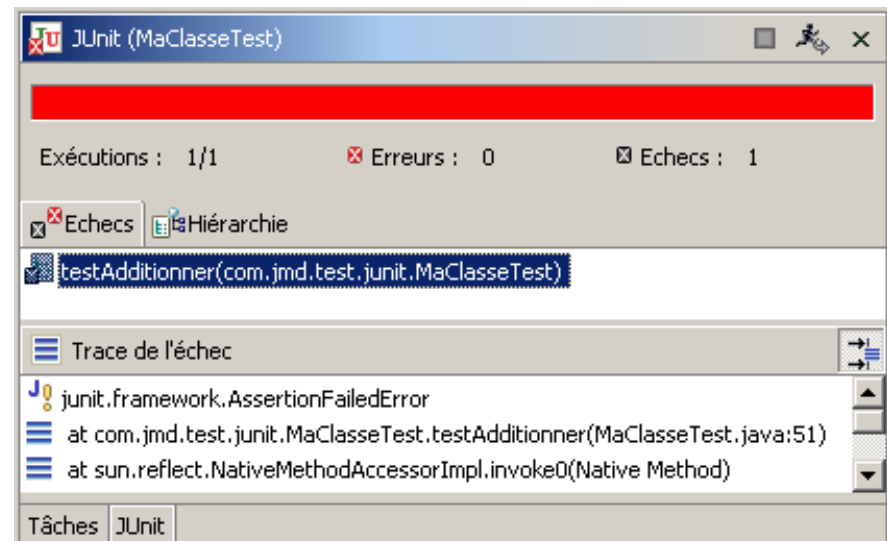
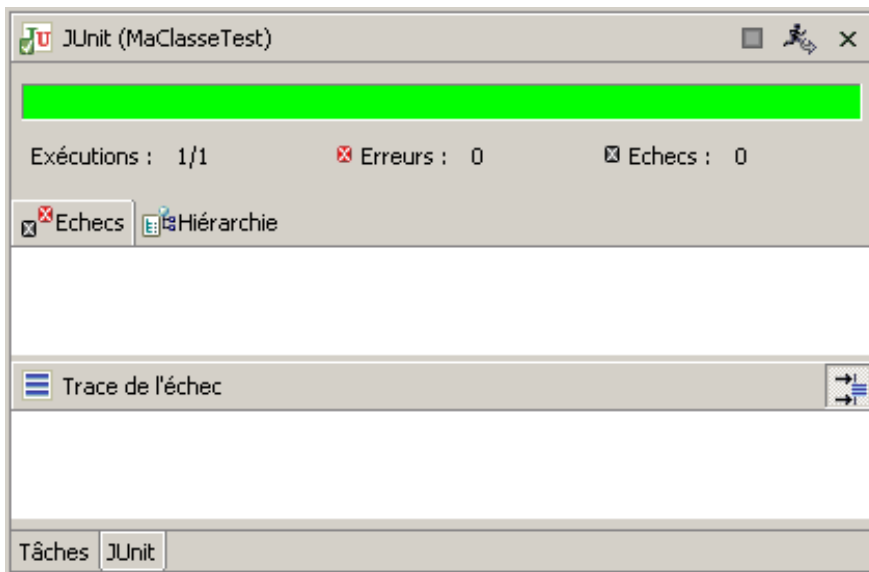
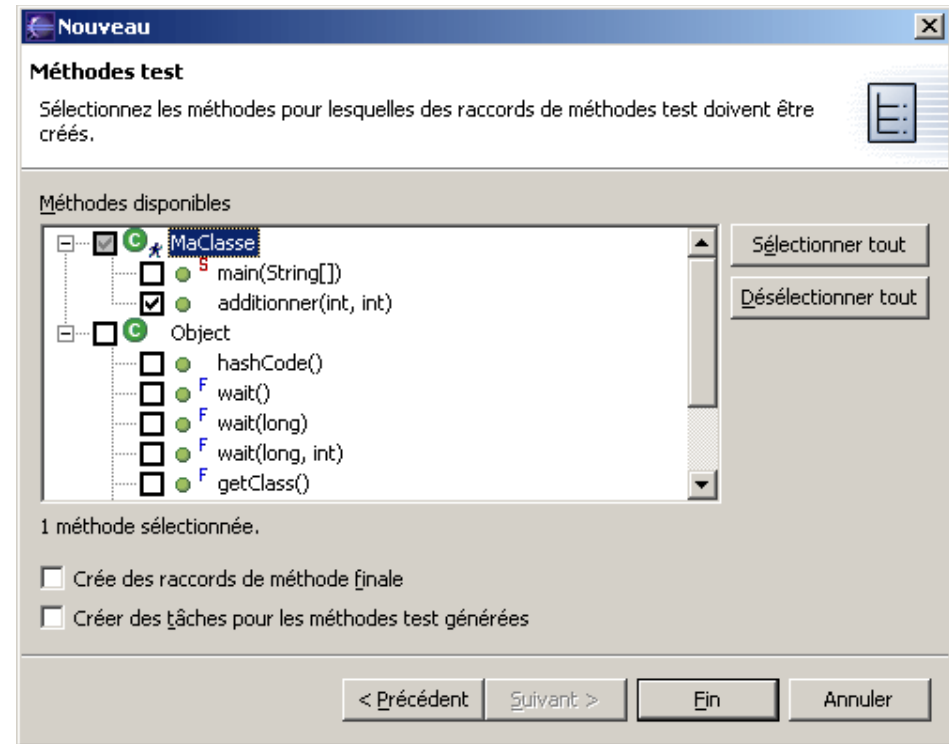
JUnit : TestRunner

- Executes and displays results
- Two versions in JUnit (textual, graphical)
- Integration in IDE



JUnit dans Eclipse

- Wizards for:
 - Creating test cases
- TestRunner integrated in the IDE



What to test? Some principles

- **Principe Right-BICEP**

- Right : Are the results right?
- B (Boundary) : Are all the boundary conditions CORRECT ?
- I (Inverse) : Can you check inverse relationships ?
- C (Cross-check) : Can you cross-check results using other means?
- E (Error condition) : Can you force error conditions to happen?
- P (Performance) : Are performance characteristics within bounds?

Right-BICEP : right

- **Right**
 - Validation of results wrt what's defined in the spec
 - One should be able to answer to « how do we know that the program executed correctly? »
 - If no answer => specifications certainly vague, incomplete
 - Tests = translation of specifications

Right-BICEP : boundary

- **B : Boundary conditions**
 - Identify conditions at the boundaries of the specification
 - What happens if data are
 - Anachronic e.g. : `!*W@V"`
 - Not correctly formatted e.g. : `fred@foobar.`
 - Empty or null e.g. : `0, 0.0, "", null`
 - Extraordinary e.g. : `10000` for a person age
 - Duplicate e.g. : duplicate in a Set
 - Non compliant e.g. : ordered list that are not
 - Disordered e.g. : print before connect

Right-BICEP : boundary

- **To correctly establish « boundaries »**
- **« CORRECT » principle =**
 - C - Conformance - does the value conform to an expected format?
 - O - Ordering - is the set of values ordered or unordered as appropriate?
 - R - Range - is the value within reasonable minimum and maximum values?
 - R - Reference - does the code reference anything external that isn't under direct control of the code itself?
 - E - Existence - does the value exist (e.g. is not null, non-zero, present in a set)?
 - C - Cardinality - are there exactly enough values?
 - T - Time (absolute and relative) - is everything happening in order? At the right time? In time?

Right-BICEP

- **Inverse – Cross check**
 - Identify
 - Inverse relationships
 - Equivalent algorithms (cross-check)
 - That allow for behavior checking
 - Example: testing square root using the power of 2 function

Right-BICEP

- **Error condition – Performance**
 - Identify what happens if
 - Disk, memory, etc. Are full
 - Network connection is lost
 - E.g., check that an element is not in the list
 - Check that the execution time is linear with the size of the list
 - Watch out! This part is the whole domain of non-functional testing (load, performance...)

Methodological Aspects

- **Coding/testing, coding/testing...**
- **Running tests as often as possible**
 - As often as compiling!
- **Start by writing tests on most critical parts**
 - Write tests that have better ROI!
 - *Extreme Programming Approach*
- **When adding a functionality, write tests first**
 - *Test-Driven Development...*
- **If you ends up debugging with `System.out.println()`, you'd better write a test instead**
- **When a bug is found, a test that characterizes it must be written**

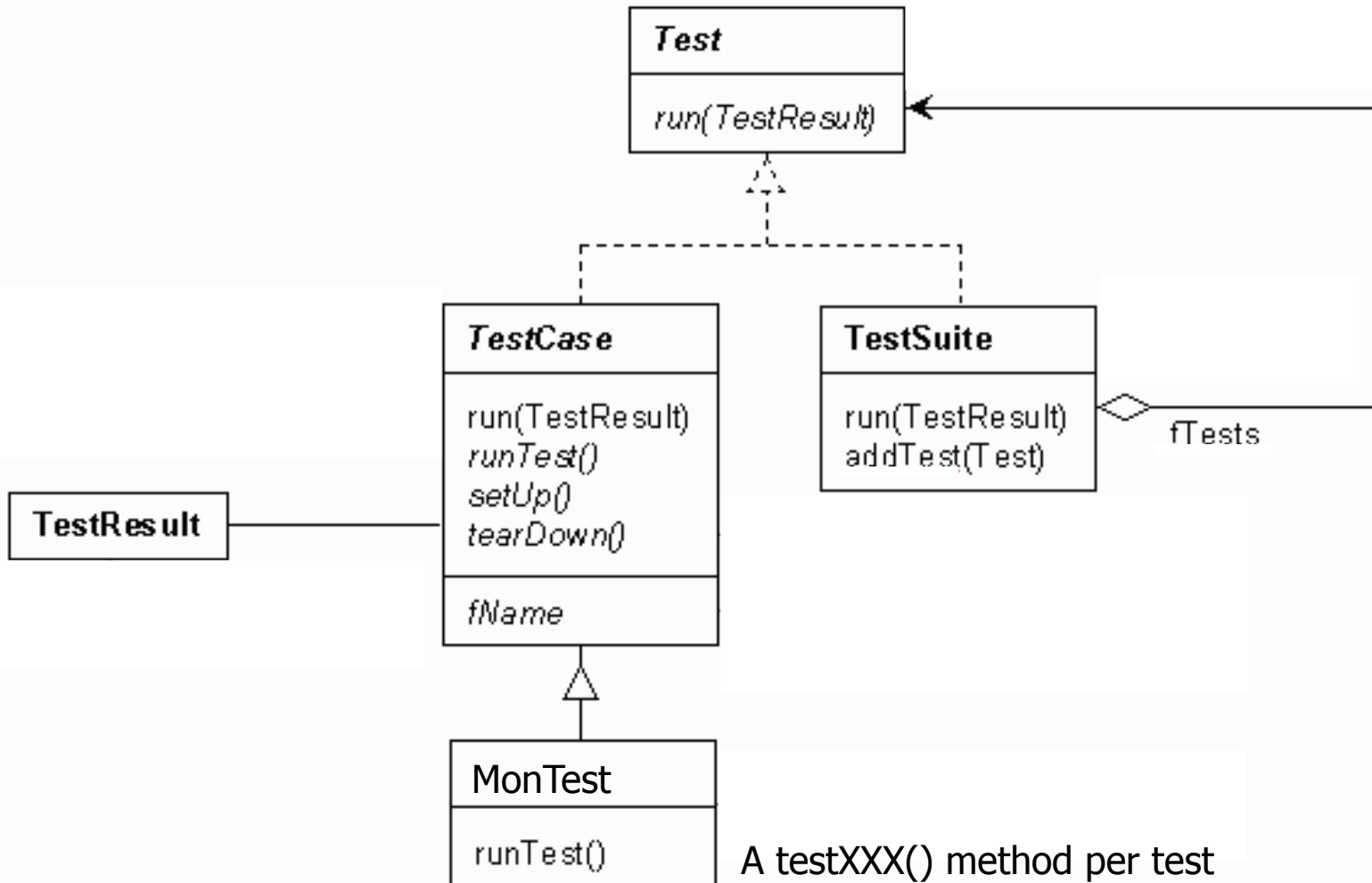
From eXtreme Programming to Test-Driven Development

- **What this is all about?**
 - Deliver only functionalities that the software needs, not those the programmer believes it must provide
 - An obviousness *a priori*
- **How?**
 - Write client code as if the code to develop already existed and was completely to make your life easier!
 - Tests are the client code!
 - Ecrire du code client comme si le code à développer existait déjà et avait été conçu en tout
 - Change the code to compile tests
 - Implement code incrementally
 - Refactor everything to make things always easier for you
 - Write a test (red), write the code (green), refactor
- **+ Principle of continuous integration**
 - During developemnt, the program always works, maybe without some requirements, but what it does, it does it well!

En JUnit 3, les TestCases...

- Write subclasses of TestCase
- A TestCase can define any number of methods testXXX()
- To check expected results (oracle), assertXXX() are provided inside the TestCase
- Setup and teardown methods handle fixture

JUnit 3: class diagram



A testXXX() method per test

JUnit 3.x JUnit 4

```
package junit3;

import calc.Calculator;
import junit.framework.TestCase;

public class CalculatorTest extends
TestCase {

    private static Calculator calculator =
        new Calculator();

    protected void setUp() {
        calculator.clear();
    }

    public void testAdd() {
        calculator.add(1);
        calculator.add(1);
        assertEquals(calculator.getResult(),
2);
    }
}
```

```
package junit4;

import calc.Calculator;
import org.junit.Before;
import org.junit.Ignore;
import org.junit.Test;
import static org.junit.Assert.*;

public class CalculatorTest {

    private static Calculator calculator =
        new Calculator();

    @Before
    public void clearCalculator() {
        calculator.clear();
    }

    @Test
    public void add() {
        calculator.add(1);
        calculator.add(1);
        assertEquals(calculator.getResult(), 2);
    }
}
```

JUnit 3.x JUnit 4

```
public void testDivideByZero() {  
    try {  
        calculator.divide(0);  
        fail();  
    } catch (ArithmeticException e) {  
    }  
}  
  
public void notReadyYetTestMultiply() {  
    calculator.add(10);  
    calculator.multiply(10);  
    assertEquals(calculator.getResult(),  
100);  
}  
}
```

```
@Test(expected =  
ArithmeticException.class)  
public void divideByZero() {  
    calculator.divide(0);  
}  
  
@Ignore("not ready yet")  
@Test  
public void multiply() {  
    calculator.add(10);  
    calculator.multiply(10);  
    assertEquals(calculator.getResult(),  
100);  
}  
}
```

Alternative to JUnit

- TestNG (www.testng.org)
 - Annotations Java 5: @Test, @Configuration...
 - Batch execution of test, data injection, distribution on slave machines...
 - Integration in IDE, in tools like Maven
 - Designed to cover several test categories: unit, functional, integration, client/server from end to end

Testing & Mock object

Definition

- Mock = Dummy/artificial object
- Mocks are simulated objects that reproduce the behavior of real objects in a controlled way
- One then tests behavior of other, real, objects, but linked to inaccessible or non implemented objects
- This object is replaced by a mock

Definition(s)

- Dummy: empty objects with no functionality implemented
- Stub: classes that returns, hard coded, a value for an invoked method
- Fake: partial implementation that always returns the same results wrt provided parameters
- Spy: class that verifies its own usage after execution
- Mock: class that acts both as a stub and a spy

Example

- Non deterministic behavior (hour, date, sensor)
- Long initialization (DB)
- Class not yet implemented or with an evolving ongoing implementation
- Complex states hard to reproduce inside tests (network error, exceptions on files)
- In order to test, one needs to add dedicated attributes or methods

Principle

- A mock has the same interface as the object it simulates
- The client object ignores it interacts with a real object or a simulated one
- Most of mock frameworks allow for
 - Specifying which methods are going to be called, with which parameters and in which order
 - Specifying values returned by the mock

Mockito

<http://code.google.com/p/mockito/>

With elements from a lecture of M. Nebut lifl.fr

Mockito

- Automatic generator of mock objects
- Lightweight
 - Focus on expected behavior and on checking after execution
- Simple
 - A single type of mock
 - A single way to create them

Principles

- The framework works in spy mode:
 - Mocks creation
 - *mock* method or `@mock` annotation
 - Behavior description
 - *When* method
 - Runtime memorization of interactions
 - Use of the mock in code testing a specific behavior
 - Queries, at the end of the test, on mocks to determine how they have been used
 - *Verify* method

import static org.mockito.Mockito.*

Creation

- Through an interface or a class (using `.class`)
 - `AnInterface mockUnnamed = mock(AnInterface.class);`
 - `AnInterface mockNamed =
mock(AnInterface.class, "thisMock");`
 - `@Mock AnInterface thisMock;`
- Default Behavior
 - `assertEquals("thisMock", thisMock.toString());`
 - `assertEquals("numeric type: 0 ", 0,
myMock.fctReturningAnInt());`
 - `assertEquals("boolean type: false",
false, myMock.fctReturningABoolean());`

Stubbing

- To replace the default behavior of methods
- Two possibilities
 - Method with a return type
 - when + thenReturn ;
 - when + thenThrow ;
 - Method of type void :
 - doThrow + when ;

Stubbing

returning an unique value

```
// stubbing  
when(myMock.fctReturningAnInt()).thenReturn(3);  
  
// description with JUnit  
assertEquals("a first time 3", 3, myMock.fctReturningAnInt());  
assertEquals("a second time 3", 3, myMock.fctReturningAnInt());
```

Stubbing

consecutive return values

```
// stubbing
when(myMock.fctReturningAnInt()).thenReturn(3, 4, 5);

// description with JUnit
assertEquals("a first time 3", 3, myMock.fctReturningAnInt());
assertEquals("a second time 4", 4, myMock.fctReturningAnInt());
assertEquals("a second time 5", 5, myMock.fctReturningAnInt());

when(myMock.fctReturningAnInt()).thenReturn(3, 4);
// shortcut for .thenReturn(3).thenReturn(4);
```

Stubbing

Raising exceptions

```
public int returnAnIntorRaiseAnExc() throws WhateverException;  
// stubbing  
when(myMock.returnAnIntorRaiseAnExc()).thenReturn(3)  
    .thenThrow(new WhateverException());  
  
// description with JUnit  
assertEquals("1st call: returns 3",  
    3, myMock.returnAnIntorRaiseAnExc());  
  
try {  
    myMock.returnAnIntorRaiseAnExc(); fail();  
} catch (WhateverException e) {  
    assertTrue("2nd call: exception", true);  
}
```

Exception raising + void method = doThrow

Some remarks

- Methods `equals()` and `hashCode()` cannot be *stubbed*
- A mock behavior not executed does not lead to an error
- One must use *verify*
 - Which methods have been called on a mock
 - How many times, with which parameters, in which order
- An exception is raised if checking fails, the test will fail as well

Verify

- Method called only once:
 - `verify(myMock).somefunction();`
 - `verify(myMock, times(1)). somefunction();`
- Method called at least/at most once:
 - `verify(myMock, atLeastOnce()). somefunction();`
 - `verify(myMock, atMost(1)) somefunction();`
- Method never called:
 - `verify(myMock, never()). somefunction();`
- With specific parameters:
 - `verify(myMock). someotherfunction(4, 2);`

Verify

- `import org.mockito.InOrder;`
- To check that the call (4,2) is done before the call (5,3):
 - `InOrder ord = inOrder(myMock);`
 - `ord.verify(myMock).somefunction(4, 2);`
 - `ord.verify(myMock).somefunction(5, 3);`
- With several mocks :
 - `InOrder ord = inOrder(mock1, mock2);`
 - `ord.verify(mock1).foo();`
 - `ord.verify(mock2).bar();`

Alternatives to Mockito

- EasyMock, Jmock
- All based on expect-run-verify