IV Máster en Ingeniería Web y Tecnologías RIA

UNIVERSIDAD DE MÁLAGA

Unit Testing

MÓDULO 5

Ingeniería del Software

Software Testing

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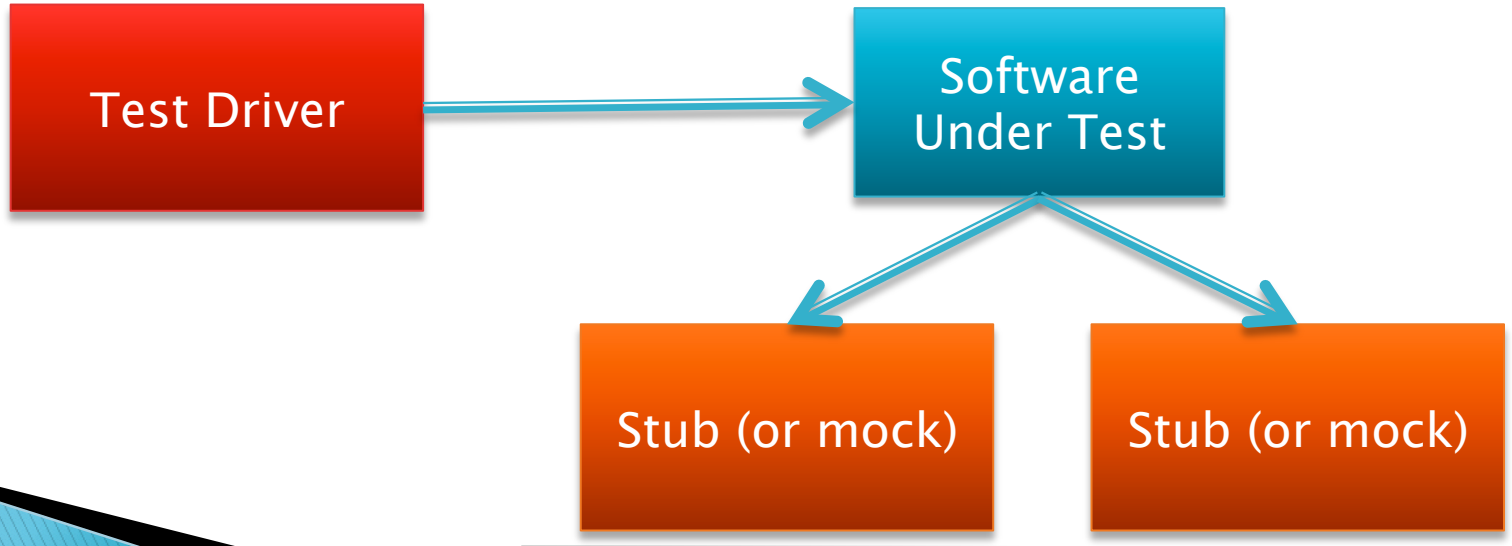
Unit testing
Background

- Unit testing consists in testing one single module or class in an isolated way.
- A white-box approach is frequently used.
- Drivers and stubs (or mocks) are required.



Unit testing
Background

- In object-oriented software
  - Classes are tested in isolation
  - Each method of the class is tested separately
  - Take into account the state of the object
- How to test:
  - Constructors
  - Getters and Setters
  - Conventional methods
    - Without (parameters/return value)
  - Exceptions
  - Non-public methods

Unit testing
Background

- Testing constructors (white-box).
  1. Call the constructor with adequate parameters
  2. Check that the fields have been properly filled (using get methods or direct access to the fields).
- Testing get/set methods.
  1. Create a new object.
  2. Set a property using a set method.
  3. Read the property using the get method.
  4. Compare the obtained value with the original one.

Unit testing
Background

- Testing conventional methods.
  - Execution depends on (determine the test data):
    1. Input parameters
    2. Internal state of the object
    3. State of collaborator objects
    4. External entities (database, file system, network…)
  - Effects of execution are (determine the check code) :
    1. Return value
    2. Changes in the parameters
    3. Exceptions
    4. Changes in the internal state of the object
    5. Changes in the external environment
  - We need to take into account the elements that influence the method and the effects of its execution in order to build suitable test cases for the method.

Unit testing
Background

- Testing conventional methods (cont.).
  - How can we influence on:
    1. Input parameters
    2. Internal state of the object
    3. State of collaborator objects
    4. External entities
  - Effects of execution:
    1. Return value
    2. Changes in the parameters
    3. Exceptions
    4. Changes in the internal state of the object
    5. Changes in the external environment

Arguments of the method

Sequence of methods call

Tested objects, stubs and mocks

Unit testing
Background

- Testing conventional methods (cont.).
  - How can we influence on:
    1. Input parameters
    2. Internal state of the object
    3. State of collaborator objects
    4. External entities

    } Methods with no-arg
  - Effects of execution:
    1. Return value
    2. Changes in the parameters
    3. Exceptions
    4. Changes in the internal state of the object
    5. Changes in the external environment

    } Methods without return value

Unit testing
Background

- Testing expected exceptions.
  1. Include the method in a try/catch block
  2. Notice a fail after the method (in case the exception is not raised)
  3. In the catch block check the parameters of the exception object.
- Testing unexpected exceptions.
  - Notice a fail if any other exception is raised.
  - Nothing to check because they are unexpected!!

Unit testing
Background

- Testing non-public methods (private, protected…)
- Several approaches:
  - Change the visibility of the method (intrusive ↓)
  - Use internal test classes (intrusive ↓)
  - Place the TC in the same package as CUT (protected and package only ↓)
  - Use the Reflection API (non intrusive ↑)
  - Use Accessor class (non intrusive ↑)

JUnit

Unit testing
JUnit

- JUnit is a framework for automating unit testing in Java applications.
- Developed by Gamma and Beck in 1997.
- It is Open Source and distributed under CPL 1.0.
- Freely available at GitHub
  - https://github.com/junit-team/junit/wiki
- Latest version: JUnit 4.11
- Web: http://www.junit.org

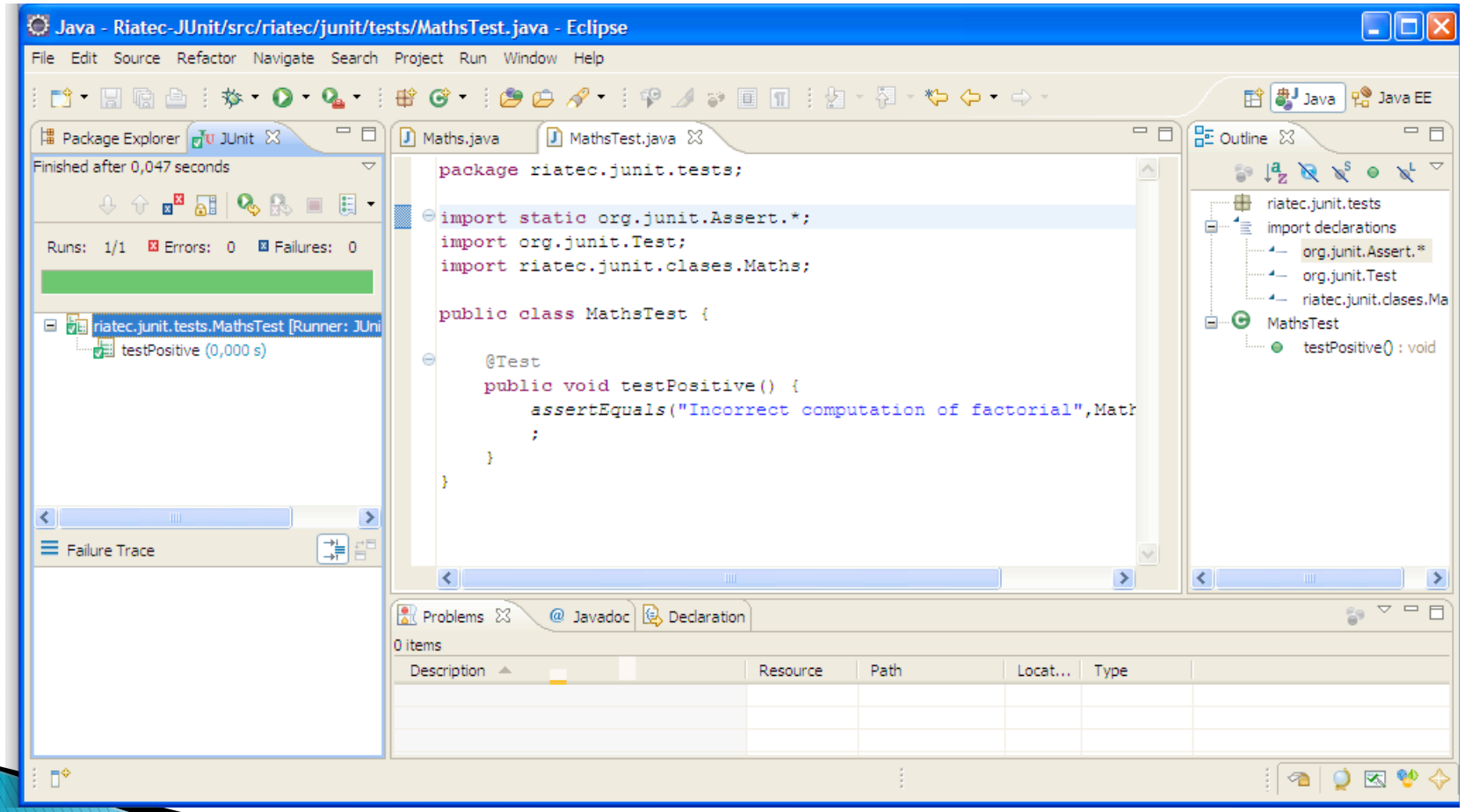
Unit testing
JUnit: getting started

1. Add the JUnit jar file to the classpath.
2. Add the @Test annotation to the test methods.
3. Import the static methods of org.junit.Assert.

```
package riatec.unit.example;

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

public class MathsTest {

    @Test
    public void testPossitive()
    {
        assertEquals("Incorrect computation of factorial", 120, Maths.f(5));
    }
}
```

Unit testing
JUnit: getting started

- Easy support for JUnit test cases in Eclipse



Unit testing
JUnit: methodology

1. Create a test class, TC, (the test driver). The name should recall the CUT (class under test)
   - For example: for class Maths -> MathsTest
2. Create a test method in TC for each method to test in CUT (annotated with @Test).
3. Use the assert… methods to report errors.
4. Use descriptive messages for the failures.

Unit testing
JUnit: assert methods

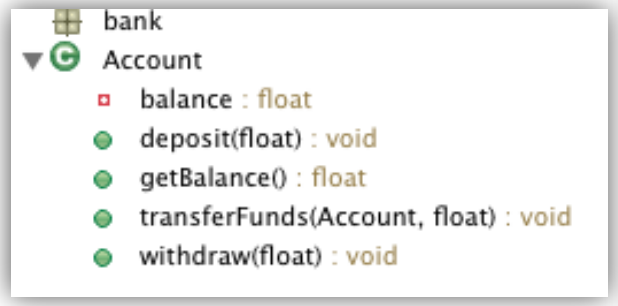
- Defined in org.junit.Assert
  - assertEquals
  - assertArrayEquals
  - assertNull
  - assertNotNull
  - assertTrue
  - assertFalse
  - assertSame
  - assertNotSame
  - fail
- Parameters:
  - (expected, actual)
  - (message, expected, actual)

Examples

```
assertEquals(200, source.getBalance());

assertEquals("Withdrawal error", 200, source.getBalance());
```

Unit testing
JUnit: one simple example

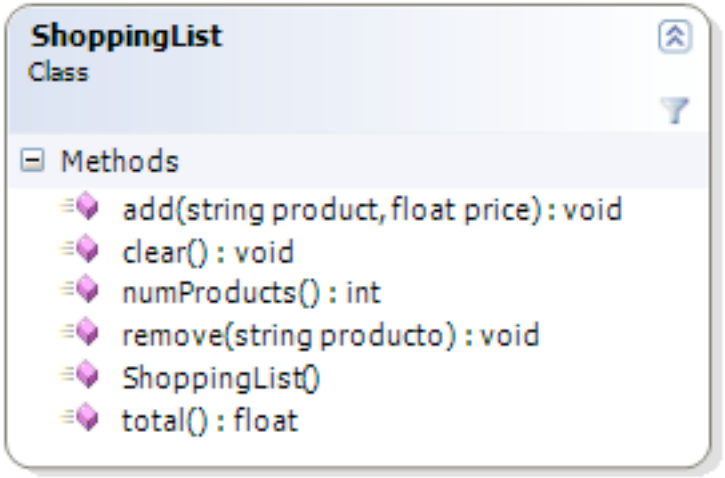
- Example




```
package bank;

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

public class BankTest {

    @Test
    public void TransferFunds()
    {
        Account source = new Account();
        source.deposit(200.00f);
        Account destination = new Account();
        destination.deposit(150.00f);

        source.transferFunds(destination, 100.00f);
        assertEquals(250.00f, destination.getBalance(),0.0);
        assertEquals(100.00f, source.getBalance(),0.0);

    }
}
```

Unit testing
JUnit: one exercise

- Book shop Web application.
  - Test the following class (in package bookshop).



  - Create a new project.
  - Include bookshop.jar in the java build path.

Unit testing
JUnit: @Before and @After

- Before running some tests some initialization might be required (fixture).
- @Before annotates the methods that do this initialization.
- All the "@Before methods" are run before each test method.
- @After annotates the methods that release the resources allocated with @Before
- If a per-class initialization and release is required use the annotations @BeforeClass and @AfterClass (on static no-arg methods).

Unit testing
JUnit: @Before and @After example

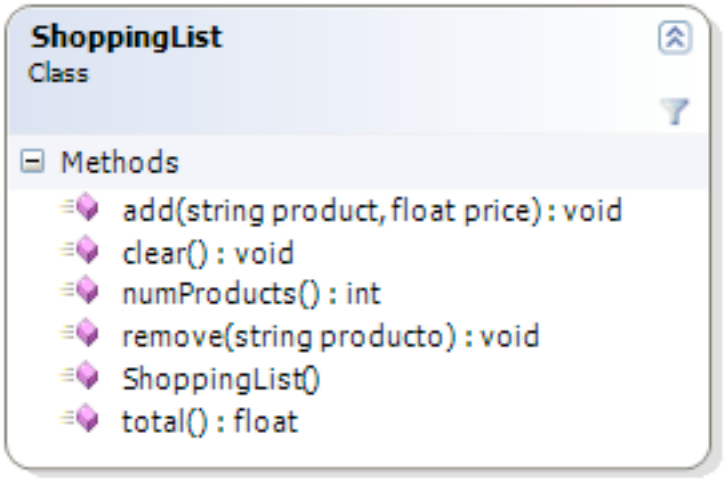
- One example with @Before

This method is executed before each test

```
package bank;

import static org.junit.Assert.*;

import org.junit.Before;
import org.junit.Test;

public class BankTest {

    Account source;
    Account destination;

    @Before
    public void initialize()
    {
        source = new Account();
        source.deposit(200.00f);
        destination = new Account();
        destination.deposit(150.00f);
    }

    @Test
    public void TransferFunds()
    {
        source.transferFunds(destination, 100.00f);
        assertEquals(250.00f, destination.getBalance(),0.0);
        assertEquals(100.00f, source.getBalance(),0.0);
    }

    @Test
    public void Withdrawal()
    {
        source.withdraw(50.00f);
        assertEquals(150.00f, source.getBalance(),0.0);
    }
}
```

Unit testing
JUnit: another exercise

- Book shop Web application.
  - Test the following class and use @Before.



  - Create a new project.
  - Include bookshop.jar in the java build path.

Unit testing
JUnit: exceptions

- Test of expected exceptions
  - @Test(expected=…Exception.class)
    - The exception must be declared using throws
    - Very simple
    - Drawback: we cannot check the exception object
  - Surround the code with try-catch
    - The most general approach (less elegant)
    - We can check the exception object
- Test of unexpected exceptions
  - Nothing to do: JUnit reports a fail if an unexpected exception occurs.

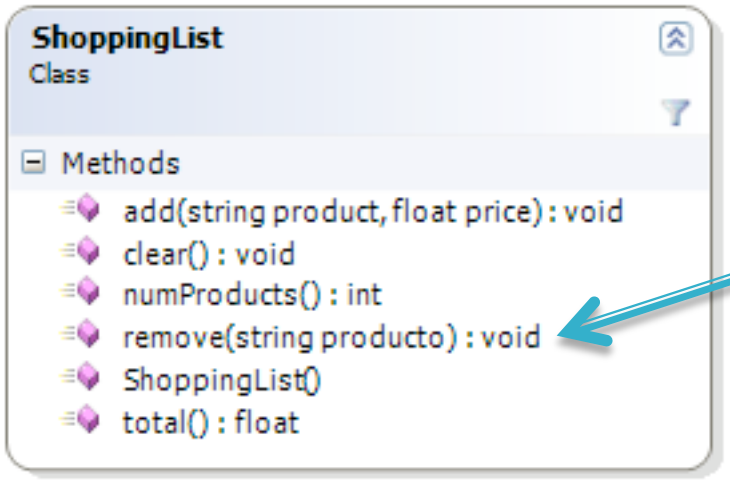
Unit testing
JUnit: non-public methods

- How to test protected, private or package methods?
- Use the Reflection API (non intrusive ↑)

```
@Test
public void testPrivate() throws Exception
{
    Class cl = sl.getClass();
    Method m = cl.getDeclaredMethod("privateMethod", int.class);
    m.setAccessible(true);
    Object o = m.invoke(sl, 6);
    assertEquals(12,o);

}
```

Unit testing
JUnit: exceptions exercise

- Book shop Web application.
  - Now, the remove method can throw an exception.



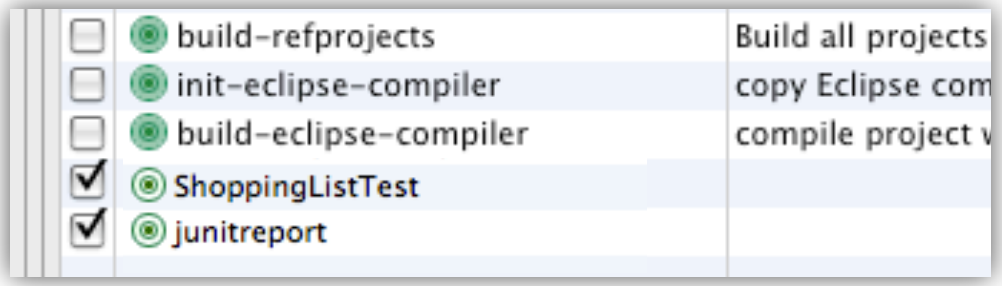
Throws a NoSuchElementException if the product is not found

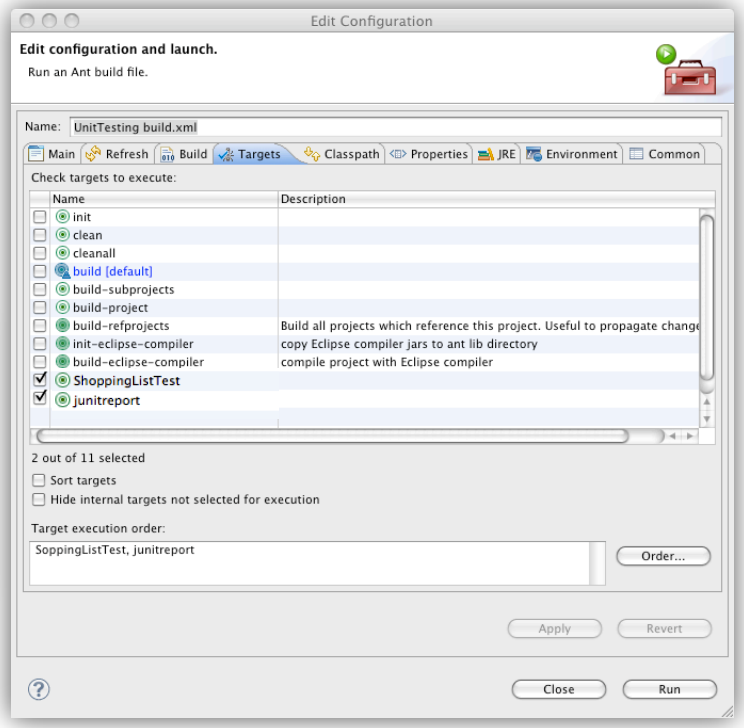
The message of the exception should be: “Product not found”

  - Check that the exception is thrown.
  - Check that the message is correct.
  - Upload the .java file of the TestClass.

Unit testing
JUnit: data-driven tests and reports

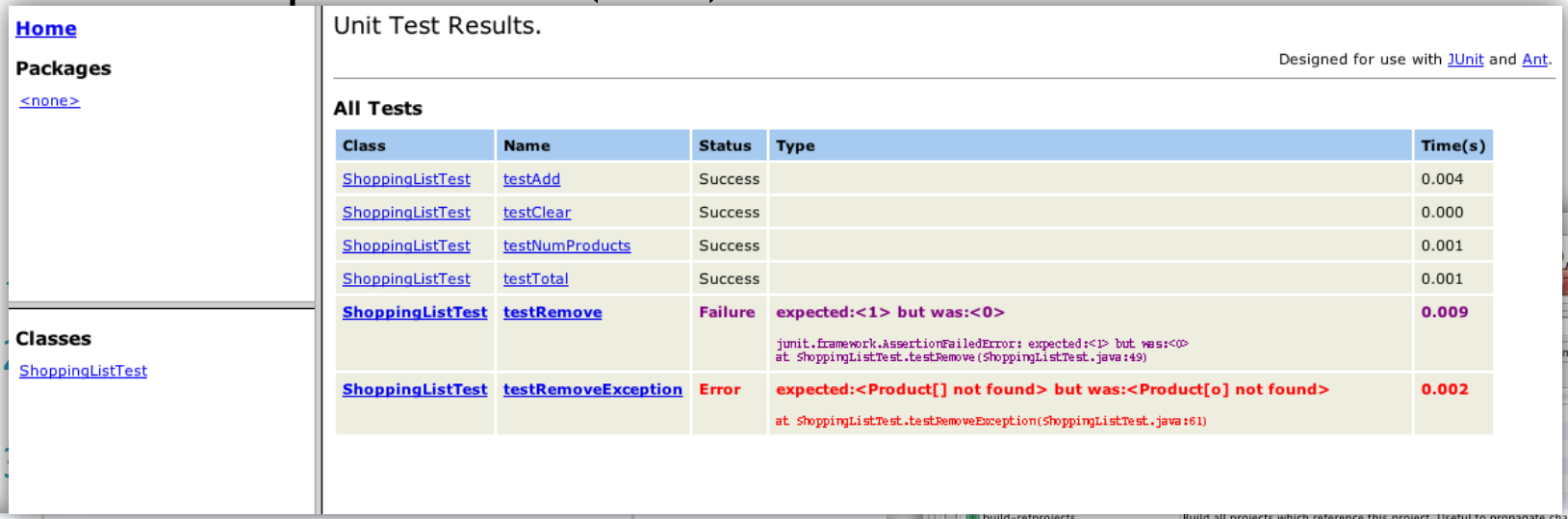
- Sometimes we want to test a method in the same way using different parameters (data).
- They are called data-driven tests.
- JTestCase can be used together with JUnit for this.
- It is possible to get junit reports.
  1. Export the project as an Ant buildfile
  2. Run the tests in ant followed by the junitreport target
  3. HTML reports will be obtained

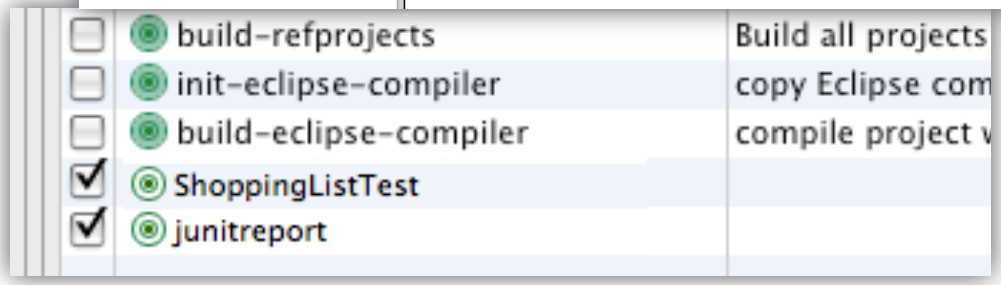


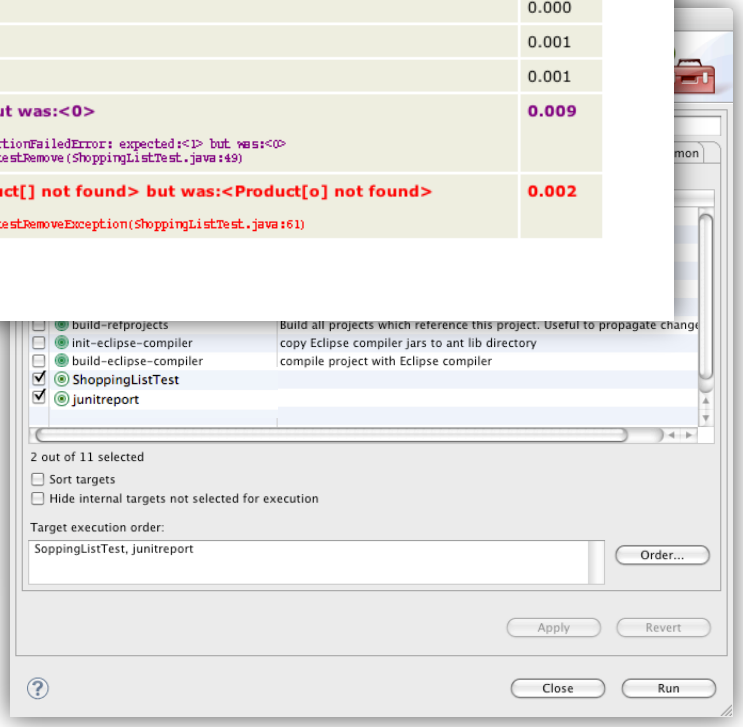


Unit testing
JUnit: data-driven tests and reports

- Sometimes we want to test a method in the same way using different parameters (data).







Visual Studio

Unit testing
Visual Studio: getting started

1. Import the namespace: Microsoft.VisualStudio.TestTools.UnitTesting
2. Add the [TestClass] attribute to the test class.
3. Add the [TestMethod] attribute to the test methods.
4. Use the static methods of Assert.

Simplified thanks to the testing integration

```
namespace Bank
{
    using Microsoft.VisualStudio.TestTools.UnitTesting;
    [TestClass]
    class AccountTest
    {

        [TestMethod]
        public void TransferFunds()
        {
            Account source = new Account();
            source.Deposit(200.00f);
            Account destination = new Account();
            destination.Deposit(150.00f);

            source.TransferFunds(destination, 100.00f);
            Assert.AreEqual(250.00f, destination.Balance);
            Assert.AreEqual(100.00f, source.Balance);
        }
```

Unit testing
Visual Studio: methodology

1. Create a test class, TC, (the test driver) and assign the attribute [TestClass]. The name should recall the CUT (class under test).
   - For example: for class Maths -> MathsTest
2. Create a test method in TC for each method to test in CUT (with attribute [TestMethod]).
3. Use the Assert static methods to report failures.
4. Use descriptive messages for the failures.

Unit testing
Visual Studio: Assert methods

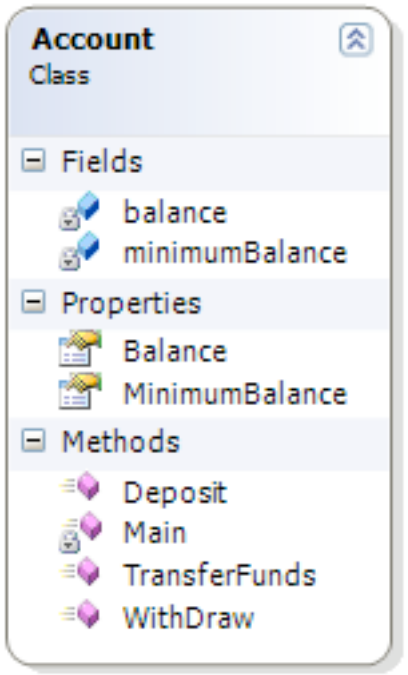
- Defined in Microsoft.VisualStudio.TestTools.UnitTesting.Assert (non-exhaustive list)
  - AreEqual
  - AreNotEqual
  - AreSame
  - AreNotSame
  - IsNull
  - IsNotNull
  - IsTrue
  - IsFalse
  - Fail
  - …
- Parameters:
  - (expected, actual)
  - (expected, actual, message)
  - (expected, actual, message, arguments)

Examples

```
Assert.AreEqual(200, source.Balance);
Assert.AreEqual(200, source.Balance, “Withdrawal error”);
Assert.AreEqual(200, source.Balance, “Withdrawal error {0}”,200);
```

Unit testing
Visual Studio: one simple example

- Example



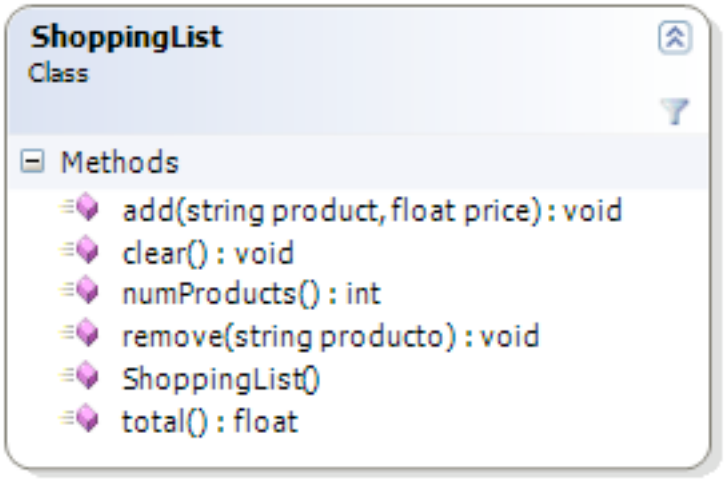
AccountTest.cs

Bank.AccountTest | TransferFunds()

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;

namespace Bank
{
    using Microsoft.VisualStudio.TestTools.UnitTesting;
    [TestClass]
    class AccountTest
    {
        [TestMethod]
        public void TransferFunds()
        {
            Account source = new Account();
            source.Deposit(200.00f);
            Account destination = new Account();
            destination.Deposit(150.00f);

            source.TransferFunds(destination, 100.00f);
            Assert.AreEqual(250.00f, destination.Balance);
            Assert.AreEqual(100.00f, source.Balance);
        }
    }
}
```

Unit testing
Visual Studio: one exercise

- Book shop Web application.
  - Test the following class (in namespace BookShop).



  - Create a new project.
  - Include BookShop.dll in your references.

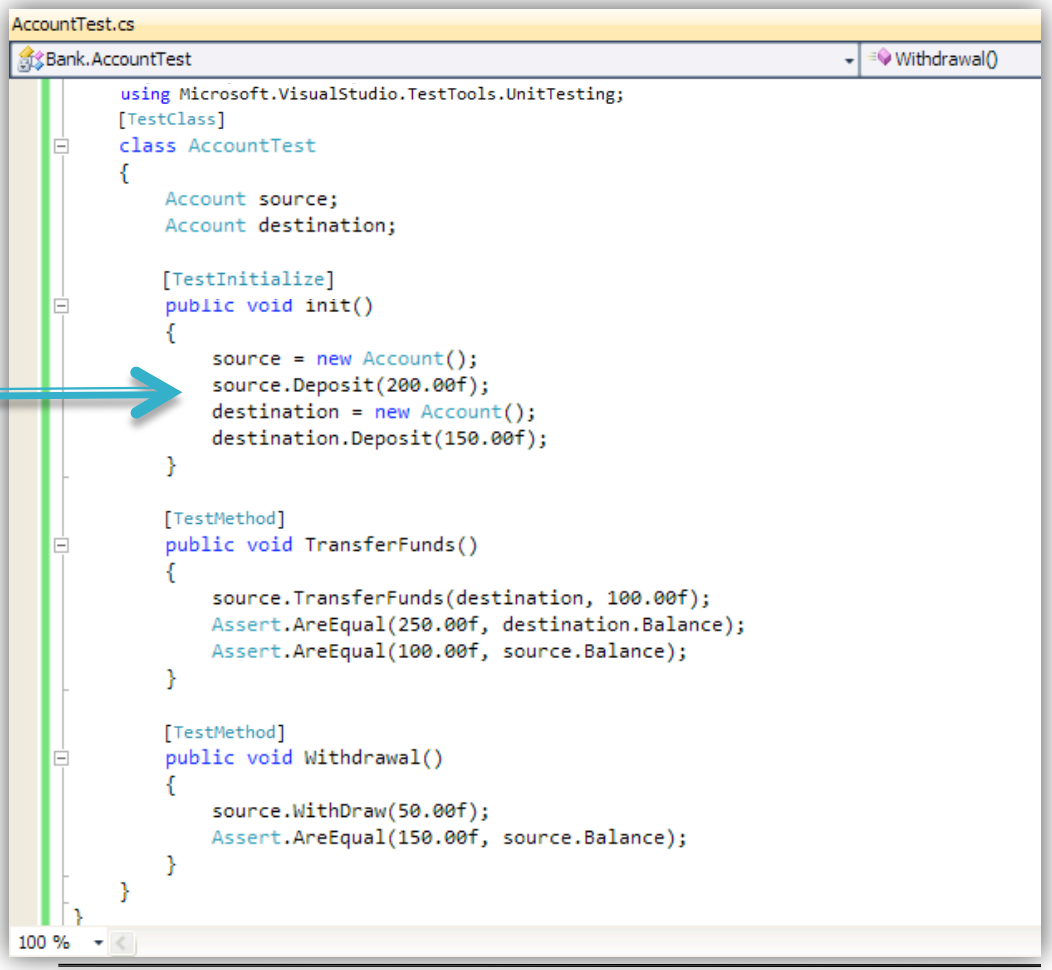
Unit testing
VS: [TestInitialize] and [TestCleanup]

- Before running some tests some initialization might be required (fixture).
- [TestInitialize] annotates the methods that do this initialization.
- All the "[TestInitialize] methods" are run before each test method.
- [TestCleanup] annotates the methods that release the resources allocated with [TestInitialize]
- If a per-class (fixture) initialization and release is required use the attributes:
  - [ClassInitilize] and [ClassCleanup].

Unit testing
VS: [TestInitialize] and [TestCleanup] example

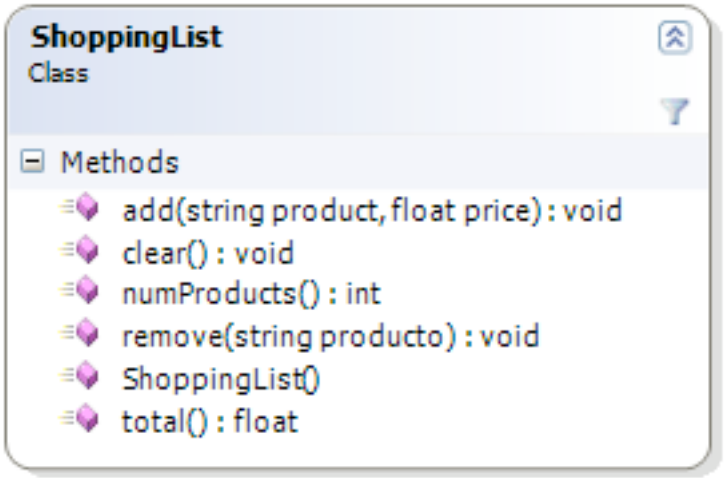
- One example with [TestInitialize]

This method is executed before each test



Unit testing
Visual Studio: another exercise

- Book shop Web application.
  - Test the following class and use [TestInitialize] methods.



  - Create a new project.
  - Include BookShop.dll in your references.

Unit testing
Visual Studio: exceptions

- Test of expected exceptions
  - [TestMethod] [ExpectedException(typeof(… Exception))]
    - Very simple
    - Drawback: we cannot check the exception object
  - Surround the code with try-catch
    - The most general approach (less elegant)
    - We can check the exception object
- Test of unexpected exceptions
  - Nothing to do: Visual Studio reports a fail if an unexpected exception occurs.

Unit testing
Visual Studio: non-public methods

- How to test protected, private or package methods?
- Use the Reflection API (non intrusive ↑)

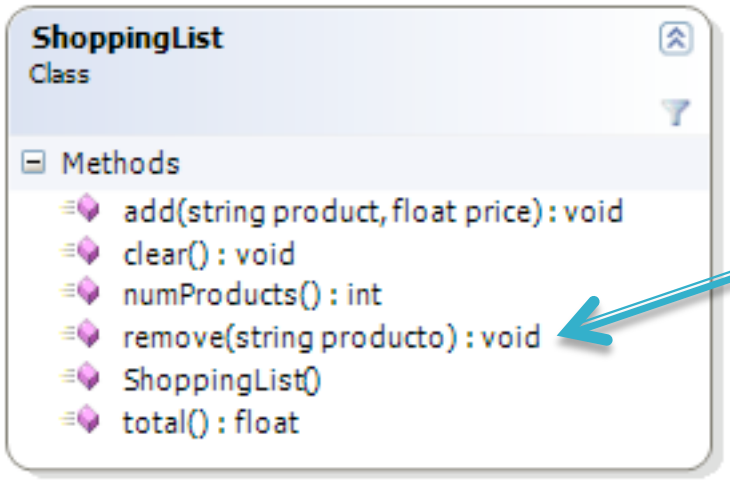
```
[TestMethod]
public void TestPrivate()
{
    Type t = sl.GetType();
    MethodInfo mi = t.GetMethod("PrivateMethod", BindingFlags.NonPublic | BindingFlags.Instance);
    object o = mi.Invoke(sl, new object[] { 6 });
    Assert.AreEqual(12, o);
}
```

- Use of Accessor classes (non intrusive ↑)

```
[TestMethod()]
[DeploymentItem("Gramatica.dll")]
public void setTerminalTest()
{
    Grammar_Accessor target = new Grammar_Accessor(); // TODO: Initialize to an appropriate value
    int v = 4; // TODO: Initialize to an appropriate value
    string t = "hola"; // TODO: Initialize to an appropriate value
    target.setTerminal(v, t);
    Assert.AreEqual("hola", target.getTerminales(v), "Error al insertar terminal");

}
```

Unit testing
Visual Studio: exceptions exercise

- Book shop Web application.
  - Now, the remove method can throw an exception.



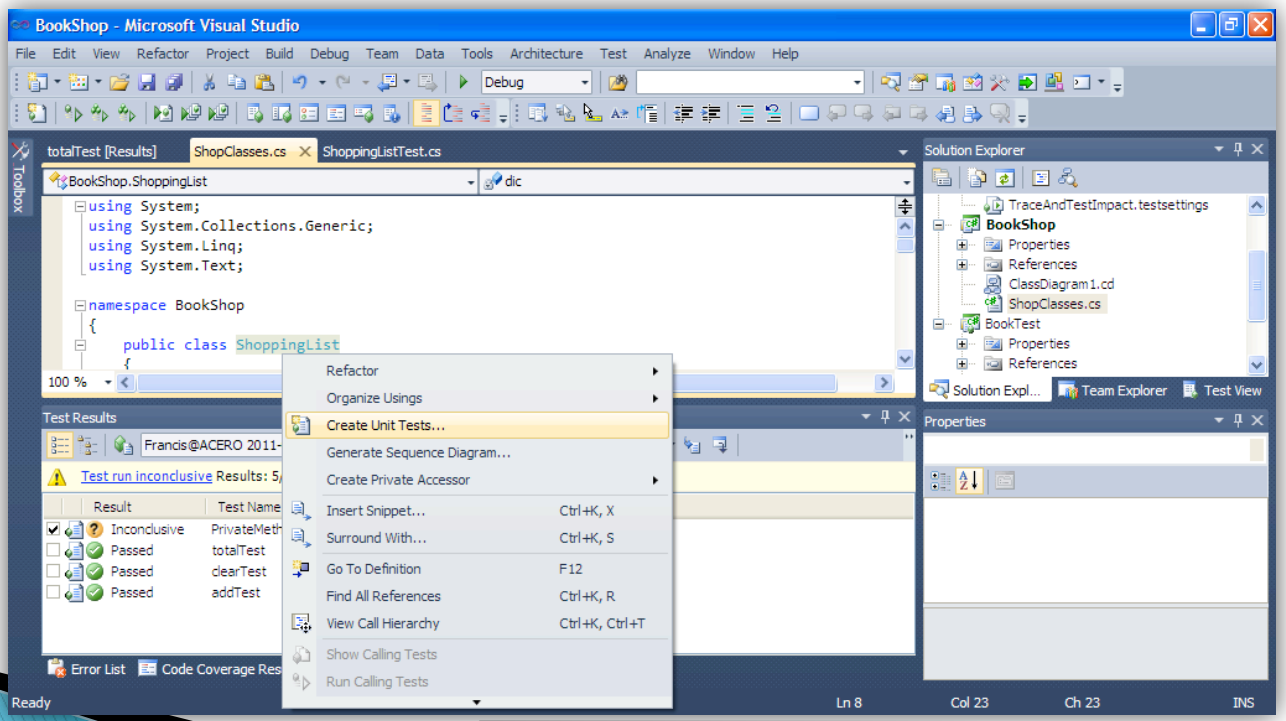
Throws an ApplicationException if the product is not found

The message of the exception should be: “No product found”

  - Check that the exception is thrown.
  - Check that the message is correct.
  - Upload the .cs file of the TestClass.

Unit testing
Visual Studio: other features

- Other features of Visual Studio:
  - Easy to generate test class (in VS 2010)
  - Easy support for data-driven tests
  - Code coverage analysis



Unit testing
Visual Studio: other features

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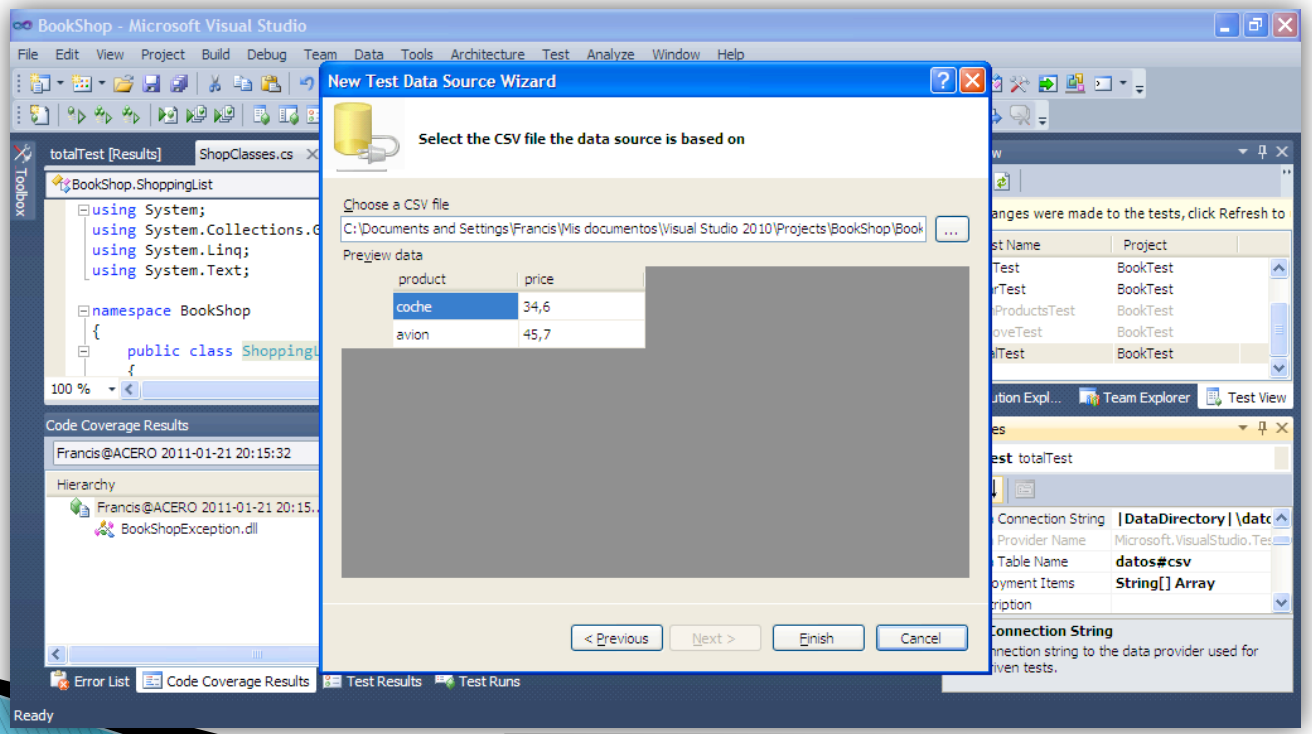

Unit testing
Visual Studio: other features

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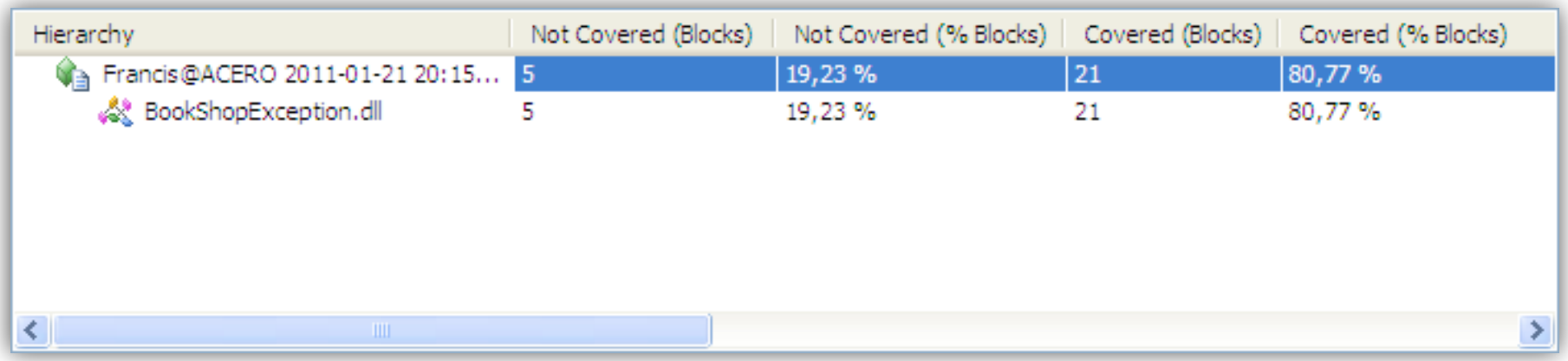


Hierarchy	Not Covered (Blocks)	Not Covered (% Blocks)	Covered (Blocks)	Covered (% Blocks)
Francis@ACERO 2011-01-21 20:15...	5	19,23 %	21	80,77 %
BookShopException.dll	5	19,23 %	21	80,77 %

Unit testing
Code Contracts

- Allows for preconditions, postconditions and invariants to be specified and dynamically and statically checked.
- Supports the “design by contract” approach.
- Introduction of formal tools in software implementation.
- Example:

Program.cs

CodeContractRational.Rational

```
using System.Text;
using System.Diagnostics.Contracts;

namespace CodeContractRational
{
    class Rational
    {
        private int N;
        private int D;

        [ContractInvariantMethod]
        void ObjectInvariant()
        {
            Contract.Invariant(D != 0);
            Contract.Invariant(N * D >= 0);
        }


        public Rational(int n, int d)
        {
            Contract.Requires(d != 0);
            Contract.Requires(n * d >= 0);
            this.N = n;
            this.D = d;

        }
```

Unit testing
Code Contracts

- Preconditions

```
Contract.Requires(p >= 0 && p <= this.getSize());
```

- Postconditions

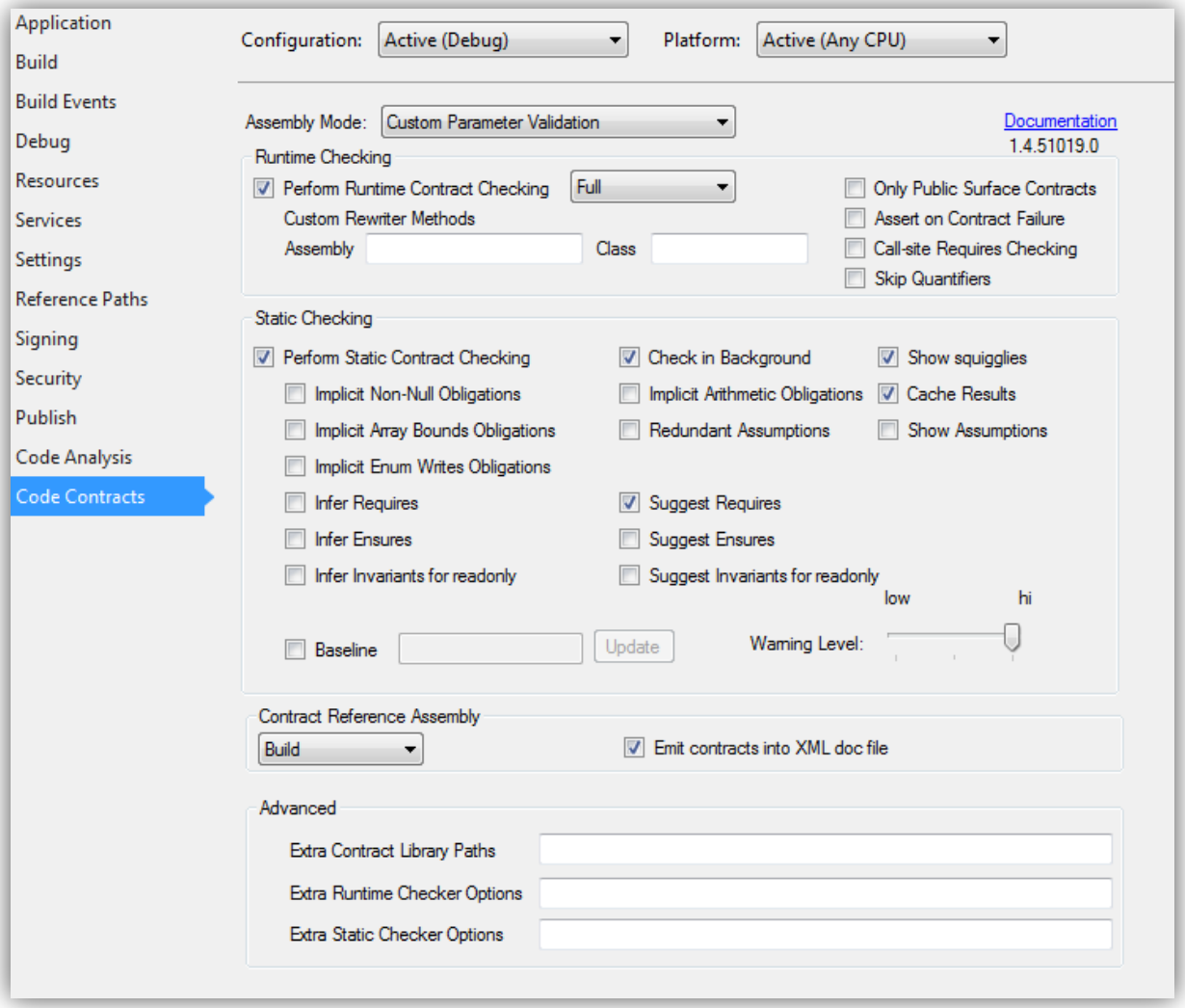
```
Contract.Ensures(Contract.Result<int>() >= 0);
```

- Invariants

```
[ContractInvariantMethod]
[System.Diagnostics.CodeAnalysis.SuppressMessage("Microsoft.Performance",
    "CA1822:MarkMembersAsStatic", Justification = "Required for code contracts.")]
private void ObjectInvariant()
{
    Contract.Invariant(n >= 0);
}
```

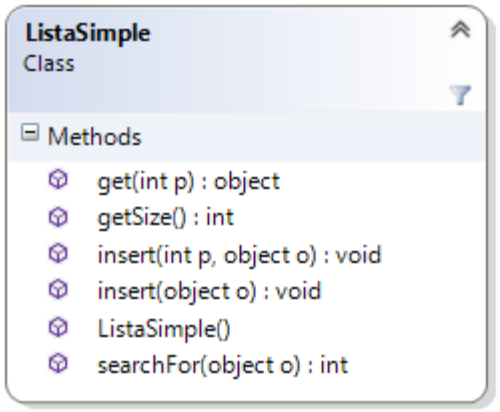
Unit testing
Code Contracts

- Configuration



Unit testing
Code Contracts: exercise

- Add contracts to the methods in a simple array-based list.




```
class MainClass
{
    public static void Main()
    {
        ListaSimple ls = new ListaSimple();
        ls.insert("hola");
        int p = ls.searchFor("hola");
        if (p >= 0)
            Console.WriteLine(ls.get(p));
    }
}
```

Unit testing
PEX

- PEX is a tool for automatically generating test cases.
- Available at: www.pexforfun.com
- Based on (decision) coverage

- Similar tools using genetic algorithms, evolutionary algorithms, and metaheuristics in general:
  - In our research group

Unit testing
PEX

- A hot topic in current research.