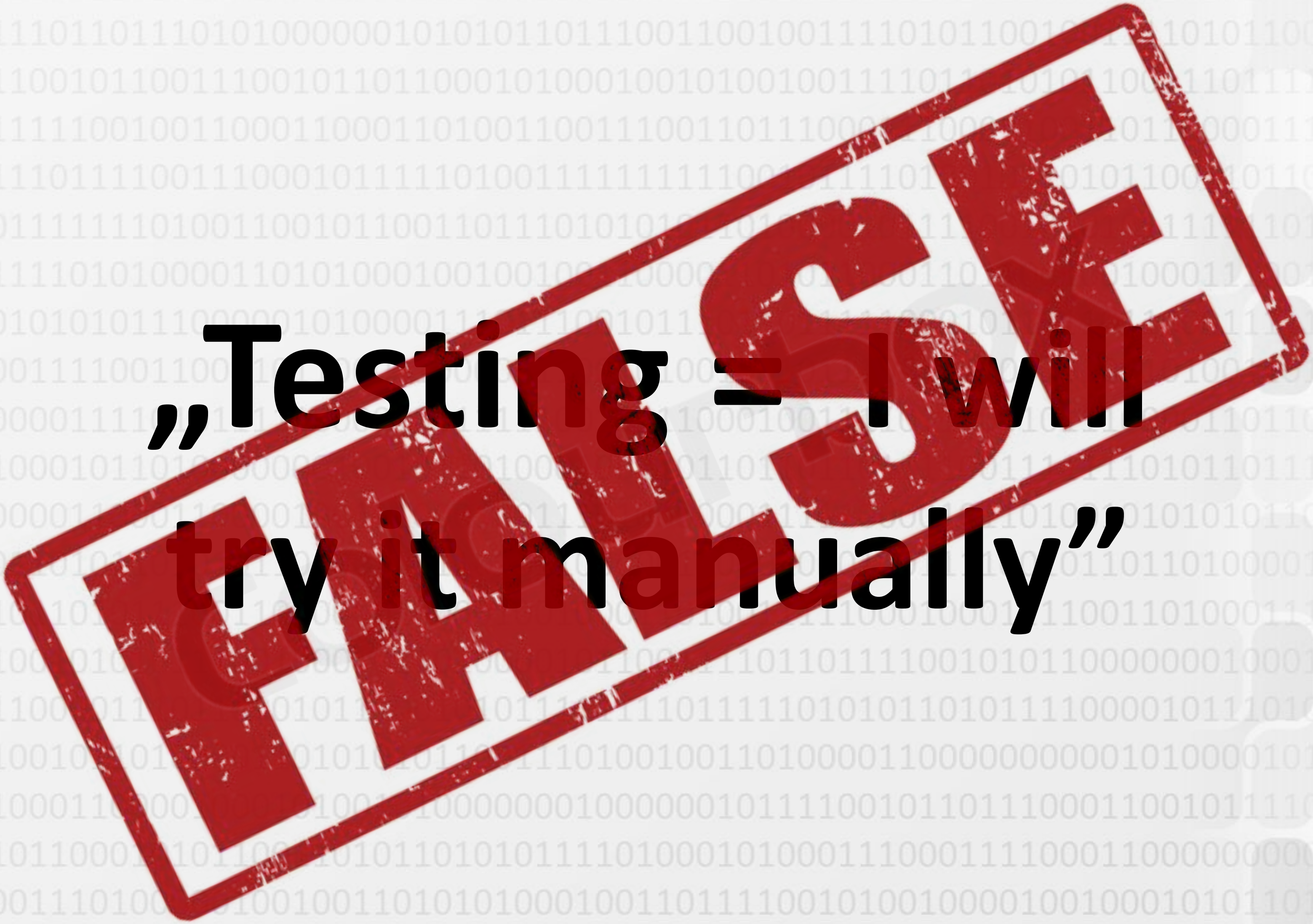
# Advanced development techniques

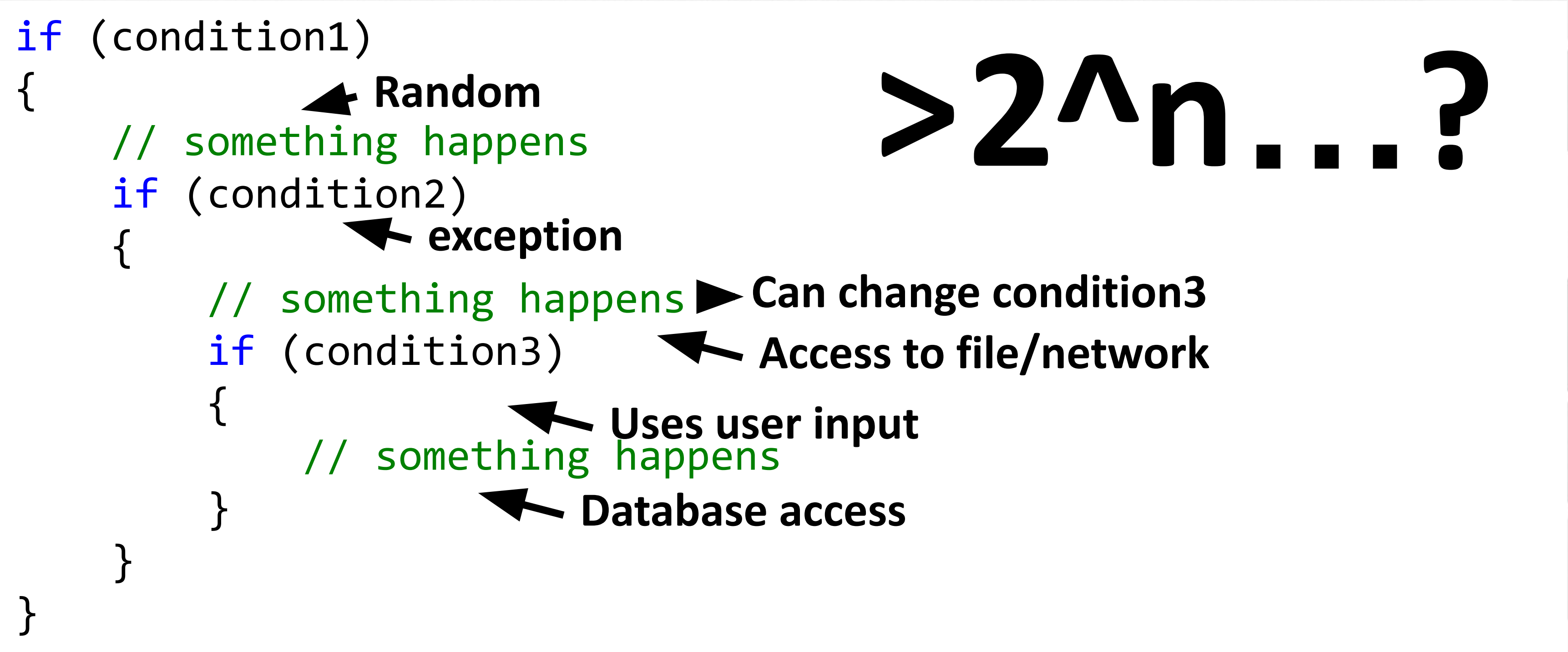
Simple Unit Tests
NUnit

# „Testing = I will try it manually”



# Automatic tests are required

- **Number of test cases?**



```
if (condition1)
{
    // something happens
    if (condition2)
    {
        // something happens
        if (condition3)
        {
            // something happens
        }
    }
}
```

**Random**

**exception**

**Can change condition3**

**Access to file/network**

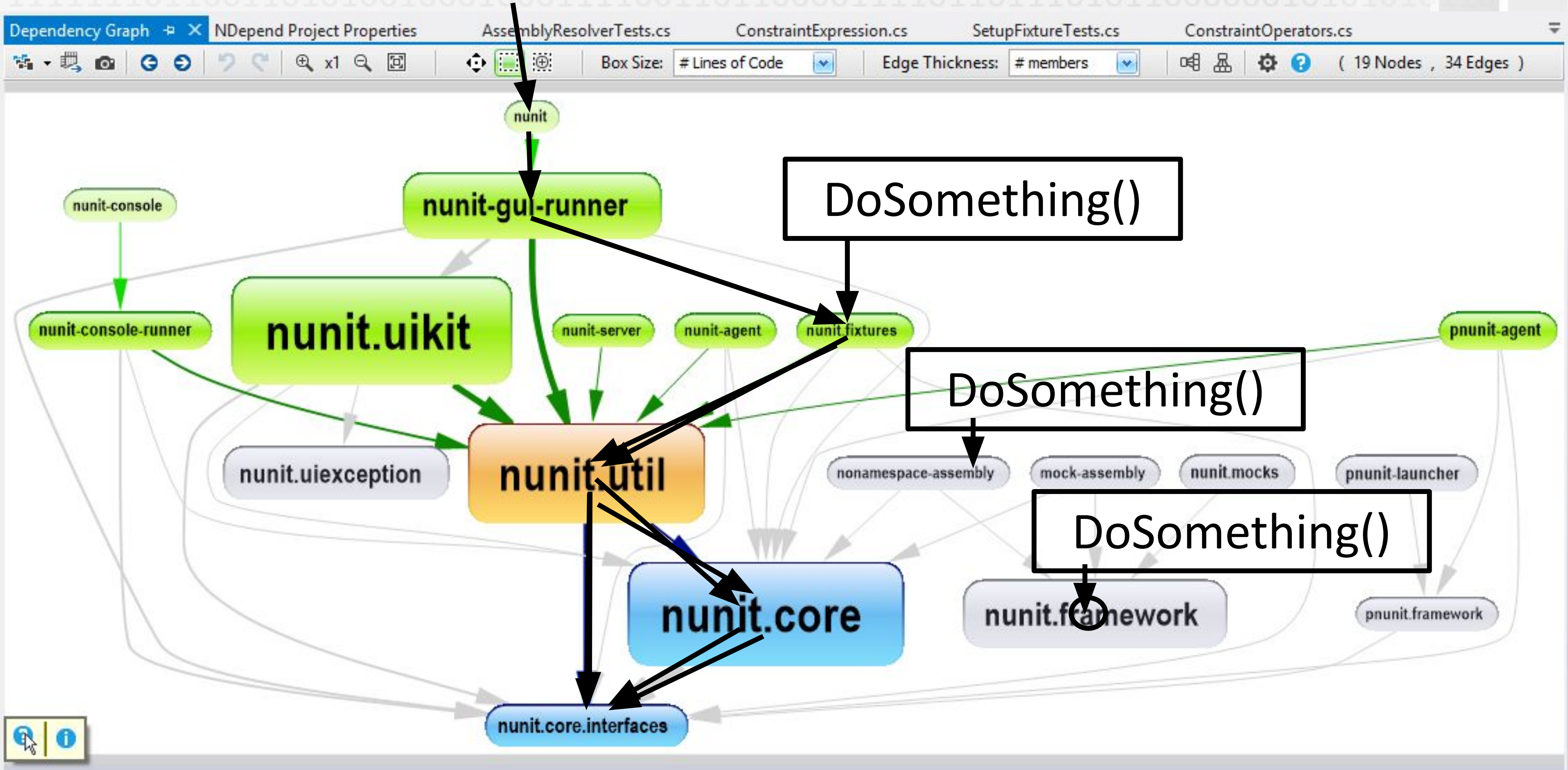
**Uses user input**

**Database access**

**>2^n...?**

- **Projects are usually A LOT BIGGER than 3 blocks!**
- **Automatic tests are developed during the development phase (“later” will mean “never”, so that is NOT an option!)**

# Different test types



- **UI tests**
- **Integration tests**
- **Component tests**
- **Unit tests**

(Names might differ from team to team)

# „The tester will test the code”

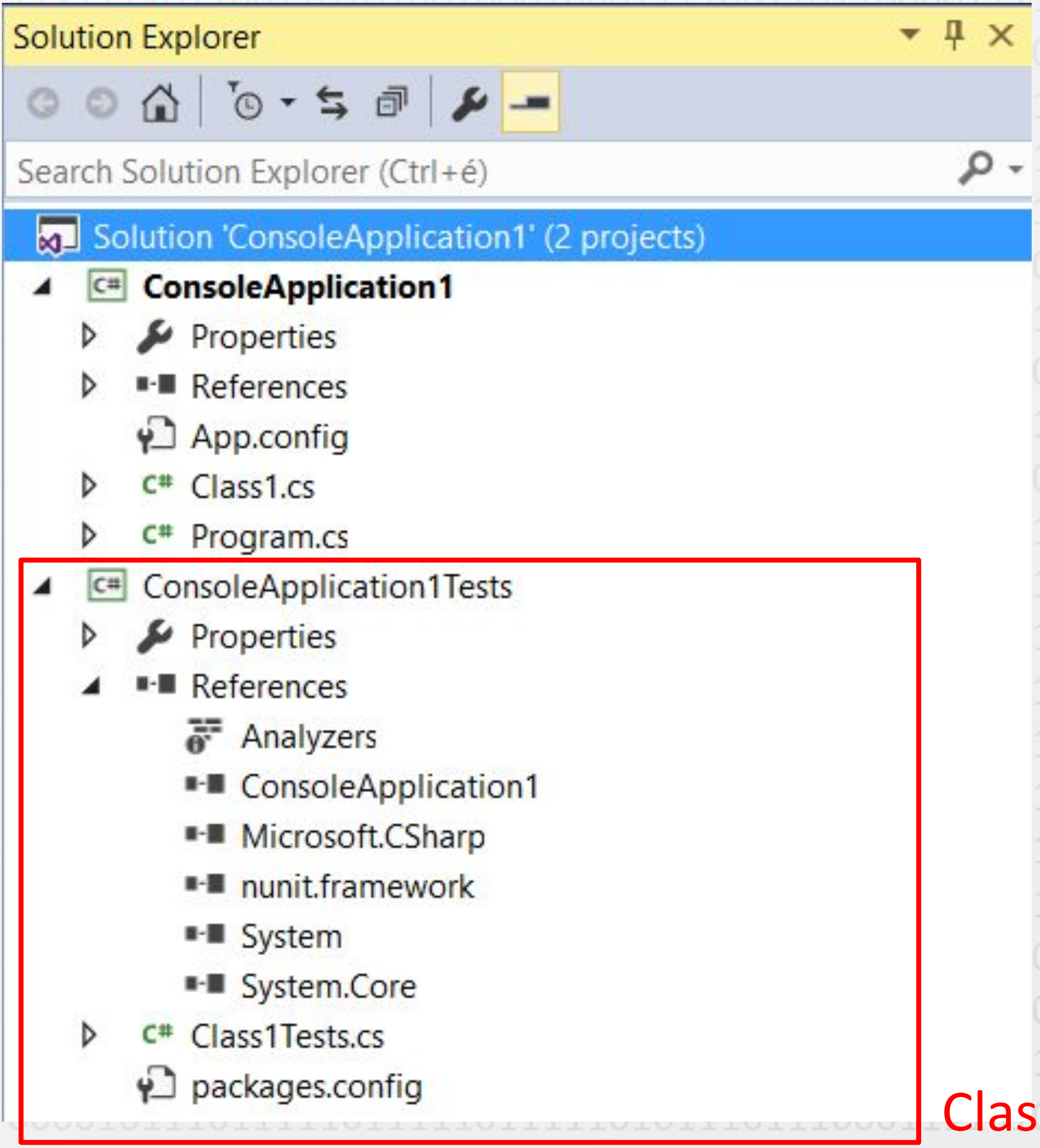
# Testing in the development work process

- **Testing moved closer to the implementation, because:**
  - Gives us an earlier feedback
  - Protects the covered code against bugs introduced later by accident
  - Helps us in clearing up requirements
  - Enforces us to write clear and well-structured code
- **(In some approaches, testing is even done BEFORE coding)**
- **„Agile crossfunctional team"**
  - The team is responsible for all aspects of the product/functionality: planning, implementation, quality check, testing…
  - More and more the maintenance and the support is also included
  - The boundaries between the old roles are grey or missing – **„crossfunctional team"**

# NUnit

- **Instead: unit test framework for .NET languages (Java: jUnit)**
- **Part of a bigger family of utilities**
  - Unit testing: **NUnit** (vs. Visual Studio Unit Testing Framework)
  - Mocking: NSubstitute (vs. **Moq**, Rhino Mocks)
  - IoC container: NInject (vs. Spring.Net, Castle Windsor, Unity)
  - Test coverage: NCover (vs. dotCover)
- **More widespread (…)**
  - Better/readable syntax
  - Good for almost all different types of tests (Unit, Integration, Performance…)
  - GUI support
  - Command line Test Runner (Dotnet Core: beta)
  - Test Explorer inside VisualStudio (with NUnit3TestAdapter)

# Simple unit test project

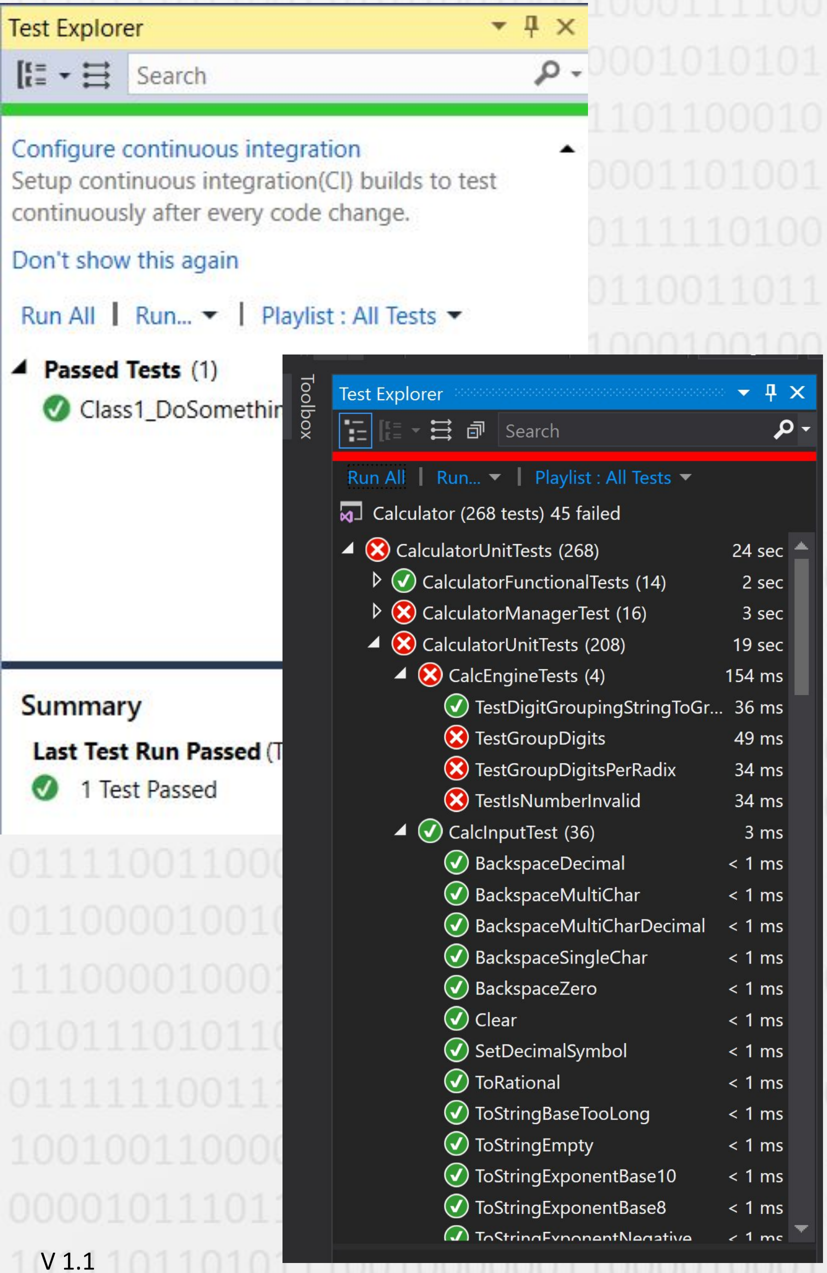


Solution 'ConsoleApplication1' (2 projects)
- **ConsoleApplication1**
  - Properties
  - References
  - App.config
  - Class1.cs
  - Program.cs
- ConsoleApplication1Tests
  - Properties
  - References
    - Analyzers
    - ConsoleApplication1
    - Microsoft.CSharp
    - nunit.framework
    - System
    - System.Core
  - Class1Tests.cs
  - packages.config

- **Live project(s) + test project(s) (Class Library)**
- **References of the test project:**
  - The project to be tested
  - Test framework
- **In the test project we want to test the public parts of the other project**
  - Internal parts: possible but rarely used [InternalsVisibleTo(„ConsoleApplication1Tests”)]
  - Private parts: forbidden
- **With unit tests we only test and check the external working of the class/module.**

Class Library

# Simple unit test project



Test Explorer

Search

Configure continuous integration

Setup continuous integration(CI) builds to test continuously after every code change.

Don't show this again

Run All | Run... | Playlist : All Tests

Passed Tests (1)

✓ Class1_DoSomethin

Summary

Last Test Run Passed (T

✓ 1 Test Passed

Test Explorer

Search

Run All | Run... | Playlist : All Tests

```
Calculator (268 tests) 45 failed
◢ ✗ CalculatorUnitTests (268)                24 sec
  ▷ ✓ CalculatorFunctionalTests (14)          2 sec
  ▷ ✗ CalculatorManagerTest (16)              3 sec
  ◢ ✗ CalculatorUnitTests (208)              19 sec
    ◢ ✗ CalcEngineTests (4)                 154 ms
        ✓ TestDigitGroupingStringToGr...     36 ms
        ✗ TestGroupDigits                    49 ms
        ✗ TestGroupDigitsPerRadix            34 ms
        ✗ TestIsNumberInvalid                34 ms
    ◢ ✓ CalcInputTest (36)                    3 ms
        ✓ BackspaceDecimal                  < 1 ms
        ✓ BackspaceMultiChar                < 1 ms
        ✓ BackspaceMultiCharDecimal         < 1 ms
        ✓ BackspaceSingleChar               < 1 ms
        ✓ BackspaceZero                     < 1 ms
        ✓ Clear                             < 1 ms
        ✓ SetDecimalSymbol                  < 1 ms
        ✓ ToRational                        < 1 ms
        ✓ ToStringBaseTooLong               < 1 ms
        ✓ ToStringEmpty                     < 1 ms
        ✓ ToStringExponentBase10            < 1 ms
        ✓ ToStringExponentBase8             < 1 ms
        ✓ ToStringExponentNegative          < 1 ms
```

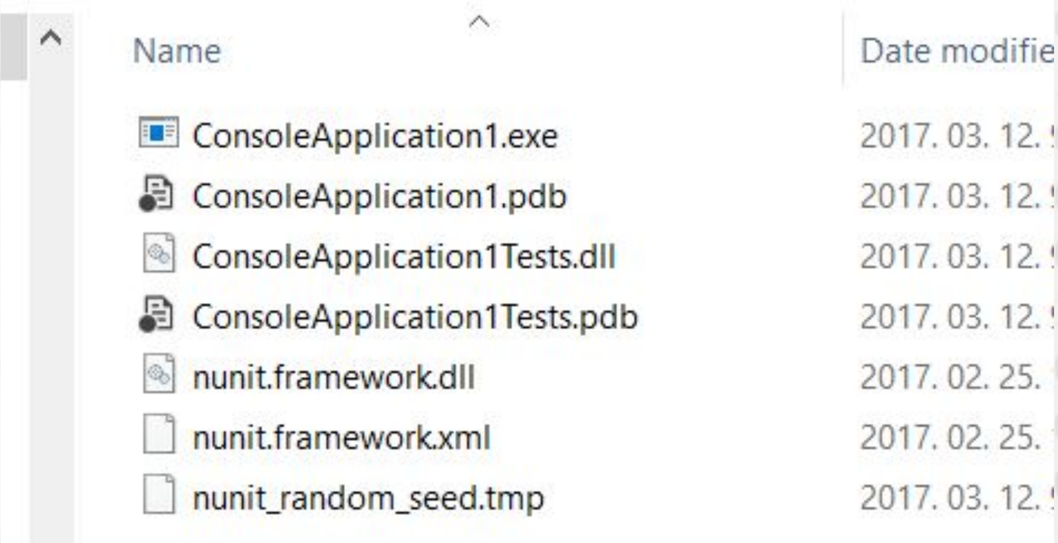
- **Test / Windows / Test Explorer**
- **NUnit3TestAdapter required! (Nuget)**

- **Depending on the development team and the tests, execute tests**
  - always,
  - or after an important change in the code,
  - before/after a merge,
  - Before push ALWAYS

- **NEVER PUSH NON-PASSING CODE!**

# How does it work?

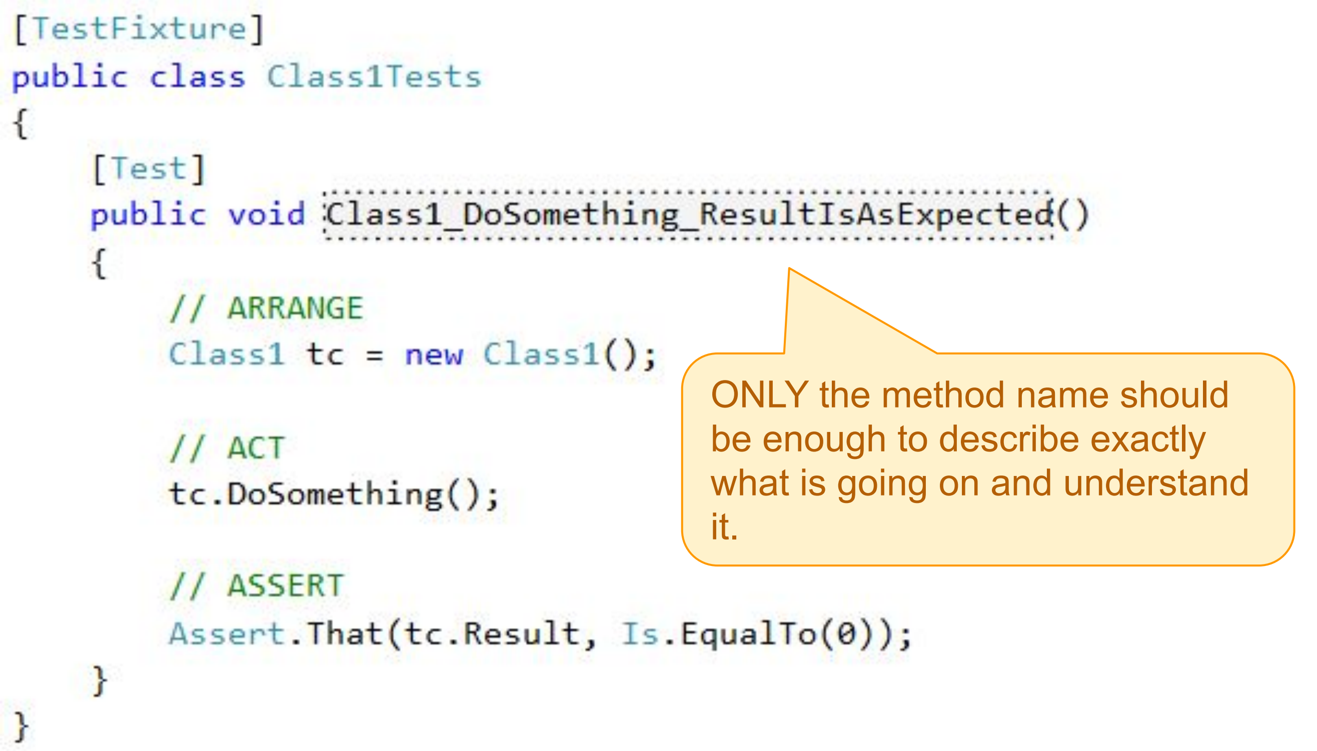
- **Reflection**



| Name | Date modifie |
|---|---|
| ConsoleApplication1.exe | 2017. 03. 12. |
| ConsoleApplication1.pdb | 2017. 03. 12. |
| ConsoleApplication1Tests.dll | 2017. 03. 12. |
| ConsoleApplication1Tests.pdb | 2017. 03. 12. |
| nunit.framework.dll | 2017. 02. 25. |
| nunit.framework.xml | 2017. 02. 25. |
| nunit_random_seed.tmp | 2017. 03. 12. |

- **Studio Test Explorer => NUnit**
  - NUnit uses reflection to look for the **[TestFixture]** attribute in all classes in the solution (exe/dll)
  - The [TestFixture] class has methods marked with [Test], those methods are located via reflection
  - It interprets the additional configuration attributes ([TestCaseSource], [Explicit], ... ... ... ) that change the input/operation/…
  - Then the test methods are executed using reflection

# NUnit

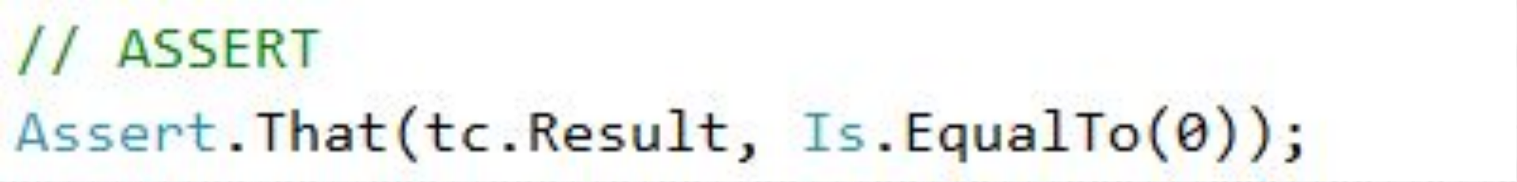


```
[TestFixture]
public class Class1Tests
{
    [Test]
    public void Class1_DoSomething_ResultIsAsExpected()
    {
        // ARRANGE
        Class1 tc = new Class1();

        // ACT
        tc.DoSomething();

        // ASSERT
        Assert.That(tc.Result, Is.EqualTo(0));
    }
}
```

ONLY the method name should be enough to describe exactly what is going on and understand it.

- **Common test parts („AAA”)**
  - **Arrange**: preparation, instance creation, setting values, etc.
  - **Act**: executing the **single** step that we want to test
  - **Assert**: comparing the actual result with the expected outcome of the call:
    - result → eg. 2 + 2 equals 4?!
    - state change → eg. after a method call some property’s value should be X, is that true or not?
    - behaviour (exceptions, events) → eg. I can check that the expected exception happened or not?
    - circumstance (backend calls) → eg. during the registration does the user received email or not? (was the sendEmail method called or not, from an other method)
- **Other naming schemes:**
  - Given…When…Then()
  - Spec / SpecFlow (BDD - Behavior Driven Development)

# NUnit



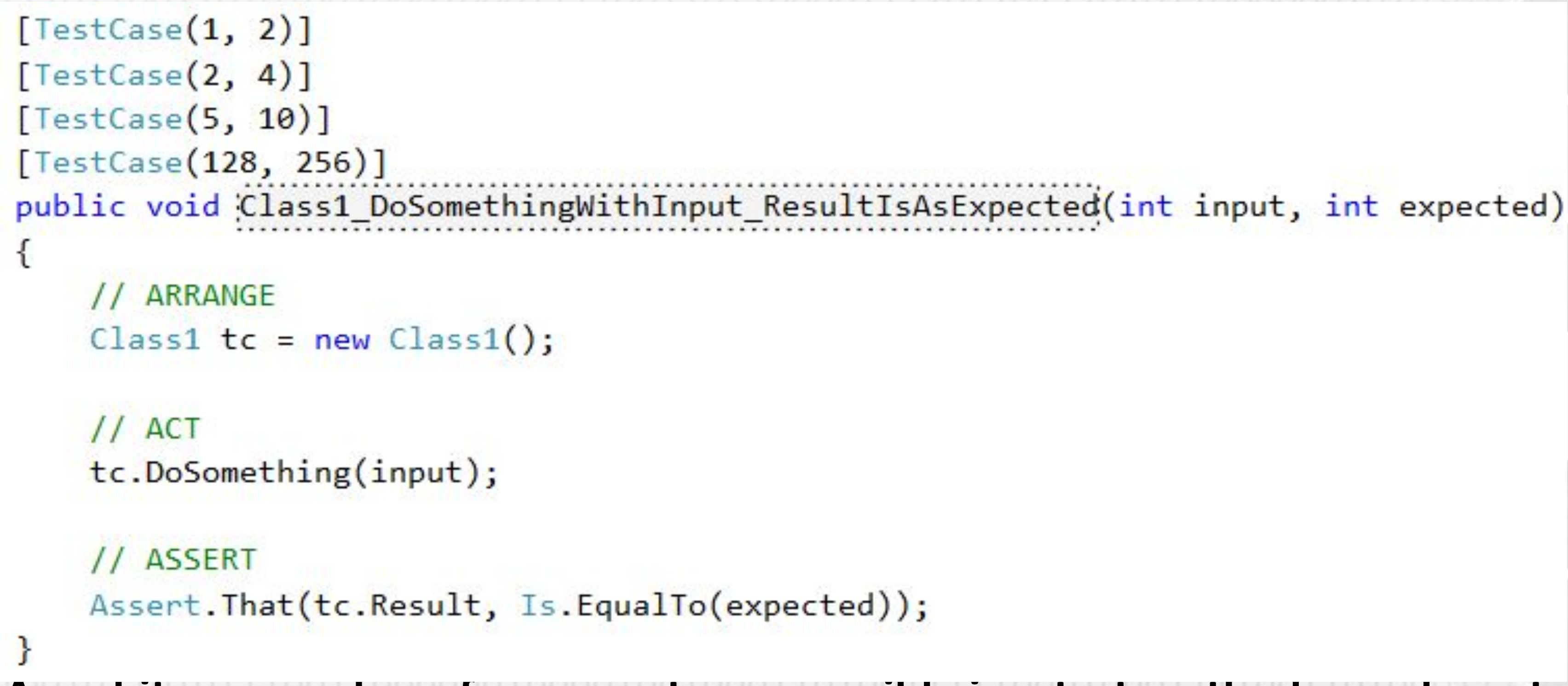
```
// ASSERT
Assert.That(tc.Result, Is.EqualTo(0));
```

- **Lot of possibilities**

```
// Values:
Assert.That(result, Is.EqualTo("MyResult"));
Assert.That(result, Is.Null);
Assert.That(result, Is.LessThan(2));
Assert.That(result, Is.SameAs(otherReferenceToTheSameObject));
Assert.That(result, Is.Not.Null); // Negate

// Exceptions:
Assert.That(() => t.MyTestedMethod(),
    Throws.TypeOf<NullReferenceException>());
Assert.That(() => t.MyTestedMethod(), Throws.Nothing);

// Old syntax: (same, as Is.EqualTo)
Assert.AreEqual(result, 42);
```

You can read out like english sentences (fluent syntax). Better, should be used.

# NUnit

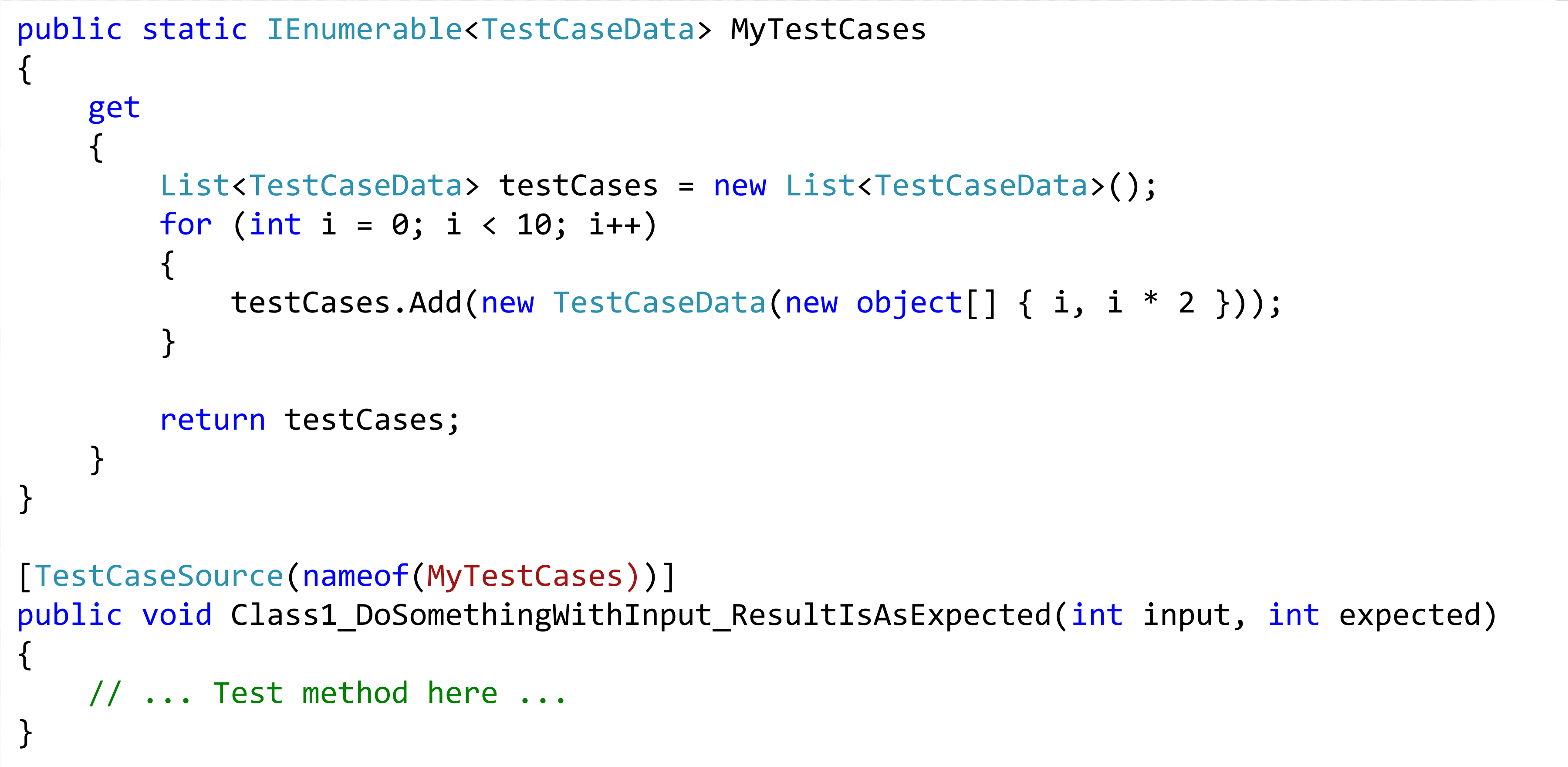


```
[TestCase(1, 2)]
[TestCase(2, 4)]
[TestCase(5, 10)]
[TestCase(128, 256)]
public void Class1_DoSomethingWithInput_ResultIsAsExpected(int input, int expected)
{
    // ARRANGE
    Class1 tc = new Class1();

    // ACT
    tc.DoSomething(input);

    // ASSERT
    Assert.That(tc.Result, Is.EqualTo(expected));
}
```

- **An arbitrary number of arguments are possible in a test method – we have to use the same number of arguments in the TestCase attribute**
  - Here we can use only constants -> TestCaseSource!
- **Similar:**
  - [Sequential] – the input parameters are used sequentially
  - [Combinatorial] – The input parameters are taken with all possible combinations
  - [Pairwise] – optimized (results in smaller number of test cases)

# NUnit

- **TestCaseSource**
  - To use dynamically generated parameters for test cases
  - If wanted, can be used in alternative ways: instead of object[], we can use a TestCaseData descendant; instead of a property we can use a method/class…



```
public static IEnumerable<TestCaseData> MyTestCases
{
    get
    {
        List<TestCaseData> testCases = new List<TestCaseData>();
        for (int i = 0; i < 10; i++)
        {
            testCases.Add(new TestCaseData(new object[] { i, i * 2 }));
        }

        return testCases;
    }
}

[TestCaseSource(nameof(MyTestCases))]
public void Class1_DoSomethingWithInput_ResultIsAsExpected(int input, int expected)
{
    // ... Test method here ...
}
```

# NUnit

If I run 1000 tests, **Setup/TearDown** will run 1000 times (before/after every test) which can mean a lot of extra work for the CPU → **tests will be slow(**er)!

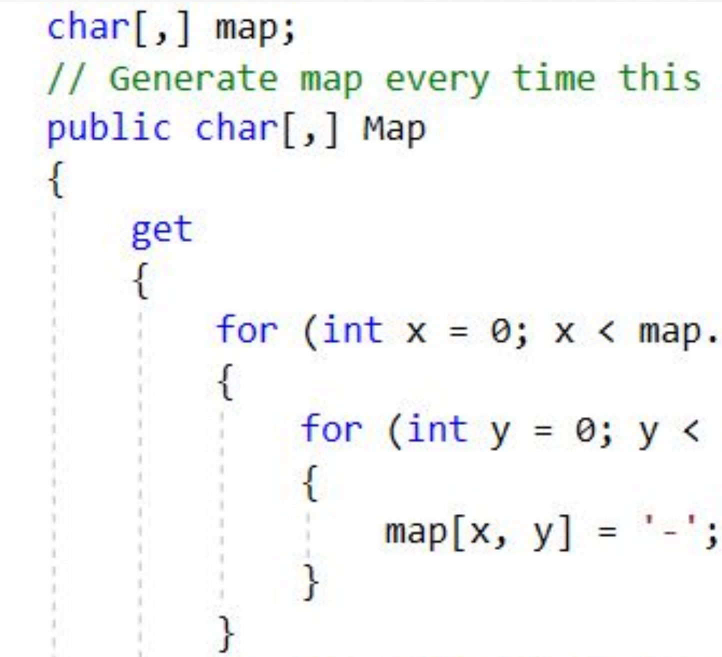
- **[Setup]**
  - The marked method will be executed **before every single** test or test case
- **[TearDown]**
  - The marked method will be executed **after every single** test or test case
- **[TestFixtureSetUp] / [OneTimeSetUp]**
  - The marked method will be executed **once before the tests** of a [TestFixture]
  - We can create common resources – look out, the tests must be independent!
- **[TestFixtureTearDown] / [OneTimeTearDown]**
  - The marked method will be executed **once after the tests** of a [TestFixture]
- **[SetUpFixture]**
  - Can be applied to a class, namespace-level setup/teardown

It can be solved using **TestFixtureSetup** where it will run only once, but in that case if 1000 tests use the same object/entity, it can be **problematic**!

# It is hard to write a good test!

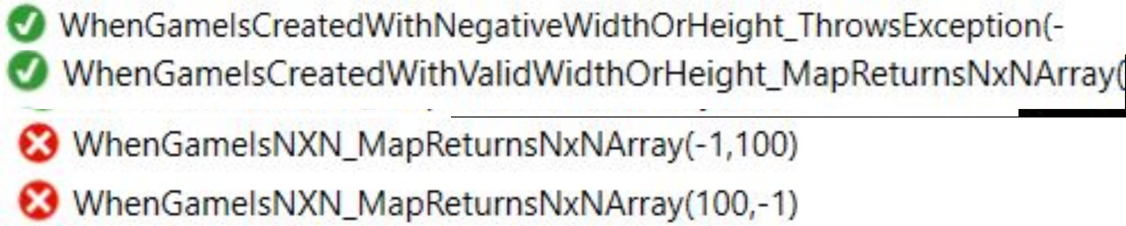
- **The tests must be fast**
  - Slow tests are impossible to run over and over again  test will not be executed, bugs will be found later
- **The tests must be independent**
  - Order, timing, etc. must not affect the results
- **Naming convention must be easy-to-read**
  - A good test list is basically a ***requirement-list*** that documents the capabilities of the program
- **We must not cover every possible inputs**
  - Examples are good
  - ***Finding the corner cases are important!***
- **Only test a single feature of a single class**
  - Always independent from the live data (database/settings)
  - We can substitute the dependencies too: Dependency Injection + fake dependencies, mocking... (=> Moq)

# Test Cases – simple code?



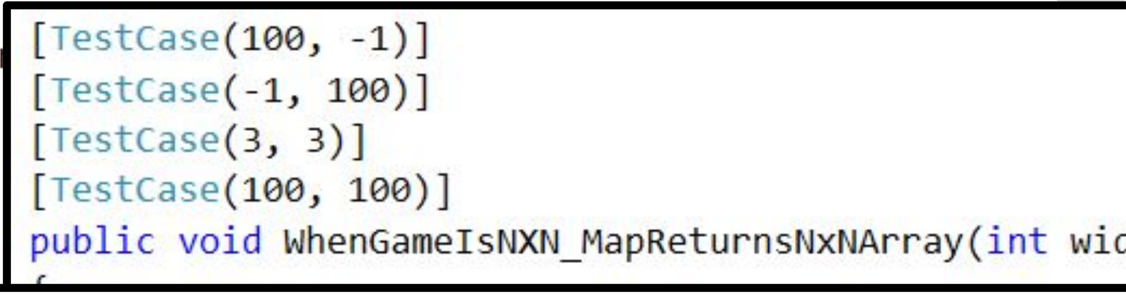
```
char[,] map;
// Generate map every time this
public char[,] Map
{
    get
    {
        for (int x = 0; x < map.GetLength(0); x++)
        {
            for (int y = 0; y <
            {
                map[x, y] = '-';
            }
        }
```

```
- - - - - - - - - -
- - - - - - - - - -
- - - - x - - - - -
- - - - - - - - - -
```

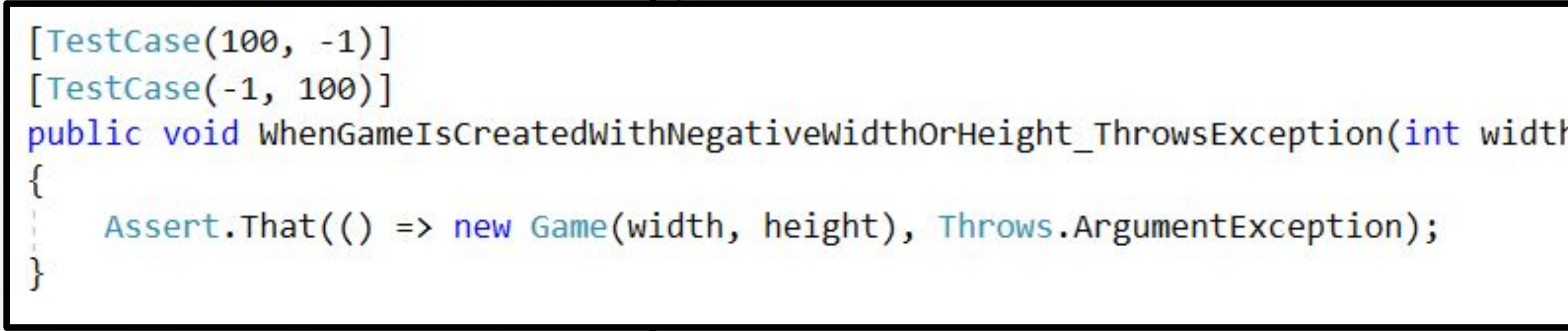


✓ WhenGameIsCreatedWithNegativeWidthOrHeight_ThrowsException(-
✓ WhenGameIsCreatedWithValidWidthOrHeight_MapReturnsNxNArray(
✗ WhenGameIsNXN_MapReturnsNxNArray(-1,100)
✗ WhenGameIsNXN_MapReturnsNxNArray(100,-1)

```
- - - - - - - - - -
- - - - - - - - - *
```



```
[TestCase(100, -1)]
[TestCase(-1, 100)]
[TestCase(3, 3)]
[TestCase(100, 100)]
public void WhenGameIsNXN_MapReturnsNxNArray(int wid
```

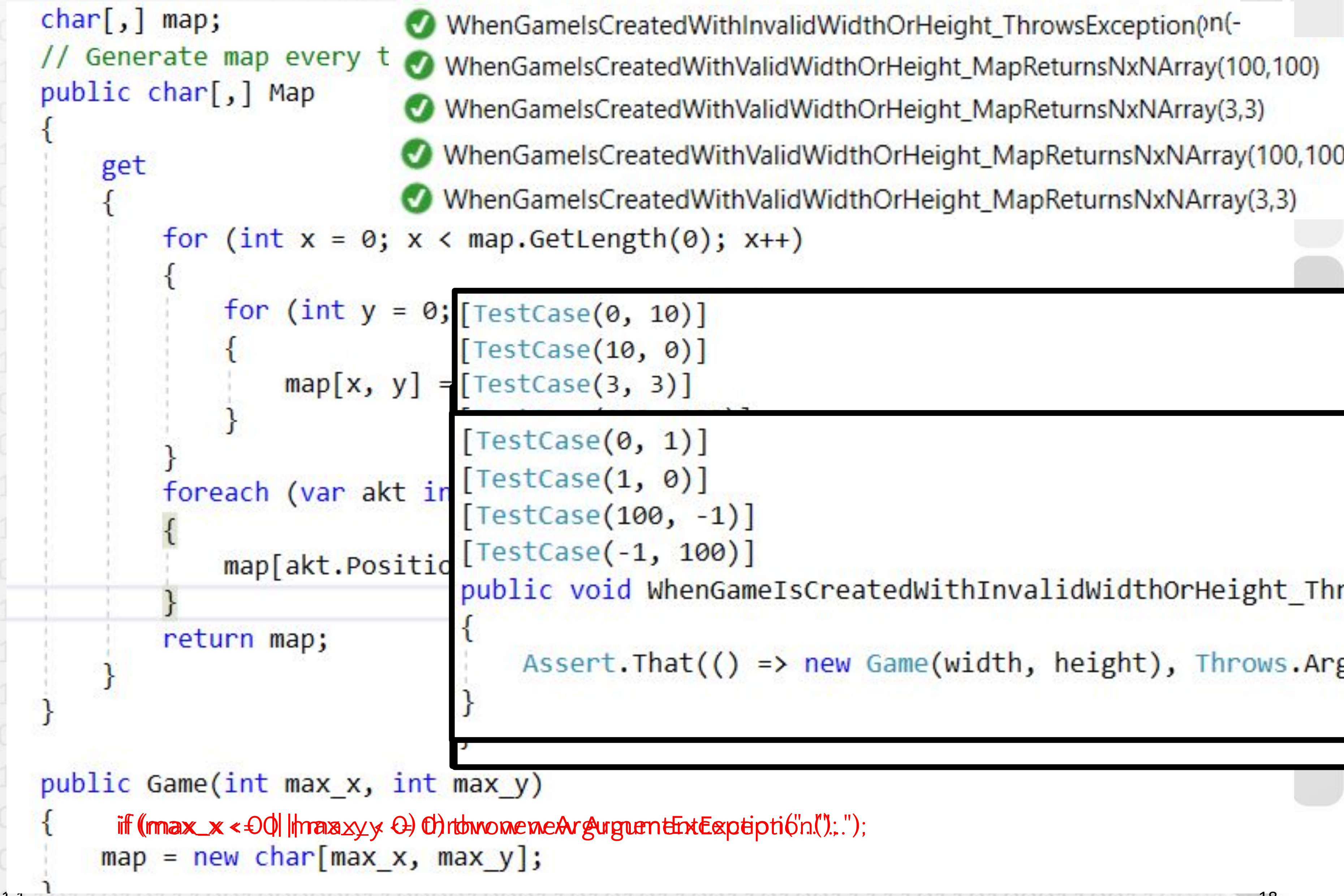


```
[TestCase(100, -1)]
[TestCase(-1, 100)]
public void WhenGameIsCreatedWithNegativeWidthOrHeight_ThrowsException(int widt
{
    Assert.That(() => new Game(width, height), Throws.ArgumentException);
}
```

```
public Game(int max_x, int max_y)
{
    map = new char[max_x, max_y];
```

if (max_x < 0 || max_y < 0) throw new ArgumentException("...");

# Test Cases – simple code?



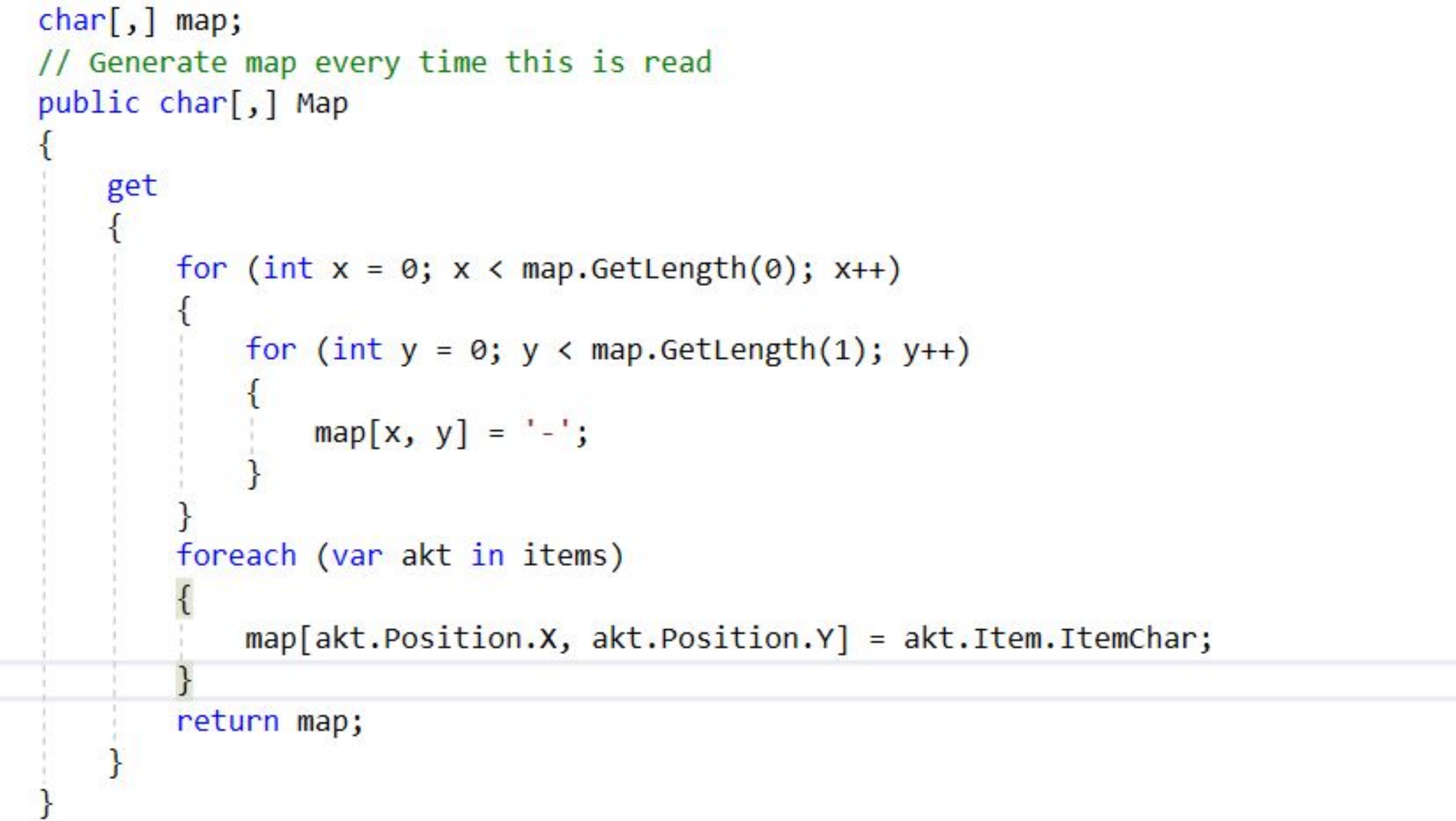
```
char[,] map;
// Generate map every t
public char[,] Map
{
    get
    {
        for (int x = 0; x < map.GetLength(0); x++)
        {
            for (int y = 0;
            {
                map[x, y] =
            }
        }
        foreach (var akt in
        {
            map[akt.Positio
        }
        return map;
    }
}

public Game(int max_x, int max_y)
{
    if (max_x < 0 || max_y < 0) throw new ArgumentException("..");
    if (max_x <= 0 || max_y <= 0) throw new ArgumentException("..");
    map = new char[max_x, max_y];
```

```
✓ WhenGameIsCreatedWithInvalidWidthOrHeight_ThrowsException(n(-
✓ WhenGameIsCreatedWithValidWidthOrHeight_MapReturnsNxNArray(100,100)
✓ WhenGameIsCreatedWithValidWidthOrHeight_MapReturnsNxNArray(3,3)
✓ WhenGameIsCreatedWithValidWidthOrHeight_MapReturnsNxNArray(100,100
✓ WhenGameIsCreatedWithValidWidthOrHeight_MapReturnsNxNArray(3,3)
```

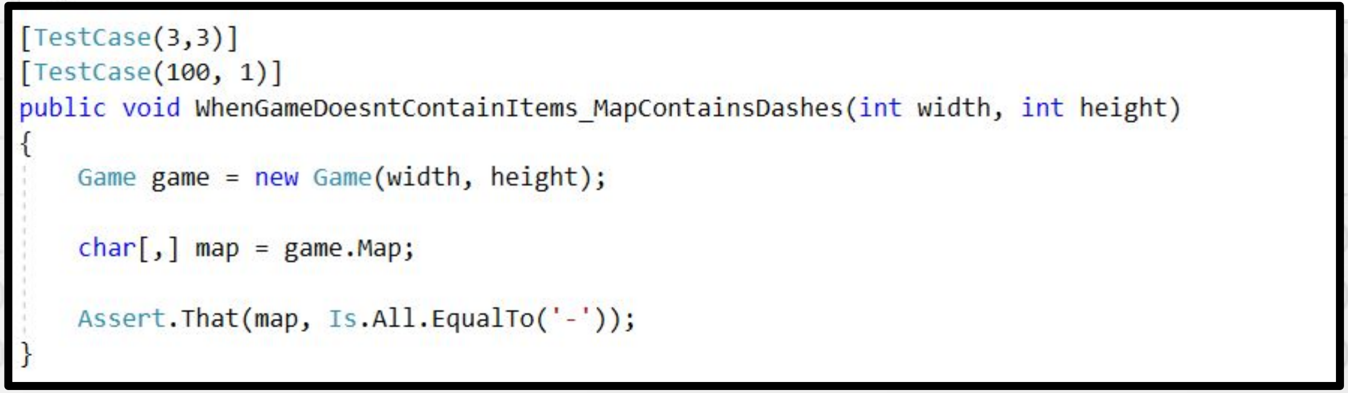
```
[TestCase(0, 10)]
[TestCase(10, 0)]
[TestCase(3, 3)]
```

```
[TestCase(0, 1)]
[TestCase(1, 0)]
[TestCase(100, -1)]
[TestCase(-1, 100)]
public void WhenGameIsCreatedWithInvalidWidthOrHeight_Thr
{
    Assert.That(() => new Game(width, height), Throws.Arg
}
```

# Test Cases – more complex code

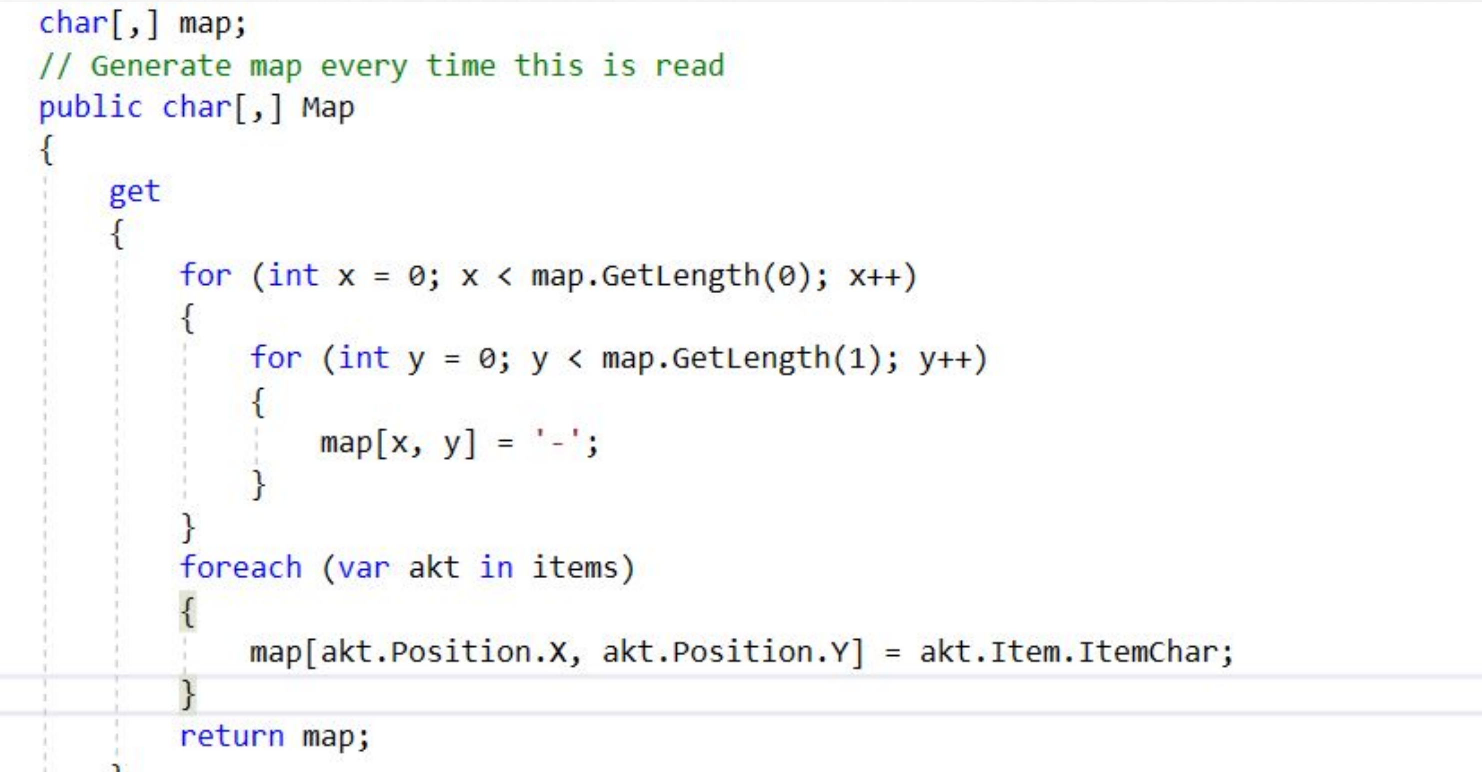


```
char[,] map;
// Generate map every time this is read
public char[,] Map
{
    get
    {
        for (int x = 0; x < map.GetLength(0); x++)
        {
            for (int y = 0; y < map.GetLength(1); y++)
            {
                map[x, y] = '-';
            }
        }
        foreach (var akt in items)
        {
            map[akt.Position.X, akt.Position.Y] = akt.Item.ItemChar;
        }
        return map;
    }
}
```

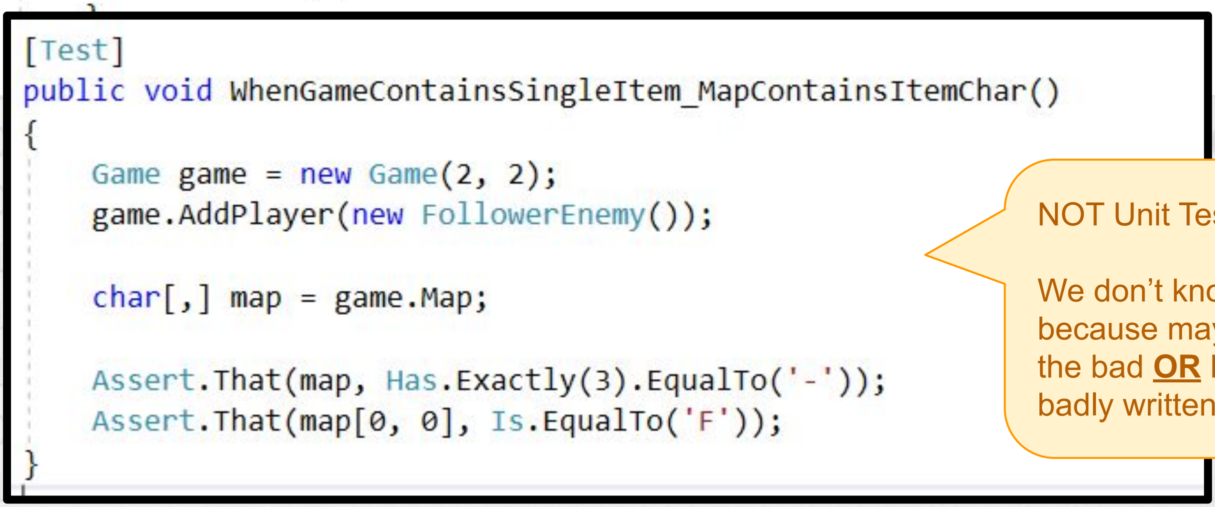


```
[TestCase(3,3)]
[TestCase(100, 1)]
public void WhenGameDoesntContainItems_MapContainsDashes(int width, int height)
{
    Game game = new Game(width, height);

    char[,] map = game.Map;

    Assert.That(map, Is.All.EqualTo('-'));
}
```

# Test Cases – more complex code



```
char[,] map;
// Generate map every time this is read
public char[,] Map
{
    get
    {
        for (int x = 0; x < map.GetLength(0); x++)
        {
            for (int y = 0; y < map.GetLength(1); y++)
            {
                map[x, y] = '-';
            }
        }
        foreach (var akt in items)
        {
            map[akt.Position.X, akt.Position.Y] = akt.Item.ItemChar;
        }
        return map;
```

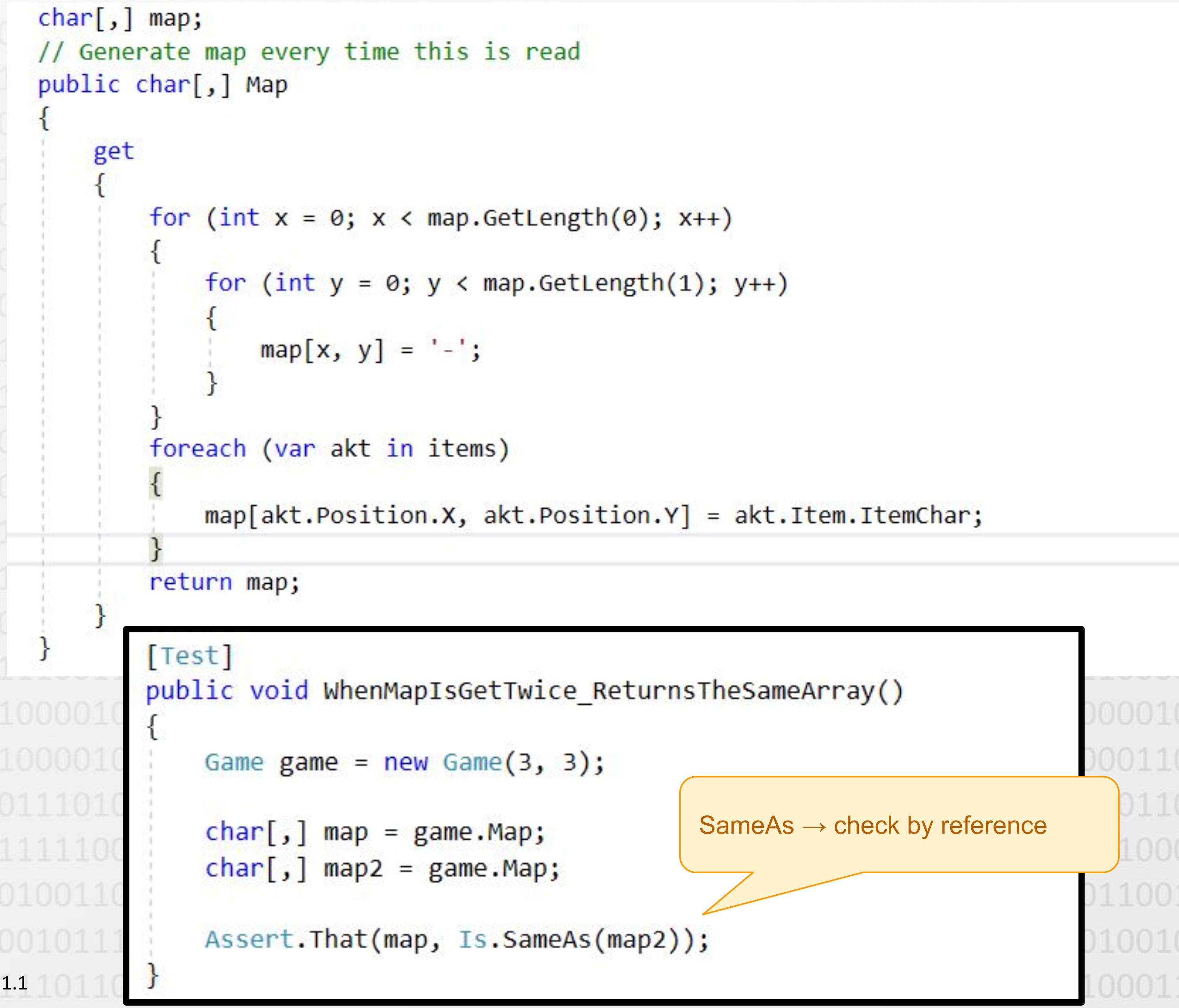


```
[Test]
public void WhenGameContainsSingleItem_MapContainsItemChar()
{
    Game game = new Game(2, 2);
    game.AddPlayer(new FollowerEnemy());

    char[,] map = game.Map;

    Assert.That(map, Has.Exactly(3).EqualTo('-'));
    Assert.That(map[0, 0], Is.EqualTo('F'));
}
```

NOT Unit Test!

We don’t know what is the problem, because maybe the FollowerEnemy is the bad **OR** Map is bad **OR** the test is badly written.

# Test Cases – more complex code



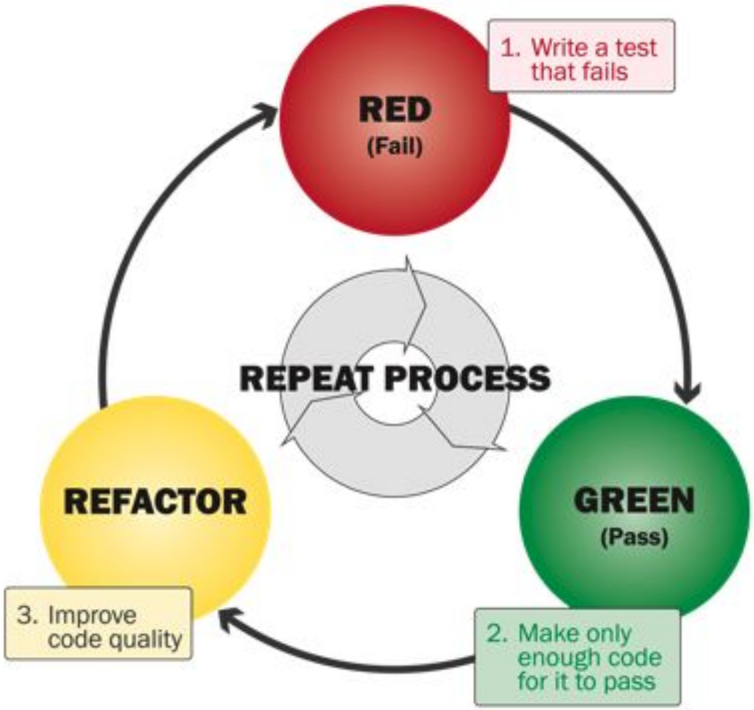
```
char[,] map;
// Generate map every time this is read
public char[,] Map
{
    get
    {
        for (int x = 0; x < map.GetLength(0); x++)
        {
            for (int y = 0; y < map.GetLength(1); y++)
            {
                map[x, y] = '-';
            }
        }
        foreach (var akt in items)
        {
            map[akt.Position.X, akt.Position.Y] = akt.Item.ItemChar;
        }
        return map;
    }
}
```

```
[Test]
public void WhenMapIsGetTwice_ReturnsTheSameArray()
{
    Game game = new Game(3, 3);

    char[,] map = game.Map;
    char[,] map2 = game.Map;

    Assert.That(map, Is.SameAs(map2));
}
```

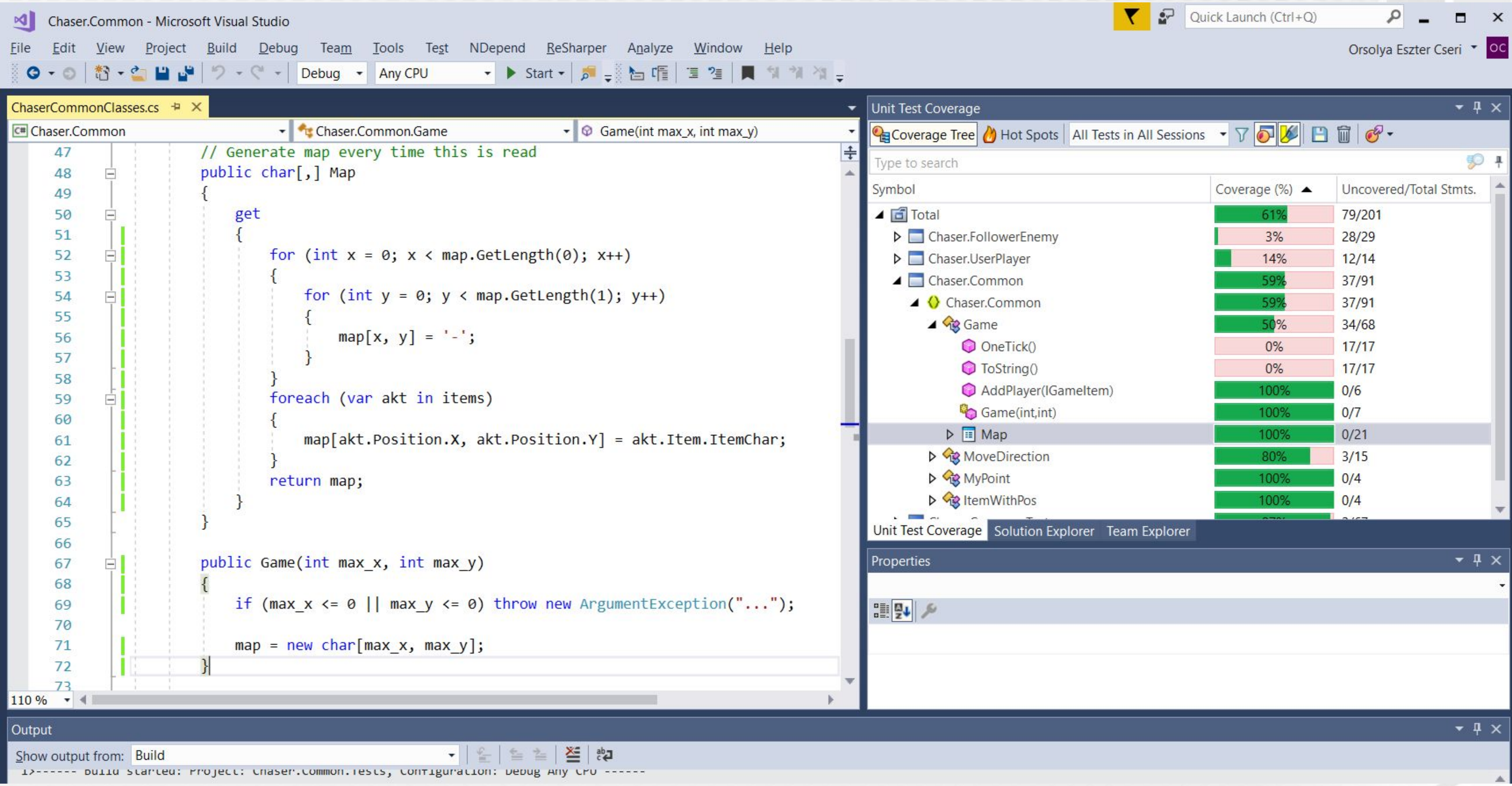
SameAs → check by reference

# Testing while developing

- **First the code, then the test**
  - Hard and not effective – also, “later” is many times “never”
- **Test First: create the tests first, then the code**
  - The requirements must be fixed beforehand – they have to be cleared up first!
  - This also ensures keeping the operational requirements when re-writing
- **TDD (Test-Driven Development):**
  - Done in pair programming
  - The code is written to be 100% “testable”
  - Development time: twice, but better quality
  - Not a generic all-around solution (typically good for the „algorithmic” tasks)
- **BDD, ATDD...**


1. Write a test that fails
RED
(Fail)
REPEAT PROCESS
REFACTOR
GREEN
(Pass)
3. Improve code quality
2. Make only enough code for it to pass

# Coverage



```
            // Generate map every time this is read
            public char[,] Map
            {
                get
                {
                    for (int x = 0; x < map.GetLength(0); x++)
                    {
                        for (int y = 0; y < map.GetLength(1); y++)
                        {
                            map[x, y] = '-';
                        }
                    }
                    foreach (var akt in items)
                    {
                        map[akt.Position.X, akt.Position.Y] = akt.Item.ItemChar;
                    }
                    return map;
                }
            }

            public Game(int max_x, int max_y)
            {
                if (max_x <= 0 || max_y <= 0) throw new ArgumentException("...");

                map = new char[max_x, max_y];
            }
```

| Symbol | Coverage (%) | Uncovered/Total Stmts. |
|---|---|---|
| Total | 61% | 79/201 |
| Chaser.FollowerEnemy | 3% | 28/29 |
| Chaser.UserPlayer | 14% | 12/14 |
| Chaser.Common | 59% | 37/91 |
| Chaser.Common | 59% | 37/91 |
| Game | 50% | 34/68 |
| OneTick() | 0% | 17/17 |
| ToString() | 0% | 17/17 |
| AddPlayer(IGameItem) | 100% | 0/6 |
| Game(int,int) | 100% | 0/7 |
| Map | 100% | 0/21 |
| MoveDirection | 80% | 3/15 |
| MyPoint | 100% | 0/4 |
| ItemWithPos | 100% | 0/4 |

```
1>------ Build started: Project: Chaser.Common.Tests, Configuration: Debug Any CPU ------
```

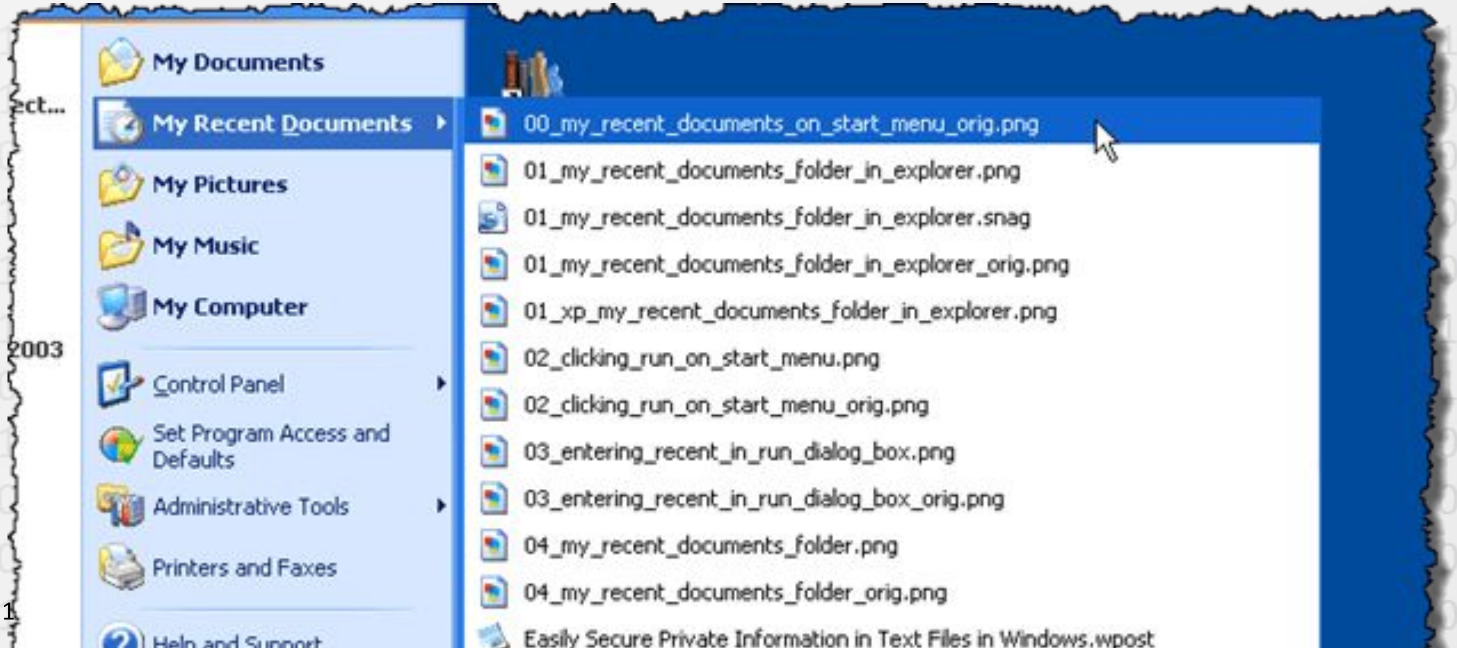
- How many percentage of my important codes are tested?!
- dotCover
- NCover
- OpenCover

# Coverage

- **Usually there is a minimum, but also a maximum (don’t aim the 100%, and also don’t be content if the coverage is 100%)**
- **More important measurements**
  - Statement Coverage: statements (if, while, for – excluded)
  - Branch Coverage: Conditions (if, else)
  - Condition Coverage: Every bool expression had true and false as well
  - Loop Coverage: Every loop was executed 0x, 1x and >1x, and if possible, then with the maximum limit and max+1 as well
  - Parameter Value Coverage: All significant values (e.g. string null, empty, whitespace…)
  - Inheritance Coverage: test for all possible return types
  - Use case coverage

# Exercise

- **Create a class that implements the Last Recently Used (LRU) functionality**
- **The class contains a list with a maximum capacity, and must have a *public void Add(object instance)* method**
- **During the development, follow the TDD approach**
  - Create an „it barely works” class
  - Write tests until we run into a red test
  - Fix the class to make the test green, then write tests…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My Music
My Computer
Control Panel
Set Program Access and Defaults
Administrative Tools
Printers and Faxes
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02_clicking_run_on_start_menu.png
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03_entering_recent_in_run_dialog_box.png
03_entering_recent_in_run_dialog_box_orig.png
04_my_recent_documents_folder.png
04_my_recent_documents_folder_orig.png
Easily Secure Private Information in Text Files in Windows.wpost

# Practice Exercise

- **A bookshop wants to sell a 5-part book series. One copy of any of the five books costs 8 EUR. Discounts:**
  - 2 different books □ 5% discount on those two books.
  - 3 different books □ 10% discount on all three books.
  - 4 different books □ 20% discount on all four books.
  - 5 different books □ 25% discount on all five books
- **If you buy, four books, of which 3 are different titles, you get a 10% discount on the 3 that form part of a set, but the fourth book still costs 8 EUR:**
  - 1, 2, 3, 1 => (1, 2, 3) 10% discount, (1) 0% discount => 3x7.2 + 8 = 29.6
- **Some „baskets” can be grouped multiple ways!**
  - 1, 1, 2, 2, 3, 3, 4, 5 => (1, 2, 3, 4, 5) (1, 2, 3) or (1, 2, 3, 4) (1, 2, 3, 5) ?
- **Write a class (and tests) to calculate the price of a “basket”**
  - Grouping using the most simple way (always create the biggest group, even if this might not be the cheapest price)