

# Software Engineering

## Testing and Debugging — Testing

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08.06.2011

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- ▶ This seems preferable, but software verification is in most cases economically impossible
- ▶ On the other hand, testing is not just a way of finding bugs during the development –
- ▶ Making testing a part of the development makes claims about the software more credible

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  - ▶ How to write a **test case**
  - ▶ How to come up with a good **test suite** (collection of test cases)

# Specifications

- ▶ Program specifications tell what a piece of code should do
- ▶ But also what it requires to be able to do its job
- ▶ A specification can be seen as **contract** between the implementor and the user of the implemented code.
- ▶ A specification consists of two parts:
  - ▶ **Requires** (precondition) – what the user should fulfill before calling the code
  - ▶ **Ensures** (postcondition) – what the implementor promises about the result of the execution (provided requires were fulfilled)

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and equal to at least one element in a

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```
public static int find_min(int[] a) {  
    int x, i;  
    x = a[0];  
    for (i = 1; i < a.length; i++) {  
        if (a[i] < x) x = a[i];  
    }  
    return x;  
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## Specification

*Requires:* a is non-null and contains at **exactly** one element

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## Specification

*Requires:* *a is non-null and contains at least one element*

*Ensures:* *Result is less than or equal to all elements in a and equal to at least one element in a, and result is greater than 0*

# What can go wrong when writing specifications?

Are all these cases of “bad” specifications?

- ▶ It's clear that we don't have invalid or incorrect specifications.
- ▶ Vague specifications is a matter of whether they can be misunderstood.
- ▶ But imprecise specifications is not such a bad thing

## Example: Strong or Weak Precondition

### Example

What does this method do?

```
public static int[] insert(int[] x, int n)
{
    int[] y = new int[x.length + 1];
    int i;
    for (i = 0; i < x.length; i++) {
        if (n >= x[i]) break;
        y[i] = x[i];
    }
    y[i] = n;
    for (; i < x.length; i++) {
        y[i+1] = x[i];
    }
    return y;
}
```

## Example, cont'd

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*Requires:*  $x$  is non-null and sorted in ascending order.

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# Specification of a Class

## Class invariant

- ▶ A class invariant is a condition about the state of each class instance that should be maintain throughout its existence
- ▶ We will focus on **weak** invariants
  - ▶ It should hold between calls to methods of the class,
  - ▶ but not during the execution of such methods

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## Class specification consists of

- ▶ Class invariant
- ▶ Requires and ensures of the methods

## Example, class invariant

```
public class HashSet {  
    private Object[] arr;  
    int nobj;  
  
    public void insert(Object o) { ... }  
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- ▶ nobj should be equal to the number of non-null elements in arr, and
- ▶ for each index  $i$  in range of arr such that arr[ $i$ ] is non-null, all elements between indices arr[ $i$ ].hash() and  $i$  are non-null, and



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- ▶ there are no two non-null elements of arr that are equal

# Testing

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# Software testing

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- ▶ Repeatable – be able to run tests over and over again

## What we don't look at here

- ▶ Running a program to see if anything goes wrong
- ▶ Letting a lot of people run the program to see if anything goes wrong (Beta-testing)

# Testing on Different Levels

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The code that is being tested is called the **IUT** (implementation under test).



# Testing Non-Functional Requirements

Not considered further

- ▶ Performance testing or load testing
- ▶ Stability testing
- ▶ Usability testing
- ▶ Security testing

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Testing early means a lot of unit testing which requires a lot of specifications.

But writing specifications for the units of a system is already needed for a large project when programming by contract.

Tested units may be replaced later on, making the tests useless.

On the other hand, writing and running tests often gives a deep understanding of the program. The need to replace the unit may have been realized during the testing activities.

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- ▶ Each individual test is called a **test case**
- ▶ Organize collections of related test cases in **test suites**
- ▶ Use precise methods to make sure that a test suite has a good coverage of the different cases of usage



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JUnit is a small tool for writing and running test cases. It provides:

- ▶ Some functionality that is repeatedly needed when writing test cases
- ▶ A way to annotate methods as being test cases
- ▶ A way to run test cases automatically in a batch

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- ▶ When writing specifications and test cases for units, the responsibilities of the different parts become clearer, which promotes good OO programming style (low coupling)
- ▶ In order to be able to test programs automatically, separating the IO and functionality becomes important

# What does a test case consists of?

## Test case

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- ▶ The test oracle is vital to run tests automatically

Small demo showing basics of how to use JUnit

# Summary, and what's next?

## Summary

- ▶ Specifications (motivation, contracts, pre- and postconditions, what to think about)
- ▶ Testing (motivation, different kinds of testing, role in software development, junit)

## What's next?

- ▶ More examples of test cases, presenting aspects of writing test cases and features of JUnit
- ▶ How to write a good test case?
- ▶ How to construct a good collection of test cases (test suite)?