Software Engineering Testing and Debugging — Testing

Prof. Dr. Peter Thiemann

Universität Freiburg

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- Making testing a part of the development makes claims about the software more credible

Specifications (informal)

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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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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;
}</pre>
```

Specification

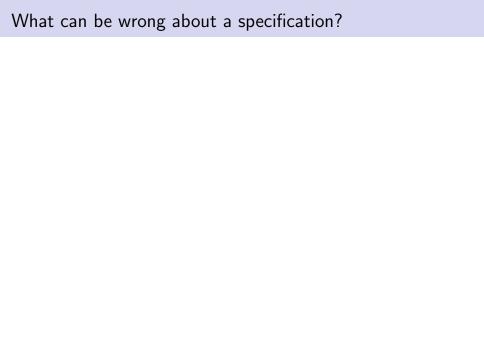
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Specification

Requires: a is non-null and contains at least one element Ensures: Result is less than or equal to all elements in a



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 - Precondition is too strong

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

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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 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++) {</pre>
      if (n \ge x[i]) break;
      y[i] = x[i];
    y[i] = n;
    for (; i < x.length; i++) {
      y[i+1] = x[i];
    return y;
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result is sorted in ascending order.

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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,
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Class specification consists of

- Class invariant
- ▶ Requires and ensures of the methods

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  private Object[] arr;
  int nobj;

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- for each index i in range of arr suc that arr[i] is non-null, all elements between indices arr[i].hash() and i are non-null, and

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- for each index i in range of arr suc that arr[i] is non-null, all elements between indices arr[i].hash() and i are non-null, and
- there are no two non-null elements of arr that are equal

Testing

Software testing

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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)

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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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- 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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Apart the obvious – that testing should result in removal of bugs

- 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?

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- ► Initialisation (of class instance and input arguments)
- Call to the method of the IUT
- A test oracle which decides if the test succeeded or failed
- ▶ The test oracle is vital to run tests automatically



Small demo showing basics of how to use $\ensuremath{\mathsf{JUnit}}$

Summary, and what's next?

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- ► 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)?