

Software Engineering

Lecture 13: Testing and Debugging — Testing

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Recap

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- ▶ **Program Verification** guarantees absence of defects
- ▶ Preferable, but verification is often economically impossible

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

Specifications

- ▶ Specification determines
 - ▶ what a piece of code should do
 - ▶ what it requires to do its job
- ▶ A specification is a **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)

Specification Example

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Specification

Requires: a is non-null

Ensures: Result is less than or equal to all elements in a
and equal to at least one element in a

Specification Example

```
1 public static int find_min(int[] a) {
2     int x, i;
3     x = a[0];
4     for (i = 1; i < a.length; i++) {
5         if (a[i] < x) x = a[i];
6     }
7     return x;
8 }
```

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Specification

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

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 - ▶ Precondition is too strong

Specification

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

Ensures: Result is less than or equal to all elements in a
and equal to at least one element in a

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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?

- ▶ We don't want incorrect specifications.
- ▶ A vague specification is open to misunderstanding.
- ▶ An incomplete specification can be useful.

Example: Strong or Weak Precondition

Example

What does this method do?

```
1   public static int[] insert(int[] x, int n)
2   {
3       int[] y = new int[x.length + 1];
4       int i;
5       for (i = 0; i < x.length; i++) {
6           if (n <= x[i]) break;
7           y[i] = x[i];
8       }
9       y[i] = n;
10      for (; i < x.length; i++) {
11          y[i+1] = x[i];
12      }
13      return y;
14  }
```

Example, cont'd

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Requires: x is non-null.

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Example, cont'd

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```

Specification

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 maintained 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

```
1 public class HashSet {
2     private Object[] arr;
3     int nobj;
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5     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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- ▶ 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
- ▶ there are no two non-null elements of `arr` that are equal

Testing

What we look at here

- ▶ Systematic – general rules for how to write test cases
- ▶ Repeatable – be able to run tests over and over again

Software testing

What we look at here

- ▶ Systematic – general rules for how to write test cases
- ▶ 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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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 tool for organizing, writing, and running test cases. It provides:

- ▶ Functionality that is needed repeatedly when writing test cases
- ▶ A way to annotate methods as test cases
- ▶ A way to run test cases automatically

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- ▶ Testing should result in removal of defects
- ▶ When writing specifications and test cases for units, the responsibilities of the different parts become clearer, which promotes good OO programming style (low coupling)
- ▶ To enable automatic program testing, it is important to separate IO and functionality (design for testability)

What does a test case consist of?

Test case

- ▶ (**Set up**) 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
- ▶ (**Tear down**) Finalization; relinquish resources etc

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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?

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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)?