Software Engineering

Lecture 09: Testing and Debugging — Testing

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Recap

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- 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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- Test Cases
  - 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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Specification Example

```
1  public static int find_min(int[] a) { ... }
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Specification

Requires: `a` *is non-null*

Ensures: *Result is less than or equal to all elements in* `a`

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1  public static int find_min(int[] a) { ... }
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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*

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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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?

- It's clear that we don't want 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?

```
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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1    public static int[] insert(int[] x, int n)
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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,
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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;
4
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

Software testing

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

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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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- System Testing – testing a whole system against the specification of its externally observable behaviour
  System testing is mostly useful for convincing about the correctness. Less useful for finding bugs because the infection phase going from defect to failure is usually complex and difficult to unwind.

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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.

Systematic testing

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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 consist of?

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- Call to the method of the IUT
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- The test oracle is vital to run tests automatically

Demo

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)?