Software Engineering I (02161)

Week 4

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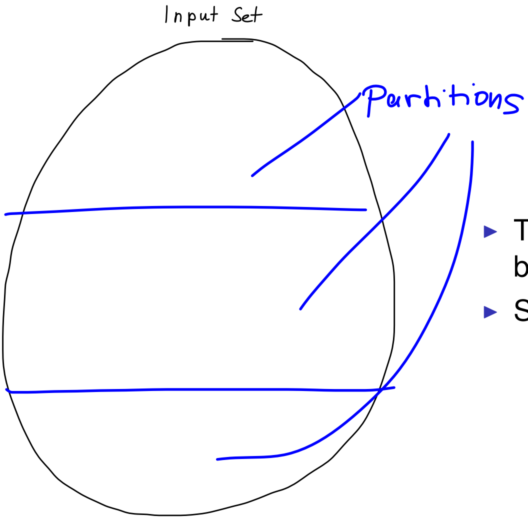
Contents

Systematic testing

- Tests are expensive
- Impractical to test all input values
- Not too few because one could miss some defects

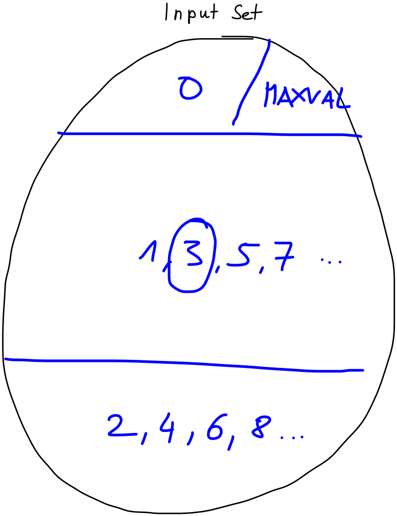
$\rightarrow$ Partition based tests

Partition based tests



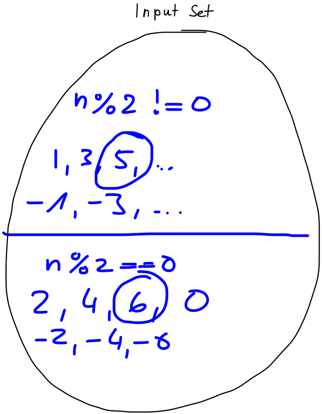
- Tests test expected behaviour
- SUT (System under test)

Partition based tests: Black box



- Expected behaviour: isEven(n)
- SUT implementation of isEven(n)

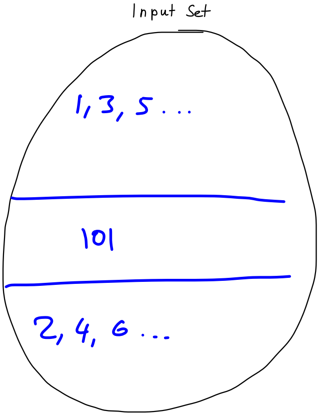
Partition based tests: White Box



- Expected behaviour: isEven(n)
- SUT implementation of isEven(n)

```
public boolean isEven(int n) {
   if (n % 2 == 0) {
      return true;
   } else {
      return false;
   }
}
```

Partition based tests: White Box



- Expected behaviour: isEven(n)
- SUT implementation of isEven(n)

```
public boolean isEven(int n) {
   if  (n == 101) return true;
   if (n % 2 == 0) {
      return true;
   } else {
      return false;
   }
}
```

How to get to the partitions

1. white box test / structural test
2. black box test / functional test

White Box tests

- Find the minimum and the maximum of a list of integers

```
public class MinMax {
    int min, max;
    public void minmax(int[] args) throws Error {
        if (args.length == 0)                                      // 1
            throw new Error("No numbers");
        else {
            min = max = args[0];
            for (int i = 1; i < args.length; i++) {                // 2
                int obs = args[i];
                if (obs > max)                                     // 3
                    max = obs;
                else if (min < obs)                                // 4
                    min = obs;
            }
        }
    }
    public int getMin() { return min; }
    public int getMax() { return max; }
}
```

Choice	Input data set	Input property
1 true	A	No numbers
1 false	B	At least one number
2 zero times	B	Exactly one number
2 once	C	Exactly two numbers
2 more than once	E	At least three numbers
3 true	C	Number > current maximum
3 false	D	Number ≤ current maximum
4 true	E number 3	Number ≤ current maximum and > current minimum
4 false	E number 2	Number ≤ current maximum and ≤ current minimum

Example of a white box test (II): Test cases

Choice	Input data set	Input property
1 true	A	No numbers
1 false	B	At least one number
2 zero times	B	Exactly one number
2 once	C	Exactly two numbers
2 more than once	E	At least three numbers
3 true	C	Number $>$ current maximum
3 false	D	Number $\leq$ current maximum
4 true	E number 3	Number $\leq$ current maximum and $>$ current minimum
4 false	E number 2	Number $\leq$ current maximum and $\leq$ current minimum

Input data set	Contents	Expected output
A	(no numbers)	'No numbers'
B	17	17 17
C	27 29	27 29
D	39 37	37 39
E	49 47 48	47 49

JUnit Tests

```
public class WhiteBoxTest {
  MinMax sut = new MinMax();

  @Test(expected = Error.class)
  public void testInputDataSetA() {
    int[] ar = {};
    sut.minmax(ar);
  }

  @Test
  public void testInputDataSetB() {
    int[] ar = {17};
    sut.minmax(ar);
    assertEquals(17,sut.getMin());
    assertEquals(17,sut.getMax());
  }

  @Test
  public void testInputDataSetC() {
    int[] ar = {27, 29};
    sut.minmax(ar);
    assertEquals(27,sut.getMin());
    assertEquals(29,sut.getMax());
  }
```

JUnit Tests (cont.)

```
  @Test
  public void testInputDataSetD() {
    int[] ar = {39, 37};
    sut.minmax(ar);
    assertEquals(37,sut.getMin());
    assertEquals(39,sut.getMax());
  }

  @Test
  public void testInputDataSetE() {
    int[] ar = {49, 47, 48};
    sut.minmax(ar);
    assertEquals(47,sut.getMin());
    assertEquals(49,sut.getMax());
  }

}
```

Example of a black box test (I): min, max computation

Problem: Find the minimum and the maximum of a list of integers

- Definition of the input partitions

Input data set	Input property
A	No numbers
B	One number
C1	Two numbers, equal
C2	Two numbers, increasing
C3	Two numbers, decreasing
D1	Three numbers, increasing
D2	Three numbers, decreasing
D3	Three numbers, greatest in the middle
D4	Three numbers, smallest in the middle

Example of a black box test (I): min, max computation

Problem: Find the minimum and the maximum of a list of integers

- Definition of the input partitions

Input data set	Input property
A	No numbers
B	One number
C1	Two numbers, equal
C2	Two numbers, increasing
C3	Two numbers, decreasing
D1	Three numbers, increasing
D2	Three numbers, decreasing
D3	Three numbers, greatest in the middle
D4	Three numbers, smallest in the middle

- Definition of the test values and expected results

Input data set	Contents	Expected output
A	(no numbers)	Error message
B	17	17 17
C1	27 27	27 27 ✓
C2	35 36	35 36 ✓
C3	46 45	45 46 ✓
D1	53 55 57	53 57
D2	67 65 63	63 67
D3	73 77 75	73 77
D4	89 83 85	83 89

White box vs. Black box testing

- White box test
  - finds defects in the implementation
  - can't find problems with the functionality
- Black box test
  - finds problems with the functionality
  - can't find defects in the implementation

TDD vs. White box and Black box testing

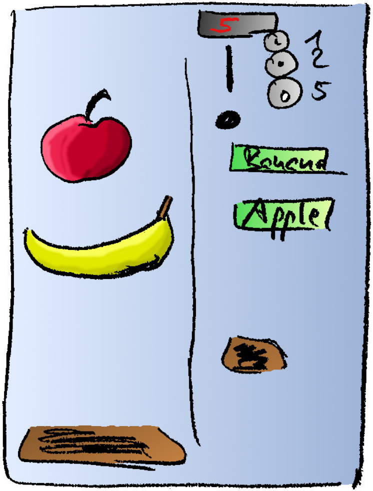
- TDD: Black box + white box testing
- TDD starts with tests for the functionality
- Any production codes needs to have a failing test first

Summary

Test plan: Two tables

- Table for the input partitions
- Table for the test data (input / expected output)

Example Vending Machine



- Actions
  - Input coins
  - Press button for bananas or apples
  - Press cancel
- Displays
  - current amount of money input
- Effects
  - Return money
  - Dispense banana or apple

Use Case: Buy Fruit

name: Buy fruit

description: Entering coins and buying a fruit

actor: user

main scenario:

1. Input coins until the price for the fruit to be selected is reached
2. Select a fruit
3. Vending machine dispenses fruit

alternative scenarios:

a1. User inputs more coins than necessary
a2. select a fruit
a3. Vending machine dispenses fruit
a4. Vending machine returns excessive coins

Use Case: Buy Fruit (cont.)

alternative scenarios (cont.)

- b1 User inputs less coins than necessary
- b2 user selects a fruit
- b3 No fruit is dispensed
- b4 User adds the missing coins
- b5 Fruit is dispensed
- c1 User selects fruit
- c2 User adds sufficient or more coins
- c3 vending machine dispenses fruit and rest money
- d1 user enters coins
- d2 user selects cancel
- d3 money gets returned

Use Case: Buy Fruit (cont.)

alternative scenarios (cont.)

- e1 user enters correct coins
- e2 user selects fruit but vending machine does not have the fruit anymore
- e3 nothing happens
- e4 user selects cancel
- e5 the money gets returned
- f1 user enters correct coins
- f2 user selects a fruit but vending machine does not have the fruit anymore
- f3 user selects another fruit
- f4 if money is correct fruit with rest money is dispensed; if money is not sufficient, the user can add more coins

Functional Test: for Buy Fruit Use Case: Input Data Sets

Input data set	Input property
A	Exact coins; enough fruits; first coins, then fruit selection
B	Exact coins; enough fruits; first fruit selection, then coins
C	Exact coins; not enough fruits; first coins, then fruit selection, then cancel
D	Exact coins; not enough fruits; first fruit selection, then coins, then cancel
E	More coins; enough fruits; first coins, then fruit selection
F	More coins; enough fruits; first fruit selection, then coins
G	More coins; not enough fruits; first coins, then fruit selection, then cancel
H	More coins; not enough fruits; first fruit selection, then coins, then cancel
I	Less coins; enough fruits; first coins, then fruit selection
J	Less coins; enough fruits; first fruit selection, then coins
K	Less coins; not enough fruits; first coins, then fruit selection, then cancel
L	Less coins; not enough fruits; first fruit selection, then coins, then cancel

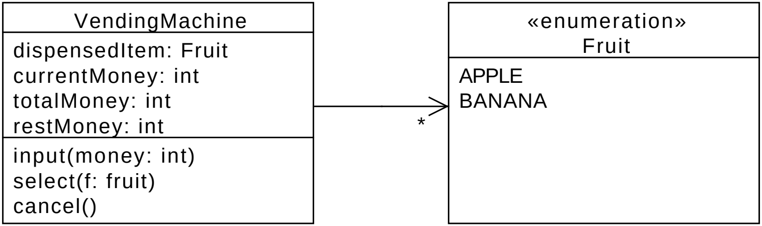
Functional Test for Buy Fruit Use Case: Test Cases

Input data set	Contents	Expected Output
A	1,2; apple	apple dispensed
B	Apple; 1,2	apple dispensed
C	1,2; apple; cancel	no fruit dispensed; returned DKK 3
D	Apple; 1,2; cancel	no fruit dispensed; returned DKK 3
E	5, apple	apple dispensed; returned DKK 2
F	Apple; 5	apple dispensed; returned DKK 2
G	5, apple; cancel	no fruit dispensed; returned DKK 5
H	Apple; 5; cancel	no fruit dispensed; returned DKK 5
I	5; banana	no fruit dispensed; current money shows 5
J	Banana; 5,1	no fruit dispensed; current money shows 6
K	5,1; banana; cancel	no fruit dispensed; returned DKK 6
L	Banana; 5,1;cancel	no fruit dispensed; returned DKK 6

Manual vs Automated Tests

- Manual test-plans
  - Table of input / expected output
  - Run the application
  - Check for desired outcome
- Automatic tests
  a. Test the GUI directly
  b. Testing ”under the GUI”
     - $\rightarrow$ Layred architecture

Application Layer



Functional Test for Buy Fruit Use Case: JUnit Tests

```
public void testInputDataSetA() {
    VendingMachine m = new VendingMachine(10, 10);
    m.input(1);
    m.input(2);
    assertEquals(3, m.getCurrentMoney());
    m.selectFruit(Fruit.APPLE);
    assertEquals(Fruit.APPLE, m.getDispensedItem());
}

public void testInputDataSetB() {
    VendingMachine m = new VendingMachine(10, 10);
    m.selectFruit(Fruit.APPLE);
    m.input(1);
    m.input(2);
    assertEquals(0, m.getCurrentMoney());
    assertEquals(Fruit.APPLE, m.getDispensedItem());
}
```

Functional Test: JUnit Tests (cont.)

```
public void testInputDataSetC() {
    VendingMachine m = new VendingMachine(0, 0);
    m.input(1);
    m.input(2);
    assertEquals(3, m.getCurrentMoney());
    m.selectFruit(Fruit.APPLE);
    assertEquals(null, m.getDispensedItem());
    m.cancel();
    assertEquals(null, m.getDispensedItem());
    assertEquals(3, m.getRest());
}

public void testInputDataSetD() {
    VendingMachine m = new VendingMachine(0, 0);
    m.selectFruit(Fruit.APPLE);
    m.input(1);
    m.input(2);
    assertEquals(3, m.getCurrentMoney());
    m.cancel();
    assertEquals(null, m.getDispensedItem());
    assertEquals(3, m.getRest());
}

...
```

Contents

Code coverage

- How good are the tests?
- The tests have covered all the code
- Code coverage
  - statement coverage ✓
  - decision coverage ✓
  - condition coverage ✓
  - path coverage ✓
  - …

EclEmma

Code coverage: statement, decision, condition

St. cov | decision | condition

```
int foo (int x, int y)
{
    int z = 0;
    if ((x>0) && (y>0)) {
        z = x;
    }
    return z;
}
```

t/f t/f

St. cov: x=1, y=1

decision:
x=1, y=1
x=0, y=1

condition:
x=1, y=1
x=1, y=0
x=0, y=0
x=0, y=1

Code coverage: path

```
int foo (boolean b1, boolean b2)
{
   if (b1) {
      s1;
   } else {
      s2;
   }
   if (b2) {
      s3;
   } else {
      s4;
   }
}
```

$b_1 = t; \; b_2 = f$
$b_1 = f; \; b_2 = t$
$b_1 = t; \; b_2 = t$
$b_1 = f; \; b_2 = f$

Coverage Tool

- Statement, decision, and condition coverage
- EclEmma (`http://eclemma.org`):

Coverage with EclEmma

Systematic_Tests (Feb 24, 2013 9:57:34 PM)

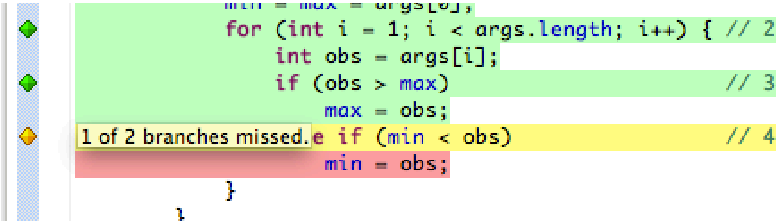
Element	Coverage
Systematic_Tests	60.8 %
test	46.9 %
src	94.3 %
dtu.example	94.3 %
MinMax.java	94.3 %
MinMax	94.3 %
minmax(int[])	93.2 %
getMax()	100.0 %
getMin()	100.0 %

100 %

Coverage with EclEmma

```java
        for (int i = 1; i < args.length; i++) { // 2
            int obs = args[i];
            if (obs > max)                        // 3
                max = obs;
            else if (min < obs)                   // 4
                min = obs;
        }
    }
```

Coverage with EclEmma



Contents

Course 02161 Exam Project

- Exam project: Monday 8.4 — Monday 13.5

Report
Eclipse Project

- Project plan: ~~Friday~~ Tuesday 2.4
- 10 min demonstrations of the software are planned for Monday 13.5
  → The tests need to be demonstrated

Introduction to the project

- What is the problem?
  - Project planning and time recording system
  - More information on CampusNet
- What is the task?
  - Create a
    - Project plan
    - Requirement specification
    - Programdesign
    - Implementation
    - Tests
- Deliver a
  - report describing the requirement specification, design, and implementation (as a **paper copy** and **PDF uploaded to CampusNet**)
  - an **Eclipse** project containing the source code, the tests, and the running program (uploaded to CampusNet as a **ZIP** file)

Organisational issues

- Group size: 2 – 4
- Report can be written in Danish or English
- Program written in Java and tests use JUnit
- Each section, diagram, etc. should name the author who made the section, diagram, etc.
- **You can talk with other groups (or previous students that have taken the course) on the assignment, but *it is not allowed to copy from others parts of the report or the program*.**
  - *Any text copy without naming the sources is viewed as cheating*
- In case of questions with the project description send email to `hub@imm.dtu.dk`