Exam CSE2115
Software Engineering Methods

Delft University Of Technology
January 28, 2022 - 9:00-11:00

Please, read these instructions carefully. The exam consists of **7** open questions that cover the material of the course. The questions are weighted, and the weights (points) can be found in the header of each question. The total number of points that can be achieved on the exam is **50** points.

The exam has in total of 11 pages.

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1. DDD - Domain Driven Design (10 pts)

Consider the following scenario:

*"The Department of Software Technology at TU Delft wants to improve the students' learning experience outside of class. For that reason, the development of an **online discussion forum** is envisioned to help students to review material before an assignment or exam, engage students in a discussion of the course material before coming to class, and reflect on material that they have read or worked with outside of class.*

All users of the system need to authenticate themselves to determine who they are and what they can do on the platform. Users need to have a NetID associated with their account to identify them across the systems of the TU Delft universally. This NetID, together with a password, serves as the credentials for the account. The password needs to be stored safely. For simplicity, the system will not be connected to the existing TU Delft authentication system (Single-Sign-On). The NetID is just a unique string used to identify each user.

The forum system should have a different board (page) for each topic. These topics can, for example, be different courses or different parts of a course. Each topic can have multiple threads consisting of posts. Each thread starts with a question or statement and can have multiple posts replying to it. Topics can only be created by teachers. Threads and posts can be created by both teachers and students. Anonymous users should be able to access the forum and read threads; however, they shouldn't be able to create or post anything.

Forum topics have a name and description that are given by the users that create them. Threads have a title displaying the purpose of the thread, a body containing the question or statement, the creator of the thread, and the time it was created. Each post has the user creating the post, the time it was posted, and the body of the post. Topics, threads, and individual posts should all be uniquely linkable so that users can share links to these resources with other people.

Teachers are able to lock and unlock a topic or thread to prevent users from adding new content. If a topic or thread is locked, it is still visible to all users. However, users should be able to edit their topics, threads, and posts. When a topic, thread, or post is edited, it should display that it is edited and when the last edit was made.

QUESTION 1: What are the **bounded contexts** for the scenario above? Explain the bounded contexts you have identified using Domain-Driven Design (DDD), their responsibilities, and how they are related to one another. For each context, please specify whether it is a core, generic, or supporting context. Please motivate your design choices over alternative ones.

Answer:

The bounded contexts are:

1. **Authentication** (generic domain): it is responsible for the authentication functionality and authenticating the users using their NetID and passwords. It will communicate with the SSO system of TU Delft.
2. **User** (core domain): its responsibility is to provide information/data of the users who register into the system.
3. **Topic** (core domain): the responsibility of this context is the creation of topics of a course of the different aspects of the course. It will also provide the functionalities to create, answer, and lock the topics and the posts within each topic.

The relations of these bounded contexts can be described as follows:

- The user is a **downstream** domain for the authentication

- The topic is a **downstream** domain for the users
- Topic and user have a **partnership** relation
- User and authentication have a **conformism** relation
- The user domain will include an **anti-corruption layer** (ACL) for the connection with the authentication context.

Note that the topic domain includes topics, threads, and posts. While these three could, in theory, be divided into different bounded contexts, they are strongly related to one another by a "part of relation"; indeed, posts compose threads, which compose topics. Hence, they are, in essence, the same domain (but just with different granularity levels): a topic is "just" a set of threads with a given label (e.g., "exam"), having a domain for threads and another domain for topics would not make sense since, in that case, the topic domain would only contain "labels" for the data in the threads domain.

We could also have a bounded context for the course if the goal of this system would also consist in managing courses. However, from the scenario description, it is clear that this is not the case. As such, the "course" will be an attribute (string) for the topics related to that course. In this design, a topic will have the following attributes:

1. The code of the course (e.g., CS2115 for SEM)
2. The title of the topics
3. A list of threads associated with that topic

We have also decided to consider user and authentication as two separate bounded contexts. This is because the user data management is separated from the authentication method, which is outsourced to the TU Delft SSO.

2. Requirement Engineering (5 pts)

Consider the following scenario:

"Alice and Bob want to develop a new system for managing the grades of the students at TU Delft as an alternative to OSIRIS. After discussing with the different stakeholders, Alice and Bob have identified the following requirements:

1. *Student shall pass a course if the grade is 5.75 or higher*
2. *The system should have a maximum response time of 0.50s*
3. *Teachers shall be able to enter grades for students*
4. *Students shall be able to see their grades and their passed courses*
5. *Teachers shall not be able to get grades*
6. *Password shall be stored safely*
7. *Users shall be able to interact with a GUI*
8. *Students shall be able to get a message after registered for an exam*

9. *The system shall be compatible with multiple operating systems*
10. *The GUI shall use a color palette that is color-blind friendly*
11. *The system shall provide statistics about the grade distribution to teachers*
12. *Courses shall have multiple categories of grades*
13. *Users must be able to log in using their NetID and password.*
14. *Students must be able to view their courses.*
15. *Teachers must be able to create new courses with a course code + course name.*
16. *The application's dependencies will be managed through Gradle.*
17. *The implementation of the application shall have at least 75% code coverage.*
18. *The system should be able to handle at least 4000 parallel sessions.*
19. *Any teacher can give a grade to a student for an exam.*
20. *A teacher shall be able to change a grade if a mistake was made."*

(2 pts) QUESTION 2.1: Examine the requirements listed above. Classify the requirements into functional (FR) and non-functional (NFR) requirements. Also, highlight any ambiguity in the requirements and indicate what is missing to complete the requirement's specification. If any requirements appear to be in conflict with one another, document that too.

Answer:
Below is the list of requirements classified in function (FR) and non-functional (NFR) requirements"

- R1 is an FR
- R2 is an NFR
- R3 is an FR
- R4 is an FR
- R5 is an FR
- R6 is an NFR
- R7 is an NFR
- R8 is an FR
- R9 is an NFR. This requirement is not precise: which operating systems shall we consider?
- R10 is an NFR
- R11 is an FR
- R12 is an FR. This requirement is incomplete: which categories shall we consider?
- R13 is an FR
- R14 is an FR
- R15 is an FR
- R16 is an NFR
- R17 is an NFR. This requirement is not precise: which coverage criteria shall we consider? Branch coverage? Statement coverage?
- R18 is an NFR

- R19 is an FR. This requirement is malformed since it leaves room to interpretation. For example, grades for SEM shall not be entered by “any” teachers but only by the responsible teachers.
- R20 is an FR

(1 pt) QUESTION 2.2: What are the stakeholders for the grade management system discussed above? For each stakeholder, justify your choice and how they would contribute to the requirement analysis process.

Answer:

- **Students**: they are the main stakeholders who will receive their grades through the new system.
- **Teachers**: they correspond to the other main stakeholders as they will use the system to enter the grades for their courses.
- **TAs**: they will help with grading the exam. So, they might need to have access to the grading system before the grades, and confirmed and signed by the responsible teacher.
- **Board of examiners**: the board will use the system to check the grade distributions for the different courses, e.g., for analytics reasons.

NB: We consider this answer correct if you also consider other stakeholders

(2 pts) QUESTION 2.3: Provide four additional functional and four additional non-functional requirements that, according to your opinion (as a potential stakeholder), should be added to the grade management system.

Answer:

1. (FR) The system shall notify the students (via email) when their grades have been registered.
2. (FR) The system shall allow the responsible teachers to search for students with registered grades
3. (FR) The system shall allow registering only grades within the range [1;10]
4. (FR) The system shall allow teachers to export grades on Brightspace.
5. (NFR) The system shall be implemented in Java 11
6. (NFR) The system shall be GDPR compliant.
7. (NFR) The website layout must be compatible with (readable on) mobile devices
8. (NFR) Data must be encrypted using the DES Symmetric Algorithm

Note, these are just possible examples. We will consider other requirements as long

as they are correctly and precisely formulated.

3. Design Patterns (10 pts)

Consider the following scenario:
"*We want to implement an online system for building robots. Robots are complex cyber-physical systems that have multiple hardware and software components that are chosen by customers based on their preferences.*

A robot has different types of physical sensors:
- *Camera sensors for vision (eyes)*
- *Tactile sensors for detecting objects (hands)*
- *Microphones for detecting sounds and speech (ears)*

For each type of sensor, customers should be able to choose a specific instance from the catalog. For example, there are alternative sensors for the eyes (e.g., full HD camera, wide-angle camera, etc.)

Besides, the signals from each sensor are fed to a specific Artificial Intelligence (AI) engine, such as
- *Deep-learning based recognition for the camera*
- *Simple regression model for the hands*
- *Text-to-speech algorithm for the sounds*

Using our system, customers should be able to build up a robot selecting the sensor and the AI engine they want incrementally."

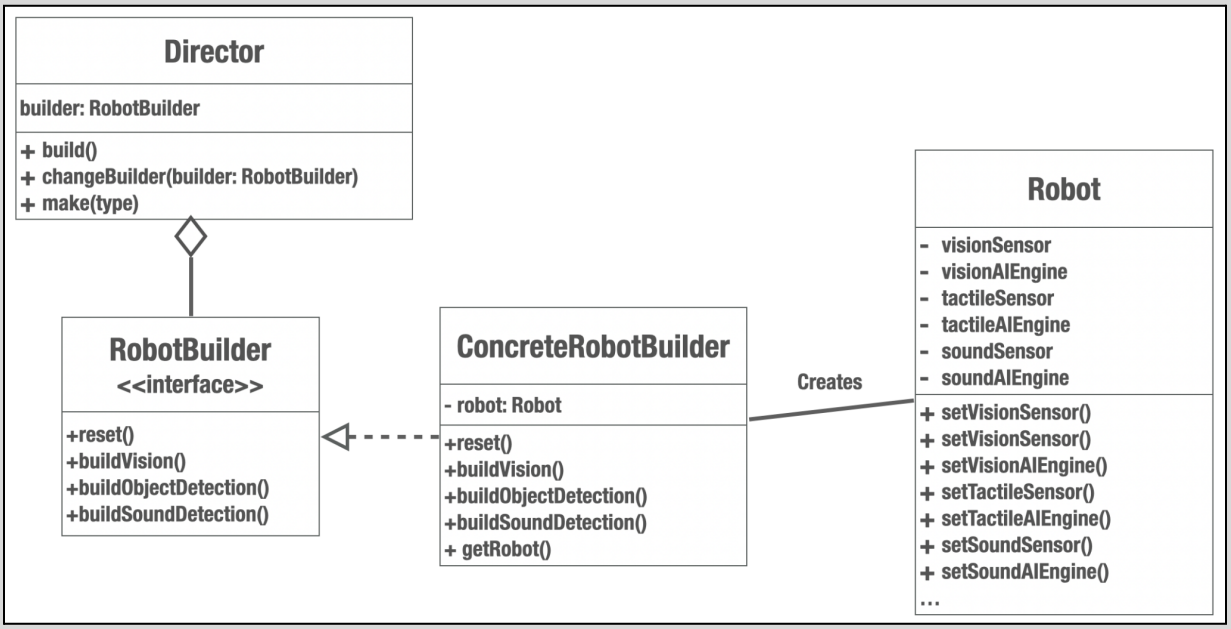
(4 pts) QUESTION 3.1: Which design pattern fits best in the implementation of this system? Please explain your choice.

Answer:
The design pattern that best fits the scenario above is the **builder pattern**. First, the scenario requires creating objects incrementally; hence, it must be a creational pattern. The builder pattern addresses the following key aspect of this problem:
- Customers can **incrementally** (step by step) choose the robot sensors
- Customers can **incrementally** (step by step) choose the AI engine associated with each sensor
- The features (sensors and AI engine) are selected from an existing catalog of alternative features (like the cars in the example from the lecture slides)
- The robot will be created at the end, once all the desired feature have been selected

(6 pts) QUESTION 3.2: For the given design pattern of your choice (part 1), draw the corresponding class diagram containing the following elements:

- The classes (the role, class name, attributes, and method names, etc.) you would write to implement the design pattern
- The type of association for each pair of classes/interfaces.

Answer:



NB: the RobotBuilder could also be an abstract class (and the arrow between the builder and its concrete implemented should have a non-dashed line).

The attribute and method names can also vary. However, “build()” and “getRobot()” are key ingredients in the builder pattern. Similarly, the concrete builder must include the robot as a private attribute.

4. Software Analytics 1 (5 pts)

Consider the program in Listing 1. Answer the following questions:

(2 pts) QUESTION 4.1: What is the value of the LCOM (Lack of Cohesion of Methods) metric for the `Fibonacci` class? Show all the steps you used to compute the LCOM (how you applied the formula).

(3 pts) QUESTION 4.2: Given the results of the LCOM, does the class contain a code smell? If yes, which one? How would you address the code smell?

Listing 1

```
1.  public class Fibonacci {
2.
3.     private static Map<Integer, Integer> map = new HashMap<>();
4.
5.
6.     public static void main(String[] args) {
7.         Scanner sc = new Scanner(System.in);
8.         int n = sc.nextInt();
9.
10.        System.out.println(fibMemo(n));
11.        System.out.println(fibBotUp(n));
12.        System.out.println(fibOptimized(n));
13.        sc.close();
14.    }
15.
16.
17. /*  This  method  finds  the  nth  fibonacci  number  using  memoization
18. technique */
19.    public static int fibMemo(int n) {
20.        if (map.containsKey(n)) {
21.            return map.get(n);
22.        }
23.
24.        int f;
25.
26.        if (n <= 1) {
27.            f = n;
28.        } else {
29.            f = fibMemo(n - 1) + fibMemo(n - 2);
30.            map.put(n, f);
31.        }
32.        return f;
33.    }
34.
35.
36.    /* This method finds the nth fibonacci number using bottom up */
37.    public static int fibBotUp(int n) {
38.        Map<Integer, Integer> fib = new HashMap<>();
39         for (int i = 0; i <= n; i++) {
40.            int f;
41.            if (i <= 1) {
42.                f = i;
43.            } else {
44.                f = fib.get(i - 1) + fib.get(i - 2);
45.            }
46.            fib.put(i, f);
47.        }
48.
49.        return fib.get(n);
50.    }
```

```
51.
52.     /** This method finds the nth fibonacci number using bottom up */
53.     public static int fibOptimized(int n) {
54.         if (n == 0) {
55.             return 0;
56.         }
57.         int prev = 0, res = 1, next;
58.         for (int i = 2; i <= n; i++) {
59.             next = prev + res;
60.             prev = res;
61.             res = next;
62.         }
63.         return res;
64.     }
65. }
```

Answer 4.1:

LCOM = 6, and it is computed as follows:

The class has four methods (including the `main` method) and one single attribute (*`map`*). Hence, in total, there are 4!/(2! * 2!) = 6 pairs of methods to analyze. Let's count the number of method pairs that share attributed (set Q) and that don't do so (set P)

Method pair	Share attributes	Don't share attributes
`main` + `fibMemo`		✅
`main` + `fibBotUp`		✅
`main` + `fibOptimized`		✅
`fibMemo` + `fibBotUp`		✅
`fibMemo` + `fibOptimized`		✅
`fibBotUp` + `fibOptimized`		✅
Total	|Q| = 0	|P| =6

LCOM = |P| - |Q| = 6 - 0 = 6

Answer 4.2:
The class has a clear low-coupling smell. To address smell, we should move the methods (except the main) in three classes apply three times a move-method refactoring. In particular, we can implement the strategy design pattern, with:

- One interface `Fibonacci`
- One class FibonacciBottomUp with the method `fibBotUp` and that implements the interface.
- One class FibonacciMemory with the method `fibMemo` and that implements the interface.
- One class FibonacciOptimized with the method `fibOptimized` and that implements the interface.
- The main method should be converted into a test suite for the three newly created classes above.

5. Software Analytics 2 (5 pts)

Consider the program in Listing 2. Answer the following questions:

(3 pts) QUESTION 5.1: What are the decision points for the `divideMessageWithP` method?

(2 pts) QUESTION 5.2: What is the Cyclomatic Complexity (CC) for the `divideMessageWithP` method?

Listing 2

```
1.  public class CRCAlgorithm {
2.
3.      private int correctMess;
4.      private int wrongMess;
5.      private int wrongMessCaught;
6.      private int wrongMessNotCaught;
7.      private int messSize;
8.      private double ber;
9.      private boolean messageChanged;
10.     private ArrayList<Integer> message;
11.     private ArrayList<Integer> dividedMessage;
12.     private ArrayList<Integer> p;
13.     private Random randomGenerator;
14.
15.     /**
16.      * The algorithm's main constructor. The most significant variables,
17.      * used in the algorithm, are set in their initial values.
18.      * @param str The binary number P, in a string form, which is
19.      * used by the CRC algorithm
20.      * @param size The size of every transmitted message
21.      * @param ber The Bit Error Rate
22.      */
23.     public CRCAlgorithm(String str, int size, double ber) {
24.         messageChanged = false;
25.         message = new ArrayList<>();
26.         messSize = size;
27.         dividedMessage = new ArrayList<>();
28.         p = new ArrayList<>();
29.         for (int i = 0; i < str.length(); i++) {
30.             p.add(Character.getNumericValue(str.charAt(i)));
31.         }
32.         randomGenerator = new Random();
33.         correctMess = 0;
34.         wrongMess = 0;
35.         wrongMessCaught = 0;
36.         wrongMessNotCaught = 0;
37.         this.ber = ber;
38.     }
39
40.
41.     /* The most significant part of the CRC algorithm. */
42.     public void divideMessageWithP(boolean check) {
43.         ArrayList<Integer> x = new ArrayList<>();
44.         ArrayList<Integer> k = (ArrayList<Integer>) message.clone();
45.         if (!check) {
46.             for (int i = 0; i < p.size() - 1; i++) {
47.                 k.add(0);
48.             }
49.         }
50.         while (!k.isEmpty()) {
51.             while (x.size() < p.size() && !k.isEmpty()) {
52.                 x.add(k.get(0));
53.                 k.remove(0);
54.             }
```

```
55.             if (x.size() == p.size()) {
56.                 for (int i = 0; i < p.size(); i++) {
57.                     if (x.get(i) == p.get(i)) {
58.                         x.set(i, 0);
59.                     } else {
60.                         x.set(i, 1);
61.                     }
62.                 }
63.                 for (int i = 0; i < x.size() && x.get(i) != 1; i++) {
64.                     x.remove(0);
65.                 }
66.             }
67.         }
68.         dividedMessage = (ArrayList<Integer>) x.clone();
69.         if (!check) {
70.             for (int z : dividedMessage) {
71.                 message.add(z);
72.             }
73.         } else {
74.             if (dividedMessage.contains(1) && messageChanged) {
75.                 wrongMessCaught++;
76.             } else if (!dividedMessage.contains(1) && messageChanged) {
77.                 wrongMessNotCaught++;
78.             } else if (!messageChanged) {
79.                 correctMess++;
80.             }
81.         }
82.     }
83.
84. …
85. }
```

Answer:
Cyclomatic complexity = # decision points + 1 = 13 + 1 = 14

List of decision points:

- if statement in line 45
- for statement in line 46
- while statement in line 50
- while statement in line 51
- if statement in line 55
- for statement in line 56
- if statement in line 57
- for statement in line 63
- if statement in line 69
- for statement in line 70
- if statement in line 74

- if statement in line 76
- if statement in line 78

6. Regression Testing (5 pts)

Consider the coverage matrix (rows are test cases and columns are branches) depicted in Table 1.

QUESTION: Which test cases are selected when using the additional greedy algorithm to reach 100% branch coverage?

Report the test case(s) in the exact order they are selected by the additional greedy algorithm. Also indicate the branches that are additionally covered by the test case selected in each iteration of the algorithm.

Table 1

	b1	b2	b3	b4	b5	b6	b7	b8	b9	b10	b11	b12	b13	b14	b15	b16	b17	b18	b19	b20
t1			x							x	x				x			x		
t2		x		x				x					x	x					x	
t3	x		x	x					x			x			x					
t4			x		x	x	x			x									x	
t5							x	x						x				x	x	
t6		x	x								x			x						x
t7							x							x	x	x				x
t8		x	x	x				x	x	x								x		
t9	x		x	x	x					x	x									
t10				x	x	x	x											x	x	
t11							x	x			x	x								x
t12			x	x	x								x		x	x				
t13																	x	x	x	x
t14		x	x						x	x				x	x					
t15	x																x	x	x	x

Answer:
The test cases are selected in the order = t8, t7, t4, t3, t1, t2, t13.

The additional coverage information are as follows:

- t8 covers branches b2, b3, b4, b8, b9, b10, b18 (7 branches)
- t7 additionally covers branches b7, b14, b15, b16, b20 (5 branches)
- t4 additionally covers branches b5, b6, b19 (3 branches)
- t3 additionally covers branches b1, b12 (2 branches)
- t1 additionally covers branch b11
- t2 additionally covers branch b13
- t13 additionally covers branch b17

7. Mutation Testing (10 pts)

Consider the program in Listing 3. Let us consider the mutant where line **43** (third condition of the if statement) is changed as follows:

- Original condition: `string.contains(banned_digits[2])`
- Mutated condition: `string.contains(banned_digits[0])`

Question: Write a test case that can kill the mutant. Remember that a meaningful test case must include assertions. Syntax errors (e.g., missing semicolons, spelling mistakes, etc.) will be ignored.

Listing 3 (Original Program)

```
1.  class Solution {
2.     int A =  1;
3.     int B =  3;
4.     int C =  9;
5.
6.     private String[] banned_digits;
7.
8.     public Solution(){
9.         banned_digits = new String[]{
10.                Integer.toString(A),
11.                Integer.toString(B),
12.                Integer.toString(C)
13.        };
14.    }
15.
16.    /**
```

```
17.      * This method counts the numbers from 0 to n with repeated digits.
18.      * For example, the only positive number (n<= 20) with at least 1
19.      * repeated digits is 11.
20.      * However, this method has a special tweak: all numbers that
21.      * contains the digits in A, B, or C are not counted.
22.      * @param n
23.      */
24.     public int numbers_duplicate_digits(int n) {
25.         if (n<=0)
26.             return 0;
27.
28.         int counter = 0;
29.         for (int i=0; i<=n; i++){
30.             String s = Integer.toString(i);
31.             if (this.hasDuplicates(s)) {
32.                 counter++;
33.             }
34.         }
35.
36.         return counter;
37.     }
38.
39      public boolean hasDuplicates(String string){
40.         // let's handle the special cases
41.         if (string.contains(banned_digits[0]) ||
42.                 string.contains(banned_digits[1]) ||
43.                 string.contains(banned_digits[2])) <-- MUTANT LOCATION
44.             return false;
45.
46.         // let's handle all the other cases
47.          for (int i = 0; i < string.length(); i++){
48.             char current = string.charAt(i);
49.             String newString = string.replaceAll(current+"", "");
50.             if (newString.length() < string.length()-1)
51.                 return true;
52.         }
53.
54.         return false;
55.     }
56. }
```

Answer:

Here, an example of a test case that kills the mutant.

```
@Test
public void testCase(){
   Solution solution = new Solution();
   int value = solution.numbers_duplicate_digits(99);
   assertEquals(6, value);
}
```

There are, of course, many alternative test cases that kill the mutant by invoking the `numbers_duplicate_digits` method using the same test case above but with different input and oracle values. Here, some additional examples of input-output values that would kill the mutant:

- For input in [99, 199], output = 6
- For input in [200,201], output = 7
- For input in [202,219], output = 8
- For input in [220,221], output = 9
- For input =[222, 223], output = 10
- For input =224, output = 11
- For input =225, output = 12
- …

Another way to kill the mutant is to invoke the mutated method directly (`hasDuplicates`). A test case for this scenario is:

```
@Test
public void testHasDuplicates(){
   Solution solution = new Solution();
   boolean value = solution.hasDuplicates("99");
   assertFalse(value);
}
```

All test cases with input like “99”, “999”, etc., will kill the mutant as well.

THIS IS THE END OF THE EXAM.