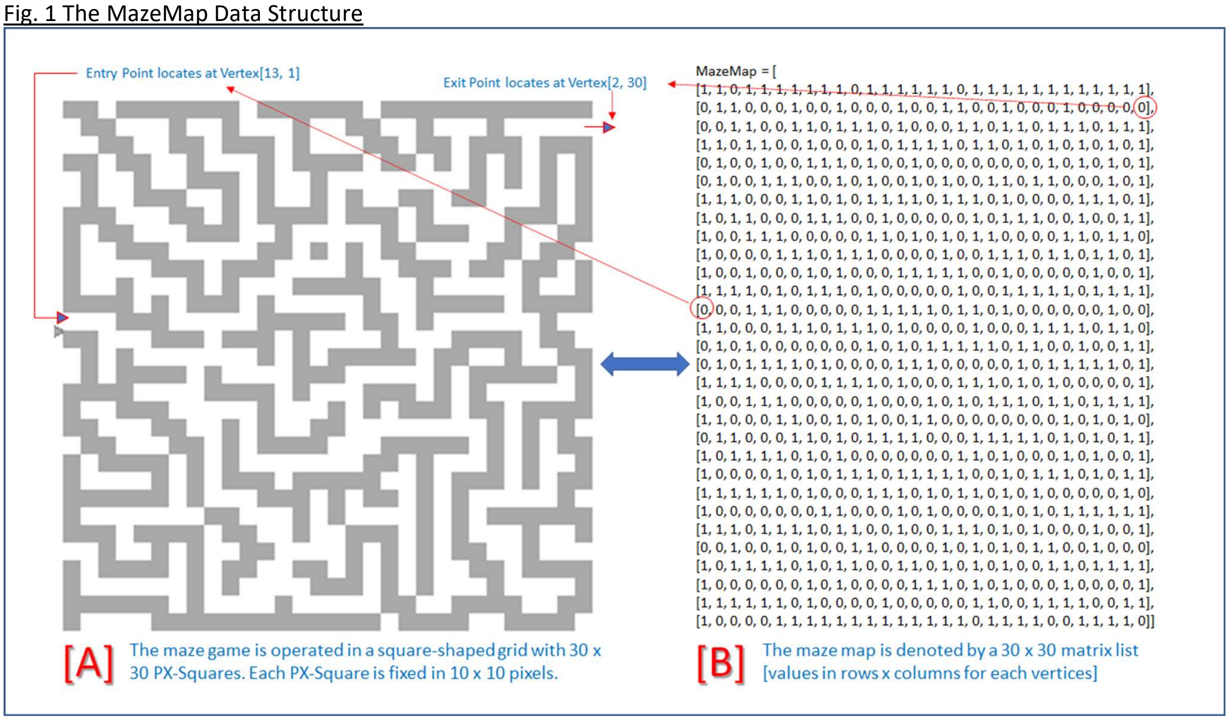
Project Title: Tom and Jerry in maze game
Project ID: TnJ1

Story: "Tom and Jerry" is an American cartoon film about a halpless cat's never-ending pursuit of a clever mouse. Tom is the scheming cat, and Jerry is the spunky mouse.

Introduction to the TnJ1 Maze Game

1. The dimension of the electronic play board is 300 x 300 = 90,000 pixels.
2. The maze game is displayed in a square-shaped grid with 30 x 30 PX-Squares filled by dark grey colour.
3. The maze graph is translated in a 30 x 30 matrix list (Fig.1 [B] – MazeMap).
4. PX-Square is a vertex of the maze graph, where vertex size = 10 x 10 pixels.
5. Each vertex address and value are expressed in {Boolean Vertex[r,c] where r=row, c=column. If Vertex[r,c]=1, it is a barrier filled by dark grey colour, else Vertex[r,c]=0, it is a clear path filled by white colour.
6. There will have only one Entry-Point e.g. Vertex[13,1] located at the left-side border of the maze.
7. There will have only one Exit-Point e.g. Vertex[2,30] located at the right-side border of the maze.
8. For each maze, it should have at least 2 possible paths that Tom and Jerry can traverse between Entry-Point and Exit-Point along all possible paths of the maze.

Fig. 1 The MazeMap Data Structure



The maze game is divided into three functions that requires each project group to complete the implementation.

Function A: Build a maze

1. For COMP3111 students, choose either one of below tasks:
   - i) Write a program of Maze-Editor that allows user to build a maze manually. See Appendix 2.1 for a reference, or, you may feel free to use your better idea to complete this task.
   - ii) Write a program of Maze-Generator, you can base~~d~~ on MST (Minimum Spanning Tree) or any other tree traversal algorithms to automatically generate a maze map data file at random time (Fig.1 [B]). A sample skeleton code that used DFS (Depth First Search) algorithm is provided. Note that the output of maze graph is displayed in text format, denoted by a text character(*). You need to translate to GUI type using PX-Squares as a sample output shown in Fig 1 [A].

2. For COMP3111H students, choose either one of below tasks:

   i) Write a program of Maze-Editor that allows user to build a maze manually. See Appendix 2.1 for reference as a minimum requirement. You should design your own way to enhance the program higher than standard.

   ii) Write a program of Maze Generator, you can base~~d~~ on MST (Minimum Spanning Tree) or any other tree traversal algorithms to automatically generate a maze map data file at random time (Fig.1 [B]). Sample skeleton code is not provided.

3. Whichever task i) or ii) is chosen, finally you should produce MazeMap file saving as csv file format delimited with "comma" likes Fig.3 [B] and sketch the GUI maze graph likes Fig.1 [A] on your laptop.

4. A sample skeleton code on how to create the GUI interface for an object moving around a 20 x 20 PX-Squares grid play board – The Snake Game (See Appendix 1.1) is provided. You may clone the git repository onto your laptop and run it for a trial, and copy part of the code into your group project.

5. Further elaboration for MST:

   Minimum Spanning Tree (MST) is not compulsorily required for function [A] to build the maze map data. It is because MST can help you to build only one path in the maze map, however, the project requires you to build at least 2 possible paths for function [B] and as more paths as feasible for function [C], otherwise, your game will not have fun enough to play. Thus, there're 2 suggested alternatives to solve function [B] problem:

   a. Choose other tree traversal algorithms to build the maze map with more than one paths between entry and exit point.

   b. Use MST-1 program to create the initial maze map data with exactly one path between entry and exit points inside the maze map. When MST-1 is executed, C1_Path is produced. We copy MST-1 program and modified it as MST-2, we call it path generator. For MST-2, we shall remove barriers (=Erase more holes) instead of add barrier to build an alternative path inside the maze map that was generated by MST-1. First, we select any 2 vertices v1 and v3 along C1_Path, and one extra vertex v2, where v2 is not in C1_Path. Then, we can simply use MST-2 to build an extra path from v1 to v3 via v2. If you want n possible paths, you just need to run MST-2 with n-1 times.

   Flexibility for function C: Note that the maze map generated from function A is capable for running function B program only, while running function C Tom catches Jerry game requires more alternative paths that it might have hundreds or thousands of paths in a 30x30 pixel map. Pac-man game and fig.3 maze maps are two of the examples. If that is the case, the project would be much scalable and very difficult to get it done well. Therefore, project group can base on the original map data generated by function A and then manually edit the map data by setting the barrier from 1 to 0 you wanna break the walls for function C.

6. Submission of function A:
   a. Take a screenshot of the maze map output from your program and a screenshot of the maze map data (the csv file) like Fig.1 sample. Then submit under JobId 215 in ONE pdf file like Fig.1 sample.
   b. Include the whole processing steps and explain how it works for the maze generation in your Youtube live demo.

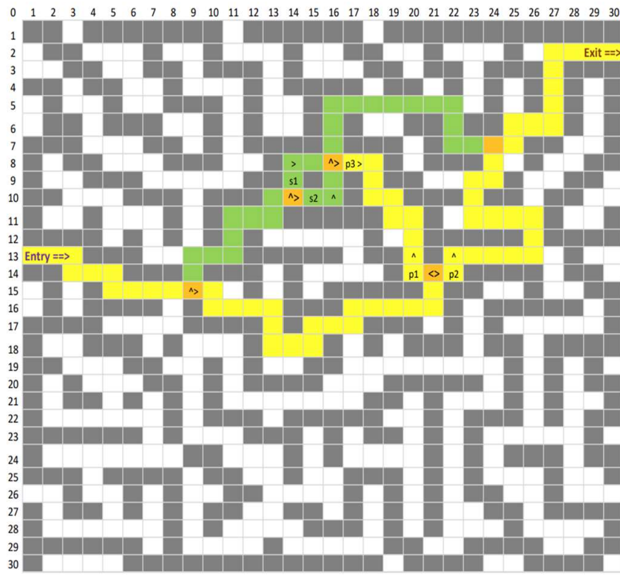
Function B: Shortest Path

To write a smart maze game program, the use of tree traversal algorithms to find possible paths and shortest path(s) between two vertices is indispensable. When a maze map file is created, see Fig. 2, two vertex-locations of Entry-Point.Vertex[13,1] and Exit-Point.Vertex[2,30] are formed.

1. Fig.2 [A] : Show the GUI maze graph with green Shortest Path(s) and yellow Other Possible Paths.
2. Fig.2 [B] : Export all path data in the format of {P(n), v1, v2, v3, ……, v(pl)}

Where P=path, n=path number, v=vertex, pl=path length=number of vertices for the path, P(n) is string, v1 to v(pl) are written as (r,c) where r=row and c=column of the maze grid. E.g. [s1, (15,9), (14,9), (13,9), ……, (2,30)]

Fig.2 Illustration of Shortest Path (This maze map data file can be found on Canvas for reference only.) (**2)



[A] Screen layout of finding Possible Paths & Shortest Path in a Maze Game

Paths from MathFile[13,1] to MathFile[2,30]											
Shortest Paths	s1 = {	13,1	13,2	13,3	14,3	14,4	14,5	15,5	15,6	15,7	15,8
	Length (Vertices) = 39	15,9	14,9	13,9	13,10	13,11	12,11	11,11	11,12	11,13	10,13
		10,14	9,14	8,14	8,15	8,16	7,16	6,16	5,16	5,17	5,18
		5,19	5,20	5,21	5,22	6,22	7,22	7,23	7,24	7,25	6,25
		6,26	6,27	5,27	4,27	3,27	2,27	2,28	2,29	2,30	}
	s2 = {	13,1	13,2	13,3	14,3	14,4	14,5	15,5	15,6	15,7	15,8
	Length (Vertices) = 39	15,9	14,9	13,9	13,10	13,11	12,11	11,11	11,12	11,13	10,13
		10,14	10,15	10,16	9,16	8,16	7,16	6,16	5,16	5,17	5,18
		5,19	5,20	5,21	5,22	6,22	7,22	7,23	7,24	7,25	6,25
		6,26	6,27	5,27	4,27	3,27	2,27	2,28	2,29	2,30	}
Other Possible Paths	p1 = {	13,1	13,2	13,3	14,3	14,4	14,5	15,5	15,6	15,7	15,8
	Length (Vertices) = 55	15,9	15,10	16,10	16,11	16,12	16,13	17,13	18,13	18,14	18,15
		17,15	17,16	17,17	16,17	16,18	16,19	16,20	16,21	15,21	14,21
		14,20	13,20	12,20	11,20	11,19	10,19	10,18	9,18	8,18	8,17
		8,16	7,16	6,16	5,16	5,17	5,18	5,19	5,20	5,21	5,22
		6,22	7,22	7,23	7,24	7,25	6,25	6,26	6,27	5,27	4,27
		3,27	2,27	2,28	2,29	2,30	}				
	p2 = {	13,1	13,2	13,3	14,3	14,4	14,5	15,5	15,6	15,7	15,8
	Length (Vertices) = 57	15,9	15,10	16,10	16,11	16,12	16,13	17,13	18,13	18,14	18,15
		17,15	17,16	17,17	16,17	16,18	16,19	16,20	16,21	15,21	14,21
		14,22	13,22	13,23	13,24	13,25	13,26	12,26	11,26	11,25	11,24
		11,23	10,23	9,23	9,24	8,24	7,24	7,25	6,25	6,26	6,27
		5,27	4,27	3,27	2,27	2,28	2,29	2,30	}		
	p3 = {	13,1	13,2	13,3	14,3	14,4	14,5	15,5	15,6	15,7	15,8
	Length (Vertices) = 63	15,9	14,9	13,9	13,10	13,11	12,11	11,11	11,12	11,13	10,13
		10,14	10,15	10,16	9,16	8,16	8,17	8,18	9,18	10,18	10,19
		11,19	11,20	12,20	13,20	14,20	14,21	14,22	13,22	13,23	13,24
		13,25	13,26	12,26	11,26	11,25	11,24	11,23	10,23	9,23	9,24
		8,24	7,24	7,25	6,25	6,26	6,27	5,27	4,27	3,27	2,27
		2,28	2,29	2,30	}						

[B] Examples of data output for 2 Shortest Paths and 3 Other Possible Paths.

1. For COMP3111 students~~, do shortest path only, show and output one of the shortest path.~~
   a. Implement one algorithm to find the shortest path between two vertices (Entry point and Exit point).
2. For COMP3111H students~~, do & show all possible paths. Additionally, use 2 algorithms (e.g. DFS vs BFS) to run ONE of the possible paths, e.g. p3 in Fig.2. To compare 2 outputs from 2 algorithms, write your comments for any findings of searching results~~
   a. Implement two algorithms to find the shortest path between any two vertices, which should be able to be called from function C.
   b. Write a short report to compare the algorithms' performance and/or output. Either one may be called from function C subject to your discretion.
   c. When the user launches function B, display the shortest path between the entry and exit.
   d. In addition, display at least 3, no more than 6 paths. Use different colors to distinguish shortest paths and other possible paths.
3. Some clarifications:
   a. First, don't mix up the design of function B and function C.
   b. Function B requires you to build an OOP class, which is simply a function call like Java libraries. It allows any external program in Function C to call in by giving the input parameters = {"Matrix of the maze map", "Vertices of point A (FROM)", "Vertex of point B (TO)", and return call with data array of {"Vertices along the shortest path from point A to point B"}. That's it.
   c. Function B is designed for Tom (the computer) only, it does not require any concerns about the behaviours of Jerry & Crystal.
   d. Some groups have made this assumption: When function B is executed and the shortest path and other possible paths are built properly, all movement processes in function C will always (all the time) refer to these pre-generated array of {"Vertices along the shortest path"}. This concept is totally incorrect! The conclusion should be: For EVERY single steps of movement whatever Tom moves from vertex a_1 to a_2 or Jerry moves from b_1 to b_2, the compute will call the f(B) shortest path to re-calculate the shortest distance between the latest position of Tom & Jerry.

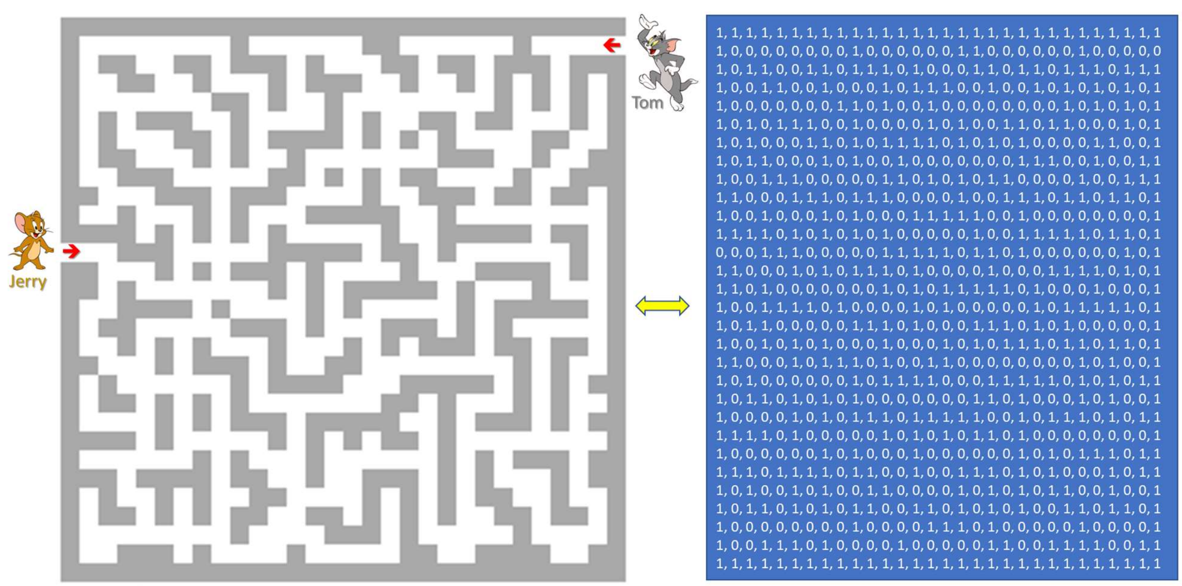
4. Submission of function B:
    a. Submission of function B requires simply a screenshot of the maze map output from your program and a screenshot of the vertices in shortest path (the csv file) like Fig.2 sample. Then submit under JobId 215 in ONE pdf file.
    b. Include the whole processing steps and explain how it works for the shortest path in your Youtube live demo.

Function C – Tom catches Jerry

This is an interactive game between user and computer with the following rules of operation:

1. ~~Jerry~~ Tom is controlled by the computer and spawns at the exit point, possibly by calling the shortest path program ~~that solution~~ from Function B to run towards Jerry. Tom's goal is to catch Jerry. ~~– Shortest Path must be reused in this part of coding for below purposes~~:
    ~~a. To find the fastest speed reaching the Exit-Point of the maze.~~
    ~~b. To avoid catching by Tom along paths in the maze.~~
2. ~~Tom~~ Jerry is controlled by the ~~user~~ player, and spawns at the entry point.
3. When the game begins, Jerry starts at Entry-Point and runs along the shortest path to reach the Exit-Point, while Tom starts at Exit-Point and runs approaching any paths to catch Jerry.
4. If Tom caught Jerry successfully, user ~~wins~~ loses, the game ~~and program stops~~ is over.
5. If Jerry reached Exit-Point, user ~~loses~~ wins, the game ~~is over~~ stops.
6. In normal circumstance, Tom's running speed is always a bit faster than Jerry.

Fig.3 Template of TnJ1 Maze Game – Tom catches Jerry, the MazeMap_TnJ.csv will be posted on Canvas for testing only.



[A]	Screen layout of Maze for Tom catches Jerry game	[B]	MazeFile.csv file for Tom catches Jerry game

1. For COMP3111 students, they can use Fig.3 template of maze map data and to simply follow the rules of operation from item 1 to 6 listed in the first paragraph, to implement the interactive Tom catches Jerry game.
2. The COMP3111H students:
    a. They can also use the above template of maze map data or design their own maze map, in order to make it more sophisticated with funs.
    b. Must follow the rules of operation from item 1 to 6 listed in the first paragraph, plus below enhanced features:

i. If Jerry touches the crystal, the roles are reversed, including running speed.

ii. Jerry (the play) may now choose to run towards the exist, or catch Tom.

iii. Tom will stop running towards the player. You can design at your own scenario how Tom responds, which could include running towards the entry point and escaping. This is your discretion.

iv. After a certain number of seconds or moves (i.e. by Tom or Jerry), subject to your discretion, everything goes back to normal.

~~v. Add an object "Crystal" at a fixed location inside the maze map.~~

~~vi. If Jerry went to get the Crystal successfully, the role-play including running speed between Tom & Jerry will be swapped within a fixed time stream, for instance 10 seconds or a traversal of 20 vertices. That is, Jerry catches Tom!~~

~~vii. When Jerry gets the crystal, Jerry will choose whether goes to catch Tom or goes toward the Exit-Point, subject to which way has the highest opportunity to win the game.~~

3. Both Grid-based and Continuous movement approaches are acceptable.

Function D – Unit Testing

You are required to hand-craft unit test cases using JUnit to test your implemented code. Your unit test cases should cover as many lines as possible.

The grading metric for the submitted test cases is related to line coverage. Specifically, the submitted test cases that have the least number of uncovered lines get the highest score. Specifically, the grading for Function D consists of two parts.

Part A: the submitted test cases that achieve more than 20% line coverage get 50% of the total score of Function D.

Part B: For the remaining 50% total score, the grade that a submission can get is 50% $* \, Total \, Score \, of \, Function \, D \, * \left(1 - \frac{rank - 1}{Total \, number \, of \, student \, groups}\right)$. Particularly, the submitted test cases that have the least number of uncovered lines get the best rank (i.e., 1). Similarly, submitted test cases that have the greatest number of uncovered lines ranked the last.

If there are multiple submitted test cases having the same number of uncovered lines, we further rank these submitted test cases according to *Test-per-function ratio* = $\frac{number \, of \, test \, cases}{max(160 - max(number \, of \, functions \, in \, the \, code, 80), 1)}$. Submissions with a lower *Test-per-function ratio* get better rank. In short, the grading scheme encourages you to use fewer test cases to cover as many lines of code as possible (Test minimization is always a good practice). Also, the denominator encourages you to implement at most 80 functions for your project.

You may build the test cases with JUnit 4 or JUnit 5, with a declaration in your report.

We have three requirements for the test cases and project code:

- Only lines of one function called by a test case will be considered covered (see Illustration 1)
- Only lines of function directly called by a test case will be considered covered (see Illustration 2)
- The implemented code should have at most one statement in each line (see Illustration 3)

Failure to achieve the above requirements will result in marks deduction.

Illustrations:

1. Only lines of one function called by a test case will be considered covered. If multiple functions (including constructors) are called in a test case, only one function's covered lines can be considered, and students are required mark which function is considered. For instance, testmultiple_legitimate() in Figure 2.2.2 calls multiple functions: *findMin()* and

finMax(). The function *findMax()* has been marked with "*target function"*, meaning that students want the covered line of *finMax()* to be considered. On the other hand, testmultiple_illegitimate() also calls *findMin()* and *finMax()*, yet no function is marked with "*target function"*. There will be mark deduction and the lines covered by testmultiple_illegitimate() will not be considered.

To ease the construction of test cases, for each test case, you are allowed to annotate at most four calls to the same function as "target function". For instance, in Figure 2.2.2, testmultiple_legitimate_call_same_function() calls findMax() five times, and four of them are annotated with "target function". Then, the lines of findMax exercised by these four calls are considered covered, while the lines exercised by the call without the "target function" annotation (i.e., Calculation.findMax(new int[]{4,4,4,4})) should not be considered covered.

2. "Uncovered lines" refers to lines explicitly marked "uncovered" by JUnit (i.e., lines with red bars nearly their line number). Lines that are marked "covered" (i.e., lines with green bars nearly their line number in Figure 2.2.3 and Figure 2.2.4) are not considered "uncovered", except that the "covered lines" are from a function not directly called by a test case. For instance, Figure 2.2.3 shows that after exercising testfindMax(), lines of findMax() and findMin() are marked "covered" by JUnit. However, we only consider the lines of findMax() are covered, and all lines of findMin() are not covered. However, lines covered by the recursive calls to the same function are considered covered.

Lastly, lines that do not have any marking (e.g., line 11 or 21 in Figure 2.2.3 and Figure 2.2.4) are not considered uncovered.

3. To objectively evaluate the test cases' effectiveness, the implemented code should have at most one statement in one line. For instance, for loop or if condition predicates should be separated from other statements. A counterexample is shown in Figure 2.2.1, where line 28 consists of both a loop predicate and the rest of the statements; a correct practice is shown in line 8-10. Moreover, in line 28, *sum += list[i]* and *return sum* should be put in two different lines.

Task:

Write a brief report to 1) show the line coverage report generated by JUnit, 2) put down which lines are not covered by each test case (e.g., provide the line numbers), 3) describe which lines are never covered by any test case, the total number of these uncovered lines, as well as the Test-per-function ratio (shows how it is computed). We will reproduce the reported result, and any inconsistency found will result in significant mark deduction. Please refer to our presentation video about Function D for more details.

Figure 2.2.1: Implemented code

```java
public class Calculation {

    no usages
    boolean dummy1 = true;
    no usages
    boolean dummy2 = true;

    1 usage
    public static int findMax(int arr[]){
        int max=0;
        for(int i=1;i<arr.length;i++){
            if(max<arr[i])
                max=arr[i];
        }
        int min = findMin(arr);
        return max;
    }

    4 usages
    public static int findMin(int list[])
    {
        int min = list[0];
        for (int i = 1; i < list.length; i++) {
            min = Math.min(min, list[i]);
        }
        return min;
    }

    no usages
    public static int sum (int list[])
    {
        int sum = 0;
        for (int i = 0; i < list.length; i++) {sum += list[i]; } return sum;
    }
}
```

Figure 2.2.2: Implemented test cases

```java
import org.junit.jupiter.api.Test;
import static org.junit.jupiter.api.Assertions.*;

class CalculationTest {

    @Test
    void testfindMax() { assertEquals( expected: 4,Calculation.findMax(new int[]{1,3,4,2})); }

    @Test
    void testfindMin() {
        assertEquals( expected: 1,Calculation.findMin(new int[]{1,3,4,2}));
    }

    @Test
    void testmultiple_illegitimate() {
        assertEquals( expected: 1,Calculation.findMin(new int[]{1,3,4,2}));
        assertEquals( expected: 1,Calculation.findMax(new int[]{1,3,4,2}));
    }

    @Test
    void testmultiple_legitimate() {
        assertEquals( expected: 1,Calculation.findMin(new int[]{1,3,4,2}));
        assertEquals( expected: 1,Calculation.findMax(new int[]{1,3,4,2}));//target function
    }

    @Test
    void testmultiple_legitimate_call_same_function() {
        assertEquals( expected: 1,Calculation.findMax(new int[]{1,2,3,4}));//target function
        assertEquals( expected: 1,Calculation.findMax(new int[]{4,3,2,1}));//target function
        assertEquals( expected: 1,Calculation.findMax(new int[]{1,3,4,2}));//target function
        assertEquals( expected: 1,Calculation.findMax(new int[]{1,1,1,1}));//target function
        assertEquals( expected: 1,Calculation.findMax(new int[]{4,4,4,4}));
    }
}
```

Figure 2.2.3: Coverage result A of testfindMax()

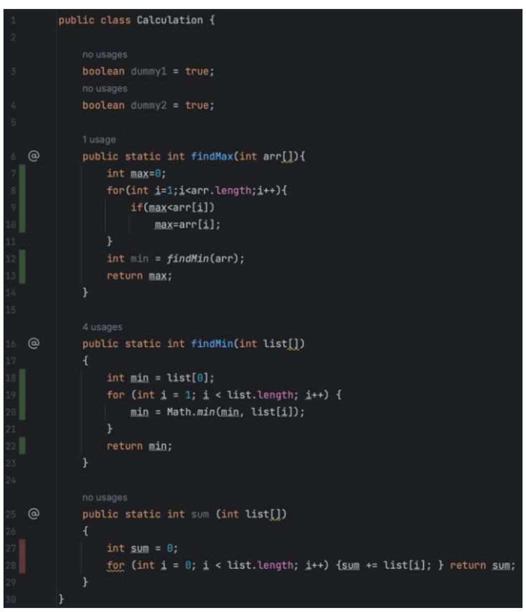


Figure 2.2.4: Coverage result B of testfindMax()

You are given a complete skeleton code of Snake Game. The Snake Game program is an open source developed by Hexadeciman Copyright © 2017 with MIT license.

The Game is simply constructed with 3 Java API packages. It works in the environment of 2D GUI.

API Package	Description	Usages in the game program
java.awt	Java Abstract Window Toolkit is an API to develop Graphical User Interface (GUI) or windows-based applications in Java.	Control keypressed, set colour.
java.util	Java Utility contains the collections framework, legacy collection classes, event model, date and time facilities, internationalization, and miscellaneous utility classes.	Basic function of ArrayList, Random-number generator.
javax.swing	Java Swing is a part of Java Foundation Classes (JFC) that is used to create window-based applications. It is built on the top of AWT (Abstract Windowing Toolkit) API and entirely written in java.	Setup of SquarePanel for 1) Playing Board; 2) Snake; 3) Apple.

These API packages are built-in tools of Java 17 and are lightweight components. The programs are developed with fully object-oriented classes.

Click here to clone the GitHub skeleton code into your local IntelliJ Java Project.
More URL for learning Java APIs: java.awt, java.util, javax.swing

Introduction to Snake Game

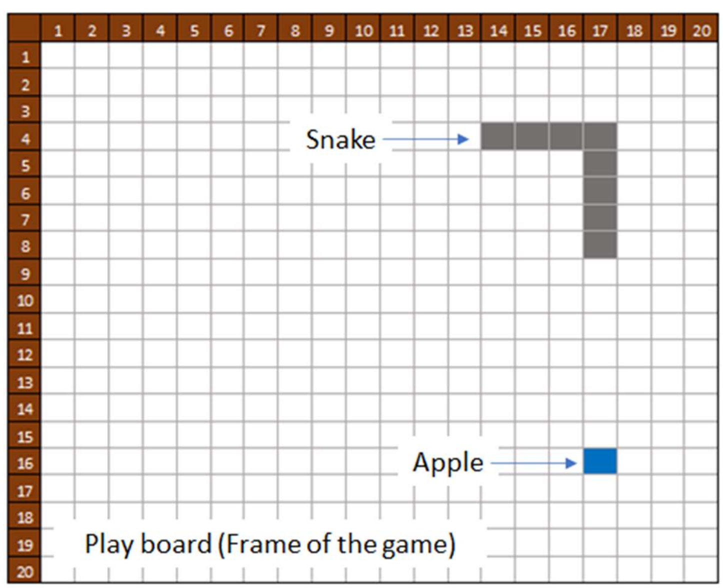
The Snake Game was first created in late 70s. In this game the player controls a snake with 4 cursor keys for 4 moving directions:

1. Pressing Up-Arrow to turn the snake moving upward;
2. Pressing Down-Arrow to turn the snake moving downward;
3. Pressing Left-Arrow to control the snake to make a left-turn;
4. Pressing Right-Arrow to control the snake to make a Right-turn;

The objective of the game is to control the snake to eat as many apples as possible. Each time the snake eats an apple its body grows. The size of each joint of a snake is 10x10 pixels. Initially, the snake has three joints. The snake must avoid the touch of its own body. If a touch is made, the game is over.

There are 3 objects running in the game. Each object is constructed with a standard component of a PX-Square (10x10 pixels)

1. The electronic play board is constructed by 20 x 20 PX-Squares in white colour.
2. The snake is constructed by 3 to many joints in dark grey colour. Each joint is equal to exactly 1 PX-Square.
3. The apple is constructed by exactly 1 PX-Square in blue colour.



Appendix 2.1 – Maze Editor (Example)

One of the idea to create a Maze Editor:

1. Build a grid editor with 30 x 30 PX-Squares, R (row) = 30, C (column) = 30
2. Initiate a plain grid:
   { Boolean MazeMap[int R, int C]
    for i in (1, 30)
        for j in (1, 30)
              MazeMap[i, j] := 0 }
3. When user moves the mouse and clicks on a particular cell e.g. MazeMap[6,10]:
   { if the cell is not filled with dark grey colour, i.e. MazeMap[6,10]=0;
       fill the cell with dark grey colour and set MazeMap[6,10]=1;
    else
       fill the cell with dark white colour and set MazeMap[6,10]=0 }

Here we introduce the most simply algorithm: "Turn On and Turn Off" approach for user's operation. Where On=1=Grey colour filled, Off=0=Colour unfilled. For every click, user turns on to fill colour or turns off to clear the filled colour.

Java API tools for reference: [Java GridLayout] or [Java Swing].