



COEN 6761 Software Testing and Validation

Development and Verification Report

Student Name	Student ID
Harshilsinh Solanki	40298679
Vraj Shah	40311967
Tanisha Fonseca	40266436
Teja Sayila	40321469

Submitted To:
Dr. Yan Liu

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1. Introduction:

This project involves creating a Java-based robot simulation where a robot moves across a grid ($N \times N$) and performs various tasks based on user commands. The robot can toggle its pen between "up" and "down" states. When the pen is down, it traces paths as it moves, when the pen is up, it moves freely without leaving a mark. The robot starts at the position $[0, 0]$, facing north, and the floor grid is initially empty (all zeros). Users can control the robot's movements, pen state, and view the current state of the floor grid through a set of commands. Commands include moving forward, turning, printing the grid, and replaying the robot's actions. This simulation allows the user to interact with the robot, observe its actions, and track its path on the floor grid.

1.1 Objective:

The objective of this project was to develop the robot code, verify its functionality, and then create and execute corresponding test cases to ensure the program behaves as expected. The robot responds to various commands like moving, turning, toggling the pen, and displaying the current state of the grid. The testing focuses on checking the robot's movement, pen functionality, and how well the grid updates as the robot performs actions. The project aims to ensure that the robot behaves reliably and accurately by thoroughly testing each part of the system with well-structured test cases.

1.2 GitHub Url:

<https://github.com/Vraj-2011/COEN-6761>

1.3 Tools and Technologies Used:

- **Java:** programming language used for the implementation of the robot simulation.
- **JUnit:** A testing framework used to create unit tests for the program. Testing ensures that each class and method in the system works as expected.
- **Maven:** An automation tool used for managing project dependencies and building the project. It helps ensure that dependencies like JUnit are properly included, and it provides a structured way to build and package the project.
- **Jira:** A project management and issue-tracking tool used for time tracking. Jira will be used to monitor the time spent on different tasks such as development, testing, and documentation.
- **GitHub:** Version control using GitHub will store the source code, track changes, and allow for collaboration or sharing of the project. All code, including classes and test cases, will be committed to GitHub for easy access and version history.

2. User Stories and Requirements:

A. Requirement-1 History [H | h]:

As a user, I want to replay all the steps I have taken since the previous start of the program so that I can review my actions and correct any mistakes. The replay should occur in the original order displaying all the previous steps taken by the robot.

B. Requirement-2 printHelp():

As a user, I want a comprehensive help function in the application so that I can easily access guidance and support for using its features. The help function should include list of commands for the movement of the robot.

C. Requirement-3 Invalid():

As a user, I want the robot to start from a default state, including the starting position at (0, 0), the pen being up, and facing north. This ensures that I have a consistent starting point for my commands, making it easier to plan my movements.

D. Requirement-4 initialize(int n):

As a user, I want to initialize the robot's environment with a specified grid size n, so I can control the robot within a defined space. If I provide an invalid size, I expect the program to inform me that the grid cannot be initialized, allowing me to correct my input.

E. Requirement-5 penup():

As a user, I want to raise the robot's pen so that it stops tracing paths on the grid. This feature allows me to move the robot freely without marking the floor, which is useful when I want to reposition the robot without leaving a trace

F. Requirement-6 pendown():

As a user, I want to lower the robot's pen so that it starts tracing paths on the grid as it moves. This enables me to create shapes or patterns on the floor, allowing us to trace the robot's operation.

G. Requirement-7 turnright():

As a user, I want to turn the robot to the right so that I can change its facing direction without moving. This capability is essential for navigating corners and adjusting the robot's orientation to create more complex shapes.

H. Requirement-8 turnleft():

As a user, I want to turn the robot to the left so that I can change its facing direction without moving. This flexibility allows me to easily navigate the grid and adjust the robot's path as needed.

I. Requirement-9 move(int steps):

As a user, I want to move the robot forward by a specified number of steps in the direction it is currently facing. If the pen is down, I expect the robot to mark its path on the grid, allowing me to visualize the robot's movements.

J. Requirement-10 printFloor():

As a user, I want to print the current state of the grid so that I can see the shapes traced by the robot. The output should clearly display asterisks for marked areas and blanks for unmarked areas, helping me understand the robot's path.

K. Requirement-11 getFloor():

As a user, I want to be able to successfully execute the quit command in the application so that I can exit the program without any errors. The application should confirm the action and ensure that all unsaved data is either saved or discarded appropriately before closing. This will enhance my experience by providing a smooth and reliable way to exit the application.

L. Requirement-12 printStatus():

As a user, I want to check the robot's current position, pen status, and facing direction so that I can keep track of its state. This information is vital for making informed decisions about the next commands to issue, ensuring smooth operation of the robot.

3. Functions & Methods:

A. public static void main(String[] args):

```
public class Main {  
    public static void main(String[] args) {  
        Scanner scanner = new Scanner(System.in);  
        RobotController robot = new RobotController();
```

- **Purpose:** This class initializes the program, sets up necessary objects, and manages user input to control the robot simulation.
- **Functionality:**
 - Initializes a Scanner object to read user input from the console.
 - Creates an instance of RobotController to manage the robot's actions.
 - Enters an infinite loop to continuously accept and process user commands until the user decides to exit by entering 'q'.

- Parses user input to determine the appropriate action, such as initializing the grid, moving the robot, changing the pen state, turning, printing the grid or status, displaying help, or showing command history.
- Manages invalid commands by prompting the user with an error message.

B. private static void printHelp():

```
private static void printHelp() {  
    System.out.println("[U|u] Pen up");  
    System.out.println("[D|d] Pen down");  
    System.out.println("[R|r] Turn right");  
    System.out.println("[L|l] Turn left");  
    System.out.println("[M s|m s] Move forward s spaces");  
    System.out.println("[P|p] Print the grid");  
    System.out.println("[C|c] Print current status");  
    System.out.println("[I n|i n] Initialize the system");  
    System.out.println("[H|h] Print the history of actions");  
    System.out.println("[Q|q] Quit the program");  
}
```

- **Purpose:** Provides users with a list of available commands and their descriptions to assist in interacting with the robot simulation.
- **Functionality:**
 - Prints a series of lines to the console, each describing a command that the user can input, such as lifting or lowering the pen, turning the robot, moving forward, printing the grid, checking the robot's status, initializing the system, viewing the history of actions, and quitting the program

C. public RobotController() (Constructor):

```
public RobotController() {  
    // Default initialization  
    x = 0;  
    y = 0;  
    penDown = false;  
    direction = Direction.NORTH;  
    history = new ArrayList<>();  
}
```

- **Purpose:** Initializes the robot with default values.
- **Functionality:**
 - Sets the starting position (x = 0, y = 0).
 - Sets the pen to be **up** (penDown = false).
 - Sets the robot's initial direction to **NORTH**.

- Initializes an empty **history list** to track actions.

D. **public void initialize(int n):**

```
public void initialize(int n) {
    if (n <= 0) {
        System.out.println("Grid size must be greater than 0.");
        return;
    }
    floor = new int[n][n];
    x = 0;
    y = 0;
    penDown = false;
    direction = Direction.NORTH;
    history.add("Initialized " + n + "x" + n + " grid.");
    System.out.println("Initialized " + n + "x" + n + " grid.");
}
```

- **Purpose:** Creates an n x n grid and resets the robot.
- **Functionality:**
 - If n is less than or equal to zero, prints an error.
 - Initializes a floor matrix of size n x n.
 - Resets the robot's position to (0, 0), sets the pen **up**, and sets direction to **NORTH**.
 - Adds an entry to history and prints a confirmation message.

E. **public void penUp():**

```
public void penUp() {
    penDown = false;
    history.add("Pen is now up.");
    System.out.println("Pen is now up.");
}
```

- **Purpose:** Lifts the robot's pen so it **does not draw** while moving.
- **Functionality:**
 - Sets penDown = false.
 - Adds an entry to history and prints a message.

F. public void penDown():

```
public void penDown() {  
    penDown = true;  
    history.add("Pen is now down.");  
    System.out.println("Pen is now down.");  
}
```

- **Purpose:** Lowers the pen so the robot **starts drawing** while moving.
- **Functionality:**
 - Sets penDown = true.
 - Adds an entry to history and prints a message.

G. public void turnRight():

```
public void turnRight() {  
    switch (direction) {  
        case NORTH -> direction = Direction.EAST;  
        case EAST -> direction = Direction.SOUTH;  
        case SOUTH -> direction = Direction.WEST;  
        case WEST -> direction = Direction.NORTH;  
    }  
    history.add("Turned right. Now facing " + direction + ".");  
    System.out.println("Turned right. Now facing " + direction + ".");  
}
```

- **Purpose:** Rotates the robot **90 degrees clockwise**.
- **Functionality:**
 - Updates the direction based on the current direction.
 - Adds an entry to history and prints the new direction.

H. public void turnLeft():

```
public void turnLeft() {  
    switch (direction) {  
        case NORTH -> direction = Direction.WEST;  
        case WEST -> direction = Direction.SOUTH;  
        case SOUTH -> direction = Direction.EAST;  
        case EAST -> direction = Direction.NORTH;  
    }  
    history.add("Turned left. Now facing " + direction + ".");  
    System.out.println("Turned left. Now facing " + direction + ".");  
}
```

- **Purpose:** Rotates the robot **90 degrees counterclockwise**.
- **Functionality:**
 - Updates the direction based on the current direction.
 - Adds an entry to history and prints the new direction.

I. public void move(int steps):

```
public void move(int steps) {  
    for (int i = 0; i < steps; i++) {  
        switch (direction) {  
            case NORTH -> y = Math.min(y + 1, floor.length - 1);  
            case SOUTH -> y = Math.max(y - 1, 0);  
            case EAST -> x = Math.min(x + 1, floor[0].length - 1);  
            case WEST -> x = Math.max(x - 1, 0);  
        }  
        if (penDown) {  
            floor[y][x] = 1;  
        }  
    }  
    history.add("Moved " + steps + " steps.");  
    System.out.println("Moved " + steps + " steps.");  
}
```

- **Purpose:** Moves the robot forward in the current direction.
- **Functionality:**
 - Moves one step at a time up to steps while ensuring **it does not move out of bounds**.
 - If the pen is **down**, marks the grid cell ($\text{floor}[y][x] = 1$).
 - Adds an entry to history and prints a message.

J. public void printFloor():

```
public void printFloor() {  
    if (floor == null) {  
        System.out.println("Error: Grid is not initialized.");  
        return;  
    }  
    System.out.println("Floor:");  
    for (int i = floor.length - 1; i >= 0; i--) {  
        for (int j = 0; j < floor[i].length; j++) {  
            System.out.print(floor[i][j] == 1 ? "*" : " ");  
        }  
        System.out.println();  
    }  
}
```

- **Purpose:** Displays the current grid, showing where the robot has drawn.
- **Functionality:**
 - If the grid is not initialized, prints an error.
 - Iterates over the floor array and prints "*" where 1 is found (indicating drawn lines) and " " for 0 (empty spaces).

K. public int[][] getFloor():

```
public int[][] getFloor() {  
    return floor;  
}
```

- **Purpose:** Returns the current grid (floor).
- **Functionality:** Returns the floor array for external use.

L. public void printStatus():

```
public void printStatus() {  
    System.out.println("Position: [" + x + ", " + y + "] - Pen: " + (penDown ? "down" : "up") + " - Facing: " + direction);  
}
```

- **Purpose:** Prints the robot's **current position**, **pen status**, and **facing direction**.
- **Functionality:**
 - Displays x, y coordinates.

- Shows whether the pen is **up or down**.
- Shows the direction the robot is facing.

M. public void printHistory():

```
public void printHistory() {  
    if (history.isEmpty()) {  
        System.out.println("No history available.");  
    } else {  
        System.out.println("History:");  
        for (String record : history) {  
            System.out.println(record);  
        }  
    }  
}
```

- **Purpose:** Displays a list of all commands executed by the robot.
- **Functionality:**
 - If the history list is empty, prints "No history available."
 - Otherwise, prints each action stored in history

4. Implementation and Testing Strategy:

4.1 Development:

The development process follows an iterative and incremental approach, with major milestones to ensure functionality is added progressively and validated.

Step 1: Create Basic Classes

- 1) Implement the RobotController class first to handle the robot's position, pen state, and facing direction.
- 2) Implement the Main class to handle user input and simulate the robot's actions.

Step 2: Define Robot Behaviour

- 1) Implement movement logic for the robot. The move() method will update the robot's position in the floor array, considering its facing direction and the pen's state.
- 2) Implement turning logic using the turnLeft() and turnRight() methods to change the robot's facing direction.

Step 3: Add Pen Functionality

- 1) Implement the penUp() and penDown() methods to allow the user to toggle the pen.

- 2) Update the floor array when the pen is down, marking cells as "1" when the robot moves over them.

Step 4: User Interaction and Command Parsing

- 1) Implement logic to handle user input for commands such as moving, turning, and toggling the pen.
- 2) We Have used a while loop to recognise and toggle commands and invoke the appropriate methods in the RobotController class.

Step 5: Implement Replay and History Functionality

Track all robot actions in a history list. Implement the replayHistory() method to replay actions from the start using the "H" command.

4.2 Testing Strategy:

The testing strategy for this project is designed to validate the behaviour and functionality of two main classes: the Main Class and the RobotController Class.

Main Class: This class handles all user inputs, processes the commands, and generates the output. The focus of testing for this class is to ensure that the user input is correctly parsed and that the appropriate actions are performed.

We will test:

- 1) Command parsing: Ensuring that the correct function is called for each user input.
- 2) Output generation: Verifying that the correct output is displayed, such as the robot's position, pen state, and grid status.
- 3) Handling edge cases, such as invalid inputs or commands that might cause the robot to exceed the grid boundaries.

RobotController Class: This class contains the functions that define the robot's behaviour, such as moving, changing the pen state, and displaying the grid. The testing of this class will focus on ensuring the correctness of the robot's movements, status updates, etc. We will test:

- 1) Movement Functions: Verifying that the moveLeft(), moveRight(), and movement logic are implemented correctly, and that the robot moves to the correct position on the grid when commands are executed.
- 2) Pen Functions: Testing the penUp() and penDown() functions to ensure the pen state changes as expected.
- 3) Status Functions: Validating the currentStatus() method to confirm the robot's position, pen state, and facing direction are accurately tracked and displayed.
- 4) Grid Display: Ensuring the printFloor() function correctly displays the grid with "1" (for traced areas) and "0" (for untraced areas) and accurately reflects the robot's movements.
- 5) Replay History: Testing the history replay function to ensure the robot's actions can be correctly replayed from the start, as intended.

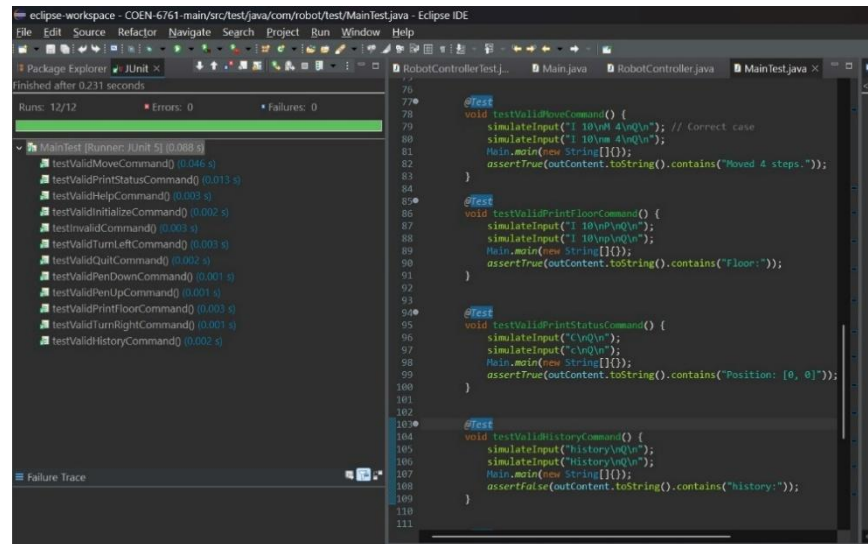
5. Mapping Unit test vs. Requirements

- Testcase-1 (T1): testValidHistoryCommand()
- Testcase-2 (T2): testValidHelpCommand()
- Testcase-3 (T3): testInvalidCommand()
- Testcase-4 (T4): testValidInitializerCommand()
- Testcase-5 (T5): testValidPenUpCommand()
- Testcase-6 (T6): testValidPenDownCommand()
- Testcase-7 (T7): testValidTurnRightCommand()
- Testcase-8 (T8): testValidTurnLeftCommand()
- Testcase-9 (T9): testValidMoveCommand()
- Testcase-10 (T10): testValidPrintFloorCommand()
- Testcase-11 (T11): testValidQuitCommand()
- Testcase-12 (T12): testValidPrintStatusCommand()

Requirements	Unit Test
Requirement-1(R1)	Testcase-1(T1)
Requirement-2(R2)	Testcase-2(T2)
Requirement-3(R3)	Testcase-3(T3)
Requirement-4(R4)	Testcase-4(T4)
Requirement-5(R5)	Testcase-5(T5)
Requirement-6(R6)	Testcase-6(T6)
Requirement-7(R7)	Testcase-7(T7)
Requirement-8(R8)	Testcase-8(T8)
Requirement-9(R9)	Testcase-9(T9)
Requirement-10(R10)	Testcase-10(T10)
Requirement-11(R11)	Testcase-11(T11)
Requirement-12(R12)	Testcase-12(T12)

6. Test cases execution

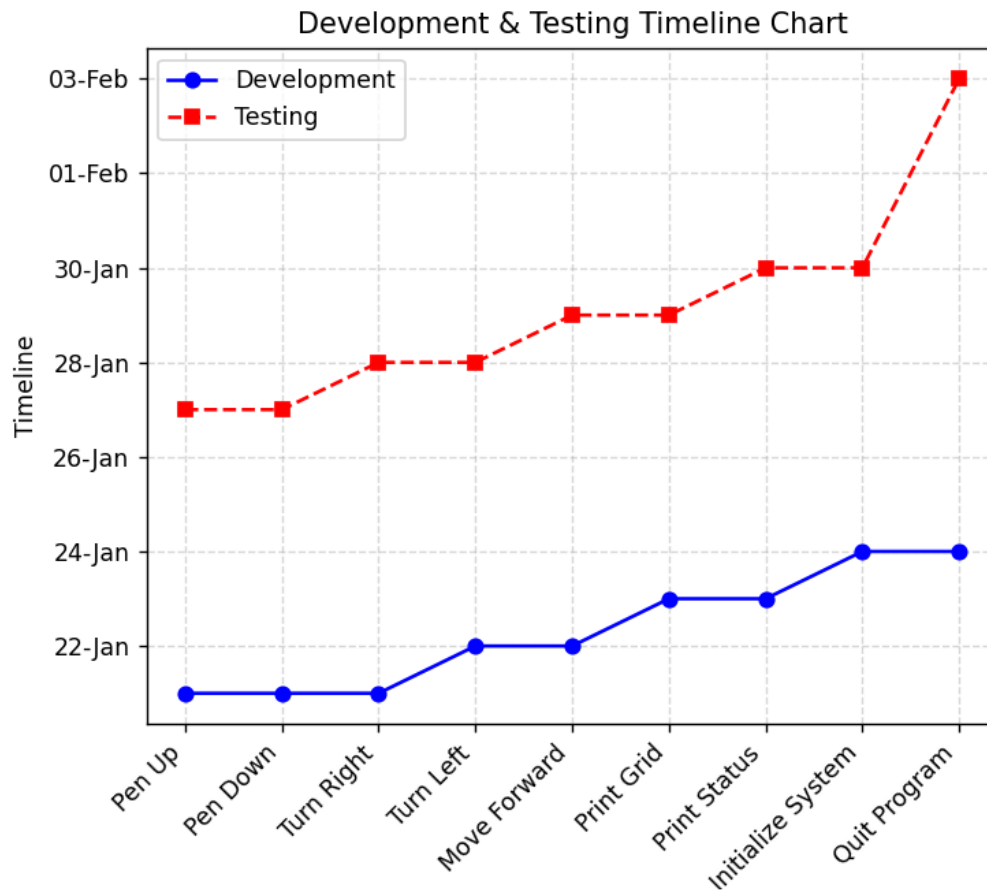
TEST CASE NAME	TEST CASE DESCRIPTION	TEST CASE RESULT PASS/FAIL
testValidMoveCommand()	Tests if the move command functions correctly.	PASS
testValidPrintStatusCommand()	Checks if the status printing command works as expected.	PASS
testValidHelpCommand()	Ensures that the help command provides the correct instructions.	PASS
testValidInitializeCommand()	Verifies that the system initializes properly.	PASS
testInvalidCommand()	Tests the behavior when an invalid command is given.	PASS
testValidTurnLeftCommand()	Checks if the left turn command executes correctly.	PASS
testValidQuitCommand()	Ensures that the quit command properly exits the system.	PASS
testValidPenDownCommand()	Tests if the pen-down command is functioning.	PASS
testValidPenUpCommand()	Verifies the pen-up command's correctness.	PASS
testValidPrintFloorCommand()	Ensures the floor printing function works as expected.	PASS
testValidTurnRightCommand()	Checks if the right turn command is implemented properly.	PASS
testValidHistoryCommand()	Tests if the command history feature functions correctly.	PASS



7. Project Timeline

FUNCTION	APPLICATION DEVELOPMENT TIME	TESTING CASE DEVELOPMENT TIME
Pen up	21/01/2025 (1 DAY)	27/01/2025 (1 days)
Pen down	21/01/2025 (1 DAY)	27/01/2025 (1 day)
Turn right	21/01/2025 (1 DAY)	28/01/2025 (1 day)
Turn left	22/01/2025 (1 DAY)	28/01/2025 (1 day)
Move forward s spaces	22/01/2025 (1 DAY)	29/01/2025 (1 day)
Print the grid	23/01/2025 (1 DAY)	29/01/2025 (1 day)
Print status	23/01/2025 (1 DAY)	30/01/2025 (1 day)
Initialize the system	24/01/2025 (1 DAY)	30/01/2025 (1 day)
Quit the program	24/01/2025 (1 DAY)	03/02/2025 (1 day)

8. Timeline Chart



9. Conclusion

In this project we have successfully developed and verified a robot control system that can follow commands like moving, turning, toggling the pen, and displaying the grid state. Through testing, we ensured the robot accurately updates its position, keeps the pen functionality in check, and properly reflects changes on the grid. The testing process confirmed that the system works reliably and correctly in different scenarios. This project highlights the use of test cases in ensuring accuracy, while also providing a strong base for future improvements.

10. AI Transparency

- **Used AI tools and details of the information gathered :**
We used AI tools to get some knowledge about our project and get some information about tests.
- **Tools used:**
 - 1) ChatGPT
 - 2) Deep seek

Prompts Used for Research:

- 1) How to resolve class not loading error in IntelliJ?
- 2) What should a help command contain for a command-driven application: exception handling?
- 3) What are the essential components of a system initialization function?
- 4) What are effective ways to manage invalid user input in a command-line application?
- 5) How can I provide meaningful feedback for invalid command: code?
- 6) How can I implement a drawing function using a pen-down command in a virtual environment?
- 7) How to generate User stories based on requirements?
- 8) I am making a robot controller testing project, can you give me an introduction and conclusion paragraph ?
- 9) I can structure file in Eclipse, but Main class does not load in IntelliJ, what are the changes I need to make to my file for code to run smoothly?

Contribution Sheet:

- 10.1 **Harshilsinh Solanki:** Code development: command parsing and Documentation.
- 10.2 **Vraj Shah(Scrum Master):** Development: Function generation and execution
- 10.3 **Teja Sayila:** Test case execution, verification and Documentation.
- 10.4 **Tanisha Fonseca:** Unit Test case development, verification and Documentation.
(Note: Scrum master would be rotated for each task)