

System Verification and Validation Plan for LiDart

Team 10

Jonathan Casella
Kareem Elmokattaf
Michaela Schnull
Neeraj Ahluwalia

November 1, 2022

1 Revision History

Date	Version	Authors	Notes
02/Nov/2022	1.0	Michaela Schnull Jonathan Casella Kareem Elmokattaf Neeraj Ahluwalia	Initial Release

Contents

1	Revision History	i
2	Symbols, Abbreviations and Acronyms	iv
3	General Information	1
3.1	Summary	1
3.2	Objectives	1
3.3	Relevant Documentation	1
4	Plan	2
4.1	Verification and Validation Team	2
4.2	SRS Verification Plan	2
4.3	Design Verification Plan	2
4.4	Verification and Validation Plan Verification Plan	3
4.5	Implementation Verification Plan	3
4.6	Automated Testing and Verification Tools	3
4.6.1	Rust	3
4.6.2	Rustfmt	3
4.6.3	Autodesk Inventor	4
4.6.4	EAGLE	4
4.7	System Validation Plan	4
4.7.1	Accurate 3D Scanning	4
4.7.2	Low Cost Hardware	4
4.7.3	Ease of Use	4
5	System Test Description	5
5.1	Tests for Functional Requirements	5
5.1.1	Area of Testing1	5
5.1.2	Area of Testing2	7
5.2	Tests for Nonfunctional Requirements	8
5.2.1	Usability Testing	8
5.2.2	Area of Testing2	10
5.3	Traceability Between Test Cases and Requirements	10
6	Unit Test Description	11
6.1	Unit Testing Scope	11
6.2	Tests for Functional Requirements	11
6.2.1	Module 1	11
6.2.2	Module 2	11
6.3	Tests for Nonfunctional Requirements	11
6.3.1	Module ?	11
6.3.2	Module ?	12
6.4	Traceability Between Test Cases and Modules	12

7	Appendix	14
7.1	Symbolic Parameters	14
7.2	Usability Survey Questions?	14

List of Tables

1	Team Member Roles	2
2	Requirements Dependency Matrix	10

List of Figures

2 Symbols, Abbreviations and Acronyms

symbol	description
CAD	Computer Aided Design
DRC	Design Rule Check
ERC	Electrical Rule Check
GUI	Graphical User Interface
HA	Hazard Analysis
LiDAR	Light Imaging, Detection, and Ranging
MG	Module Guide
MIS	Module Interface Specification
SLAM	Simultaneous Localization and Mapping
SRS	System Requirements Specification
V&V	Verification and Validation
T	Test
TA	Teaching Assistant

This document presents a verification and validation plan for the LiDart system. It will be used to establish verification and testing procedures and create a plan to determine if LiDart meets its goals as defined in the Problem Statement and Goals document.

The remainder of this document is structured as follows:

- **Section 3** provides background information about the LiDart system which will be subject to verification and validation activities. It also outlines the objectives of this plan and lists relevant documents.
- **Section 4** defines the verification and validation team roles and responsibilities. It presents verification methodologies and tools that will be used.
- **Sections 5 and 6** define what will be tested, and provide specific test cases. Furthermore, traceability matrices are provided to link test cases to requirements.

3 General Information

3.1 Summary

LiDart is a low cost, simple to use, 3D scanning robot. The LiDart system uses low cost LiDAR sensors, consumer grade web cams, and inexpensive location markers. The user interfaces with the robot through GUI that allows them to remotely drive the robot and perform 3D scans.

3.2 Objectives

The purpose of this document is to create a plan to demonstrate that LiDart satisfies requirements as specified in the SRS and meets the goals of the project. This includes following objectives:

- Validate that the LiDart system meets its goals
- Create a plan to assess if the LiDart system is in conformance with both functional and non-functional requirements as specified in the SRS
- Identify the methodologies, tools, and equipment that will be used to perform V&V activities
- Create test cases to execute the V&V plan

3.3 Relevant Documentation

Project documentation such as the SRS and design documents are referred to throughout the V&V plan. Relevant documents are included below for reference.

- System Requirements Specification (SRS) [1]
- Problem Statement and Goals [2]
- Module Interface Specification (MIS) [3]
- Module Guide (MG) [4]
- Hazard Analysis (HA) [5]

4 Plan

This section introduces methods and techniques used to verify design requirements and provides a high-level plan to validate the LiDart system.

4.1 Verification and Validation Team

Table 1 summarizes the roles and responsibilities of the verification and validation team.

Table 1: Team Member Roles

Team Member	Roles and Responsibilities
Jonathan Casella	<ul style="list-style-type: none">- Software testing lead- Implementation of automated software testing methods- Design review lead
Michaela Schnull	<ul style="list-style-type: none">- Verification of project documents including the SRS and V&V plan- Reporting of verification and validation activities- Printed circuit board verification
Kareem Elmokattaf	<ul style="list-style-type: none">- Responsible for the design and execution of testing procedures- Maintenance of records documenting results from testing activities- Code verification
Neeraj Ahluwalia	<ul style="list-style-type: none">- Preparation and maintenance of testing equipment- Hardware verification
Independent Reviewers (i.e. Teaching Assistant)	<ul style="list-style-type: none">- Quality assurance and independent review

4.2 SRS Verification Plan

The SRS will be verified to ensure that requirements are complete, unambiguous, and meet the goals of the LiDart system. The following methods shall be used to verify the SRS:

- Verify that the SRS follows the SRS checklist [6]
- Review from all team members using GitHub pull request reviews
- Independent review from the TA and classmates

4.3 Design Verification Plan

The design of the LiDart system will be verified throughout development to ensure the system meets specifications and functions as intended. The following methods shall be used to verify the design:

- Hold internal design reviews before the proof of concept demo and prior to manufacturing of the system for Revision 0 and Revision 1 project phases
- Perform a failure modes and effects analysis

- Independent review from teaching assistants and classmates
- Verify that the design documentation follows the MIS [7] and MG [8] checklists

4.4 Verification and Validation Plan Verification Plan

The V&V plan will be verified to ensure that the plan to verify and validate the LiDart system is complete and feasible. The following methods shall be used to verify the V&V plan:

- Independent review from the TA and classmates
- Review from all team members using GitHub pull request reviews
- Verify that the V&V plan follows the V&V plan checklist [9]

4.5 Implementation Verification Plan

The implementation verification plan will be used to ensure the LiDart system meets all requirements as specified in the SRS. Verification methods that will be used include review, analysis, demonstration, and testing.

- **Review:** Review can be used when meeting a requirement is evident to a trained observer. Review of engineering drawings, code, or the physical device may be used. Techniques include code walk-throughs, code inspection, and drawing reviews.
- **Analysis:** Analysis can be used to verify design requirements where physical testing is not necessary, for example through mathematical and computer modeling. Analysis of data obtained through testing may be used to verify requirements. This verification method must be conducted by qualified individuals.
- **Demonstration:** Demonstration can be used to show that the system functions as intended. Unlike testing, demonstration does not require further analysis to determine if the system meets a requirement.
- **Testing:** Testing can be used to verify the behaviour of the system. Testing is conducted in a controlled environment with defined inputs and outputs. Test results must be analyzed to determine if tests pass or fail. Techniques that will be used include unit testing, automated testing, regression testing, and integration testing.

Section 5 specifies system test cases and Section 6 specifies unit test cases.

4.6 Automated Testing and Verification Tools

4.6.1 Rust

Software for the LiDart project will be written in Rust, which natively includes testing facilities. The testing facilities built into Rust are explained in chapter 5 of the rustc book [10].

4.6.2 Rustfmt

The primary linter for Rust is Rustfmt. Rustfmt will be used to ensure a consistent programming style across all contributors.

4.6.3 Autodesk Inventor

LiDart's CAD suite of choice, Autodesk Inventor, will be used to ensure no mechanical conflicts exist in the design prior to manufacturing and assembly. This will be done by first modeling the LiDart robot in Autodesk Inventor then using tools within Inventor to detect any collisions or interpenetrating components.

4.6.4 EAGLE

Printed circuit board design will be done in EAGLE, which has built-in error checking tools. ERC (Electrical Rule Check) will be used to test schematics for electrical errors. DRC (Design Rule Check) will be used to ensure there are no board layout errors.

4.7 System Validation Plan

This section lays out a series of validation exercises that will be performed before the system is deemed suitable for general users. The following exercises are designed to test the 3 major goals set out in the problem statement.

4.7.1 Accurate 3D Scanning

To validate the accuracy of the 3D scans a test environment will be constructed and scanned. Said test environment will have objects with known shapes at predetermined positions. The resulting 3D scan will be compared against the expected values for the test environment. If the point cloud matches the expected result within some tolerance this validation exercise will be deemed complete.

4.7.2 Low Cost Hardware

To validate that the goal of low cost, easily accessible hardware was met two exercises will be performed.

The first exercise will be to compare LiDart's price to other options in the market with equivalent features and comparable build quality. LiDart's price should fall below the median price of the existing solutions.

The second exercise will be to evaluate the accessibility of the hardware used by LiDart. During this exercise a list of alternative hardware components will be created for all major components of the LiDart system (e.g. motor controller, motors, cameras). This exercise will be deemed complete when all major components have at least one alternate part listed.

4.7.3 Ease of Use

To validate LiDart's ease of use a focus group will be used. The focus group will consist of subjects with no prior knowledge of the system. Each member of the focus group will be provided with the user manual then asked to scan an object. The time required to complete the scan and the percentage of successful subjects will be used to determine the success of this exercise.

Usability survey questions

5 System Test Description

5.1 Tests for Functional Requirements

5.1.1 Area of Testing1

Title for Test

1. R1T

Initial State: Nothing has been sent to the robot to output

Input: Arrow key movement (example: right arrow key)

Output: Robot moves in the direction specified (example: to the right)

How test will be performed: The robot will be given a series of inputs from the keyboard such as Right, Left and forward. The robot will then be observed and make sure that it follows the motions specified. This will verify that the robot is taking the input from the user as specified

2. R2T

Initial State: Robot is operating normally

Input: Emergency stop button is pressed

Output: Robot should completely shut down

How test will be performed: Inputs will be sent to the robot and the robot should not action any of them. So the inputs can be movement (left, right and forward) or it can be to scan the object.

3. R3T

Initial State: Robot is stationary

Input: From the control, there will be input specified to move the robot forward, backwards, left and right

Output: Robot should move in all specified directions

How test will be performed: Inputs will be sent to the robot and the robot should operate accordingly. The robot should move forward, backward, and rotate left and right.

4. R4T

Initial state: Robot is stationary

Input: No inputs are given to the robot

Output: Robot does not move or do any functions

How test will be performed: Robot will be left without any inputs given to it and its behaviour will be monitored/observed

5. R5T

Initial state: Robot is stationary

Input: Through a remote device connected over the internet, there will be commands given to the robot (example: Move left and Scan)

Output: Robot should move left and then start scanning

How test will be performed: Robot will be remotely connected to a control source and the robot will then be given commands from the control source and the actions of the robot will

be observed

6. R6T

Initial state: Robot will be idle (TO BE REVIEWED)

Input: Through the internet connection established, parameters will be sent to the robot (example: robot status)

Output: Robot will respond over wifi connection with the robot status

How test will be performed: Over a wifi connection a control will send certain parameters to the robot and the expected output should be received from the robot

7. R7T

Initial state: Robot is currently operating

Input: Robot switch will be flicked to go from "On" to "Off"

Output: Robot should power down and not have any power

How test will be performed: Robot will be powered on working. After confirming that the robot is powered on and performing actions, the robot's switch will be flicked to off and the robot should turn off

8. R8T

Initial state: Robot battery is low

Input: Robot battery will be connected to a battery charger

Output: Robot battery percentage should start increasing

How test will be performed: Robot will have a low battery. The battery will then be connected to a charger and tester will observe as the battery percentage increases on the GUI.

9. R9T

Initial state: Robot is operating without having scanned anything

Input: Robot scan

Output: Output from the robot to the remote connection will be the scans coming from the LiDAR sensor

How test will be performed: Robot will be placed close to an object and instructed to scan the object. The tester will then observe the output from the robot on the remote connection.

10. R10T

Initial state: Robot uncalibrated

Input: Landmarks in the surrounding and the instruction to calibrate the position of the robot

Output: Coordinate of the robot in comparison to the landmarks

How test will be performed: Landmarks will be placed a specific distance away from the robot at a specific orientation. The robot will be asked to calibrate. The tester will verify the measurements from the robot and verify that they are correct

11. R11T

Initial state: Robot has scanned an object

Input: User identifies that they are done scanning and what to see the results

Output: Robot will send the output file to the remote connection

How test will be performed: (TO BE REVIEWED) Robot will have files preinstalled and then asked to communicate them in the same that they will communicate the results of the scan.

Those files will be verified to be correct and uncorrupted

12. R12T

Initial state: Robot moving with the camera installed

Input: User moving the robot around

Output: Live feed from the camera onto the remote connection

How test will be performed: Tester will place different objects in front of the robot and watch them change on the live feed on the GUI

13. R13T

Initial state: Robot scanning the object

Input: User continuing the scan of an object

Output: Current information on the scan. The current 3D scan model of the scan

How test will be performed: Tester will observe as the scan is happening and look at the output on the GUI from the robot. The tester will be able to confirm that the scan is coming as the robot is scanning

14. R14T

Initial state: Robot is ready to scan

Input: User asking for the current state of the robot

Output: Robot outputs that it is ready to scan

How test will be performed: Robot will be put in different states (Idle, ready to scan, etc..) and then asked to output the state to the GUI. The tester will be able to confirm that the output is matching what is expected

15. test-id2

Control: Manual versus Automatic

Initial State:

Input:

Output:

Test Case Derivation:

How test will be performed:

5.1.2 Area of Testing2

...

5.2 Tests for Nonfunctional Requirements

5.2.1 Usability Testing

Title for Test

1. test-id1

2. NFR10

Verification Method: Testing

Initial State: Robot is fully assembled

Input: n/a

Output: The robot must weight less than ROBOT_MAX_WEIGHT.

How test will be performed: The robot shall be weighed on a scale. The weight of the robot and the accuracy of the measuring device must be recorded.

3. NFR11

Verification Method: Testing

Initial State: Robot is fully assembled

Input: n/a

Output: The robot dimensions must be less than ROBOT_MAX_DIM.

How test will be performed: The robot dimensions (length x width x height) shall be measured with a measuring tape. The robot dimensions and the accuracy of the measuring device must be recorded.

4. NFR12

Verification Method: Review

Initial State: The GUI main page is open

Input: n/a

Output: n/a

How test will be performed: Each page will be navigated to from the main screen. The number of navigation levels will be recorded for each page. It must take less than MAX_NUM_LEVELS to navigate to any page on the application

5. NFR13

Verification Method: Review

Initial State: The GUI main page is open

Input: n/a

Output: n/a

How test will be performed: A qualified individual will review the website to ensure all text is

consistent, has a minimum font size of MIN_FONT_SIZE, and is sans-serif.

6. NFR9

Verification Method: Testing

Initial State: The robot is powered-on and connected to the GUI through WiFi

Input: Module Guide document

Output: At least 9/10 users with no prior knowledge of the system are able to successfully drive the robot, perform a scan, and save the scan data

How test will be performed: A usability test shall be performed. Users will be given the Module Guide and instructed to drive the robot, perform a scan, and save the scanned data. user manual.

7. NFR14, NFR12, NFR9

Verification Method: Usability Survey

Initial State:

Input:

Output:

How test will be performed:

8. NFR15

Verification Method: Testing

Initial State: The robot is powered-on and connected to the GUI through WiFi

Input: User begins scanning and then attempts to move the robot

Output: Error message stating the robot cannot move until scanning is complete

How test will be performed:

9. NFR20, NFR21

Verification Method: Testing

Initial State: The GUI application is installed

Input: Open the application

Output: The application must run without crashing or performance issues

How test will be performed: The application will run on a computer with the specifications IntelCore i5 processor and 8 GB of RAM or equivalent.

10. NFR22

Verification Method: Review

Initial State: The robot is fully assembled

Input: n/a

Output: n/a

How test will be performed: A qualified individual shall inspect the robot to ensure there is no exposed wiring.

11. NFR25

Verification Method: Review

Initial State: The robot is fully assembled

Input: n/a

Output: n/a

How test will be performed: A qualified individual shall inspect the robot to ensure it is in conformance with CSA 22.1:21 (Canadian Electrical Code) [11] and CSA Z434 (Industrial robots and robot systems) [12]

5.2.2 Area of Testing2

...

5.3 Traceability Between Test Cases and Requirements

Table 2: Requirements Dependency Matrix

	RT1	RT2	RT3	RT4	RT5	RT6	RT7	RT8	RT9	RT10	RT11	RT12	RT 13	RT14
R1	X													
R2		X												
R3			X											
R4				X										
R5					X									
R6						X								
R7							X							
R8								X						
R9									X					
R10										X				
R11											X			
R12												X		
R13													X	
R14														X

6 Unit Test Description

6.1 Unit Testing Scope

6.2 Tests for Functional Requirements

6.2.1 Module 1

1. test-id1

Type:

Initial State:

Input:

Output:

Test Case Derivation:

How test will be performed:

2. test-id2

Type:

Initial State:

Input:

Output:

Test Case Derivation:

How test will be performed:

3. ...

6.2.2 Module 2

...

6.3 Tests for Nonfunctional Requirements

6.3.1 Module ?

1. test-id1

Type:

Initial State:

Input/Condition:

Output/Result:

How test will be performed:

2. test-id2

Type: Functional, Dynamic, Manual, Static etc.

Initial State:

Input:

Output:

How test will be performed:

6.3.2 Module ?

...

6.4 Traceability Between Test Cases and Modules

References

- [1] N. Ahluwalia, J. Casella, K. Elmokattaf, and M. Schnull, “Software requirements specification,” 2022.
- [2] J. Casella, “Problem statement and goal,” 2022.
- [3] N. Ahluwalia, J. Casella, K. Elmokattaf, and M. Schnull, “Module interface specification,” 2022.
- [4] N. Ahluwalia, J. Casella, K. Elmokattaf, and M. Schnull, “Module guide,” 2022.
- [5] M. Schnull and K. Elmokattaf, “Hazard analysis,” 2022.
- [6] S. Smith, “SRS and CA checklist,” 2022.
- [7] S. Smith, “MIS checklist,” 2022.
- [8] S. Smith, “MIS checklist,” 2022.
- [9] S. Smith, “System verification and validation plan checklist,” 2022.
- [10] Rust Programming Language, *Testing*. <https://doc.rust-lang.org/rustc/tests/index.html>.
- [11] CSA Group, “CSA C22.1:21 Canadian electrical code, part I (25th edition), safety standard for electrical installations,” tech. rep., 2021.
- [12] CSA Group, “CAN/CSA-Z434-14 Industrial robots and robot systems (adopted ISO 10218-1:2011, second edition, 2011-07-01, with Canadian deviations and ISO 10218-2:2011, first edition, 2011-07-01, with Canadian deviations),” tech. rep., 2019.

7 Appendix

7.1 Symbolic Parameters

The definition of the test cases will call for SYMBOLIC_CONSTANTS. Their values are defined in this section for easy maintenance.

7.2 Usability Survey Questions?

Appendix — Reflection

The information in this section will be used to evaluate the team members on the graduate attribute of Lifelong Learning. Please answer the following questions:

1. What knowledge and skills will the team collectively need to acquire to successfully complete the verification and validation of your project? Examples of possible knowledge and skills include dynamic testing knowledge, static testing knowledge, specific tool usage etc. You should look to identify at least one item for each team member.
2. For each of the knowledge areas and skills identified in the previous question, what are at least two approaches to acquiring the knowledge or mastering the skill? Of the identified approaches, which will each team member pursue, and why did they make this choice?