Preliminary Design Review

A Preliminary Design Review of the robotic system design project submitted to
The University of Manchester for the degree of
Master of Science in Robotics
in the Faculty of Science and Engineering

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Declaration of originality

I hereby confirm that this dissertation is my own original work unless referenced clearly to the contrary, and that no portion of the work referred to in the dissertation has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Intellectual property statement

1 Introduction

1.1 Problem Statement

Design and develop an autonomous robot to retrieve a target object within an unmapped static room to enhance efficiency and safety in tasks requiring autonomous object retrieval.

1.2 Objectives

- Establish a Robust Simulation Framework: Develop proficiency in utilizing the Gazebo simulator and RViz visualization tools, employing the provided manipulator and Leo Rover files. Ensure a comprehensive understanding of the simulation environment by thoroughly reviewing associated README files.
- Integrate Sensor Data for Monitoring and Analysis: Connect various rover feeds, including camera, odometry, and map topics, to RViz for real-time monitoring and analysis. Emphasize the critical role of sensor data in both teleoperation and autonomous navigation.
- Implement SLAM Algorithms for Mapping: Initiate Simultaneous Localization and Mapping (SLAM) algorithms during teleoperation to map the unknown workspace. Analyze the impact of obstacles, evaluate different mapping algorithms, and conduct a comparative study to inform the selection of the most effective approach.
- Transition to Autonomous Navigation: Progress from teleoperation to autonomous navigation using a SLAM-based approach. Conduct extensive tests to fine-tune navigation stack parameters, considering the specific structure and sizing of the Leo Rover in relation to the unmapped static room.
- Facilitate Iterative Optimization: Engage in an iterative process of testing and optimizing various parameters within the navigation stack. Adapt code based on the unique features of the Leo Rover and the unmapped static room to continually enhance the performance of the autonomous navigation system.
- Explore and Modify Model Files for Versatility: Demonstrate flexibility and exploration by modifying model files to test scenarios beyond the customer's requirements. Ensure adaptability to unforeseen challenges and a proactive approach to refining the system.
- Validate Secondary Libraries for Additional Functionality: Incorporate additional components like the px150 robotic arm, depth camera, and LiDAR for autonomous traversal and object retrieval.
- Utilize Simulation for Baseline Verification: Leverage the simulation as a baseline to verify algorithms and approaches. Ensure the readiness of the system by validating its performance in a controlled environment closely resembling a similar unmapped static room.

- Holistic Preparation for Tasks: Address both primary (navigation) and secondary (object retrieval) tasks within the simulation environment. Conduct thorough tests, including path planning algorithms and various odometry source combinations, to ensure a comprehensive and well-prepared system.
- Document and Analyze Simulation Results: Maintain detailed documentation of simulation tests, results, and observations. Analyze the outcomes to inform further refinements, and utilize the simulation as a valuable tool for continuous improvement in preparation for real-world applications.

2 System

2.1 System Components

1. Leo Rover:
   - Type: Base Rover
   - Function: Felicitates traversal in the unmapped environment
2. Battery Power Box:
   - Type: Lithium-ion battery pack
   - Function: Provides the electrical power required to operate the robotic arm and its components
   - Specifications: 11.1V DC, 8A
   - Capacity: 5000 mAh
3. Intel NUC Computing Module:
   - Type: Intel NUC mini PC
   - Function: Serves as the central processing unit (CPU) of the robotic arm, handling sensor data processing, control algorithm execution, and communication with external devices
   - Specifications: Intel Core i5 processor, 4GB RAM, 500GB SSD
4. RPLiDAR A2M12 LiDAR Sensor:
   - Type: 2D laser rangefinder (LiDAR) sensor
   - Function: Provides accurate distance measurements to surrounding objects, enabling obstacle avoidance and navigation
   - Specifications: 360-degree scanning range, 20cm-16m detection range
5. PX150 Robotic Manipulator:

- Type: 5-axis robotic arm
- Function: Executes manipulation tasks (object retrieval), including grasping, moving, and placing objects
- Specifications: 5 degrees of freedom (DOF), 0.45m reach, 0.05kg payload

6. Intel Realsense Depth Camera:

   - Type: RGB-D stereo camera
   - Function: Captures both depth and RGB information, enhancing object recognition and manipulation capabilities
   - Specifications: Depth resolution of 1280x720, RGB resolution of 1920x1080

2.2 System Interactions

1. The battery power box provides power to all system components.
2. The Intel NUC computing module processes sensor data robot's IMU and RPLiDAR A2M12 LiDAR sensor, generates control commands and communicates with the PX150 robotic manipulator and Intel Realsense Depth Camera to identify and grasp a target object.
3. The RPLiDAR A2M12 LiDAR sensor provides distance measurements to the Intel NUC computing module for obstacle avoidance and navigation.
4. The PX150 robotic manipulator executes control commands received from the Intel NUC computing module to perform manipulation tasks.
5. The Intel Realsense Depth Camera provides depth and RGB information to the Intel NUC computing module for enhanced object recognition and manipulation (object retrieval task).

2.3 System Block Diagram

As observed from Fig.1 the Leo Rover robotic arm system combines sensor data acquisition, data processing, control algorithm execution, and robotic manipulation to achieve its primary objective of performing grasping, moving, and placing objects in a controlled manner. The system's components work together seamlessly to enable precise and efficient object retrieval tasks.

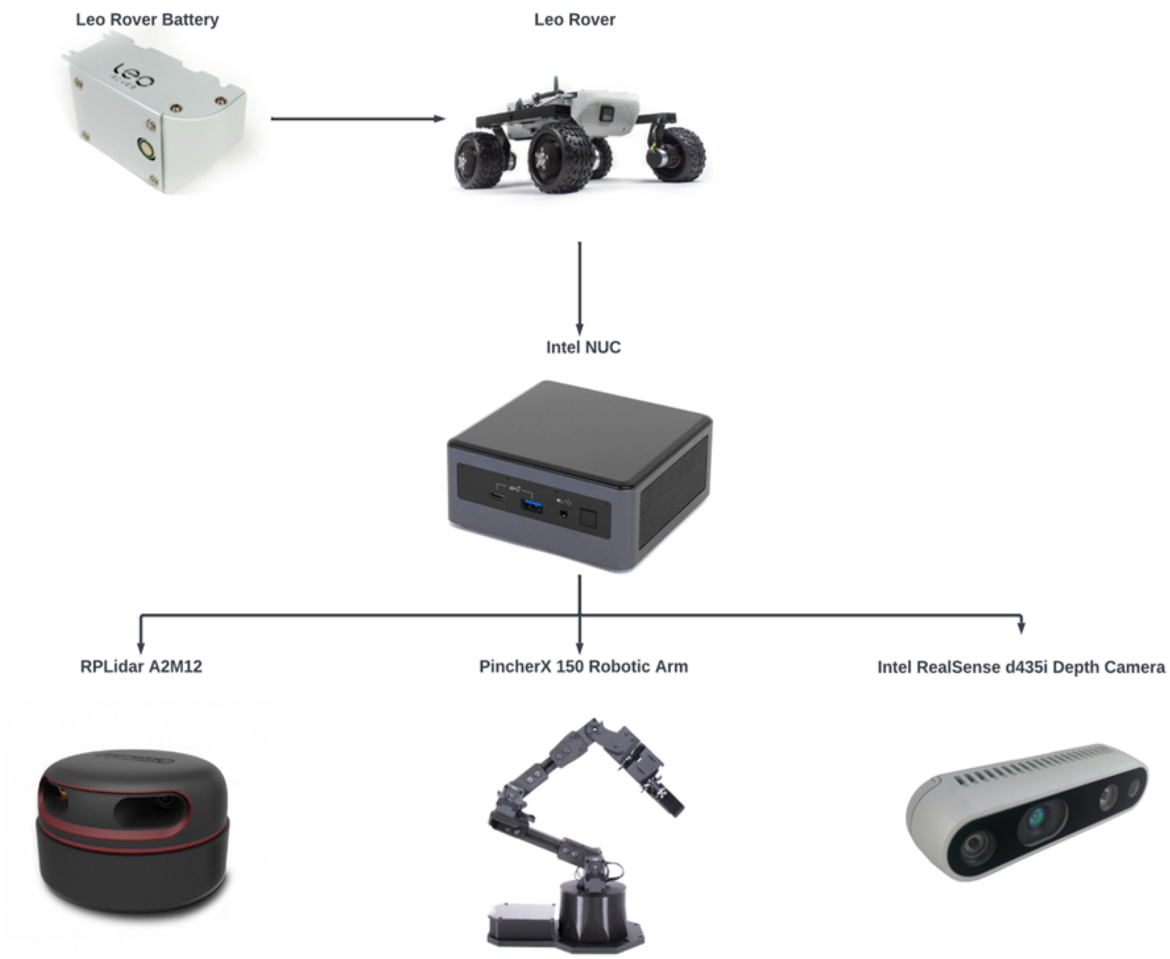


Fig. 1. System Block Diagram

3 Mechanical Design

3.1 3D CAD Model

The Robot payload sleds were designed such that the Manipulator is elevated above the LiDAR using four 3D-printed pillars. This will allow the LiDAR to have a clear front view while the back view will only be slightly obstructed by the pillars. As the two front pillars are closer to the LiDAR, their width was designed to be smaller than the back pillars to reduce the LiDAR's blind spots. Fig.2 below shows the main design configuration for the payload sleds.

The base platform consists of two separate plates that will be joined together after laser-cutting to make the manufacturing process easier. The first plate will be used to make the surface of the robot leveled as well as to secure the four pillars using 2 mm screws. The second layer has four slots for the pillar to rest in to provide stability for the structure and prevent the pillars from moving or shifting while the robot is in operation. Fig.3 below shows the different components of the base plate.

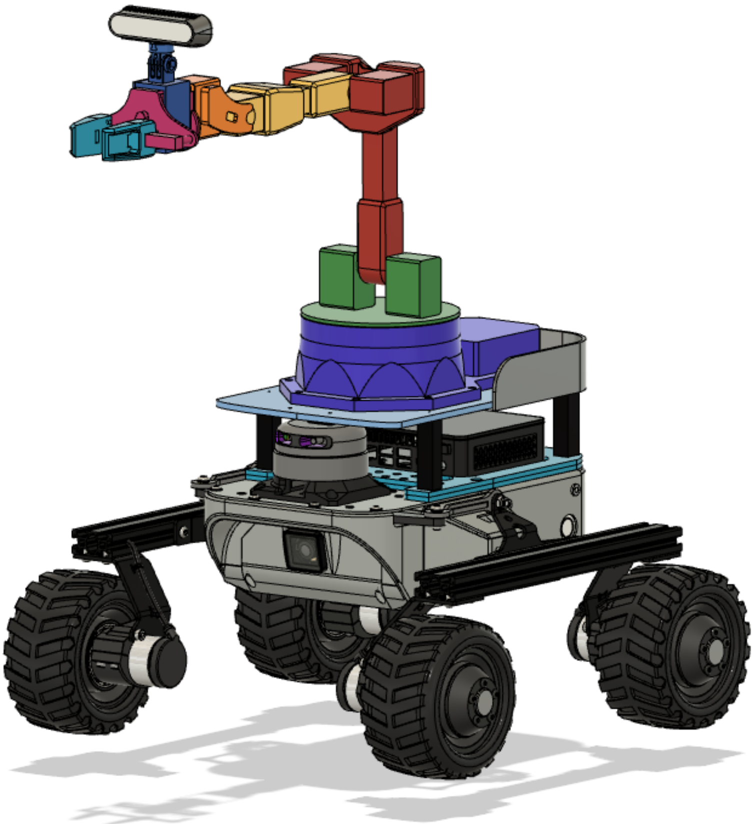


Fig. 2. CAD model of Robot with the payload sleds.

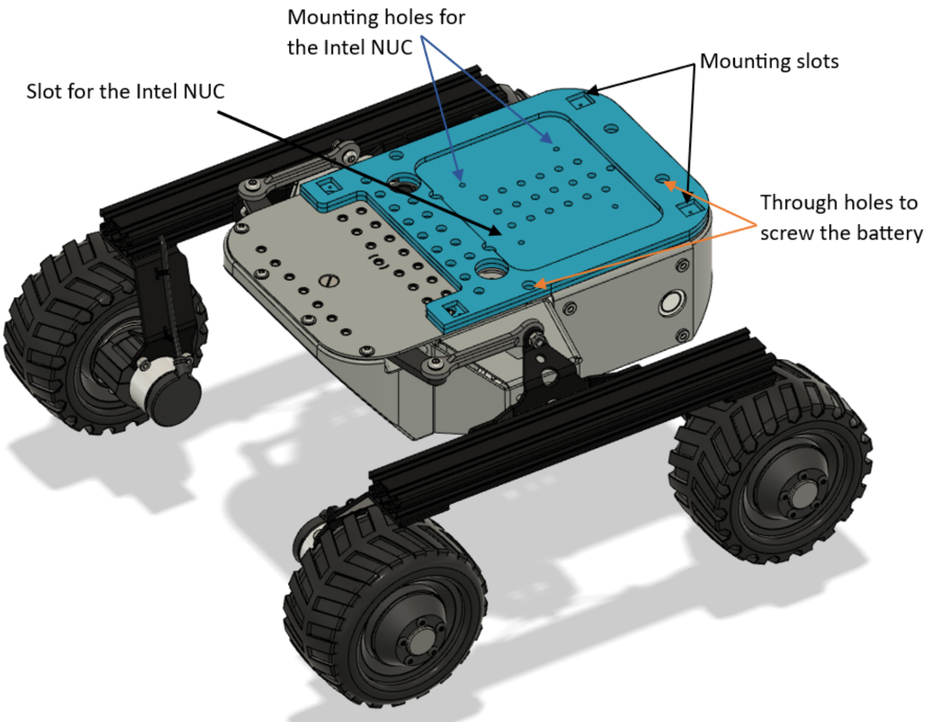


Fig. 3. CAD model of the base plate mounted on the robot.

A second platform is placed on top of the pillars for the Manipulator to rest on, it has a 40 mm edge that can be attached to act as a storage for the blocks while keeping the whole design symmetrical. The edge will also be laser-cut from a piece of acrylic and bent using heat to match the outer profile of the upper platform. The main aim was to make the payload sled modular and repairable, and therefore, two camera mountings for the real-sense depth camera were designed. The first camera mount, which is the main approach, is designed to be attached to the Manipulator as shown in Fig.4 below. This design allows the camera to move freely using the Manipulator so that the camera can scan the environment and the target object can be detected without the need for the robot to turn. The camera mount also has marks of different angles so that the camera tilting angle can be changed when needed to allow for testing and improvement (with different camera view angles).

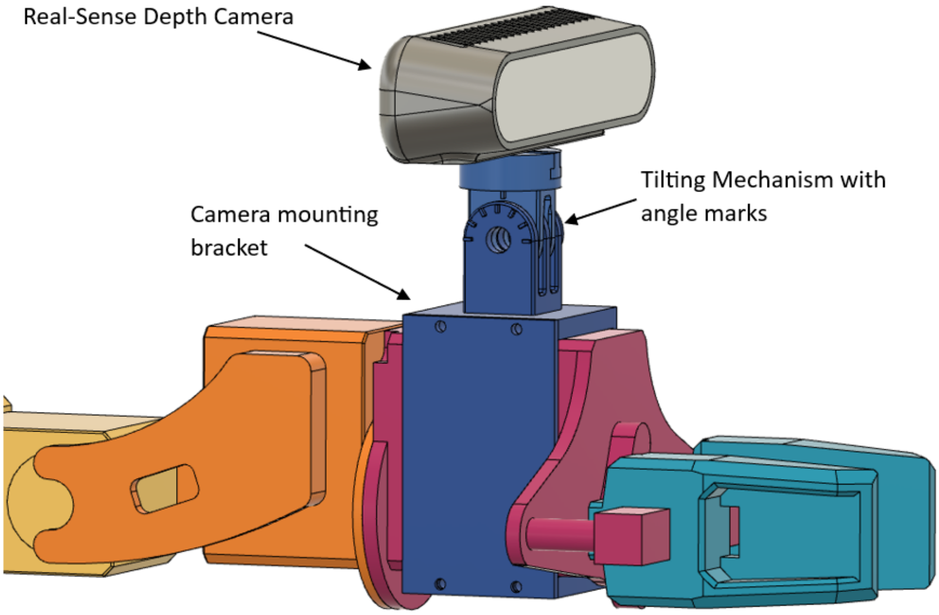


Fig. 4. Depth camera mount attachment for the Manipulator.

The upper platform has mounting holes for a camera holder if it is decided to make the depth camera fixed in place and it can be mounted at the edge of the platform. Therefore, the top part of the camera holder can be repurposed and used in either the Manipulator or fixing it on the platform. Additionally, the Intel NUC will mounted on the base platform to make the design compact, however, if it is found that the NUC or its wiring may obstruct the view of the LiDAR, a separate case was designed to be placed at the back of the robot and attached to the second layer of the base platform using L shaped metal brackets as illustrated in Fig.5 below.

The LiDAR mount was imported from the Leo Rover website under the name of (07010 RPLiDAR A2M8 adapter)[1].

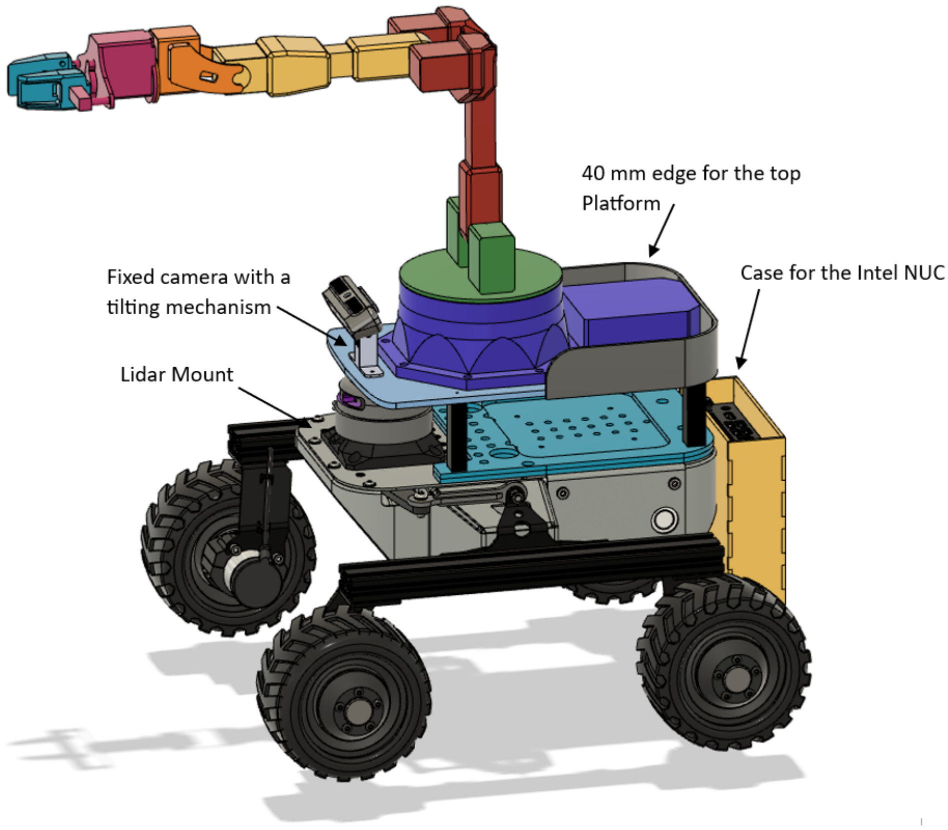
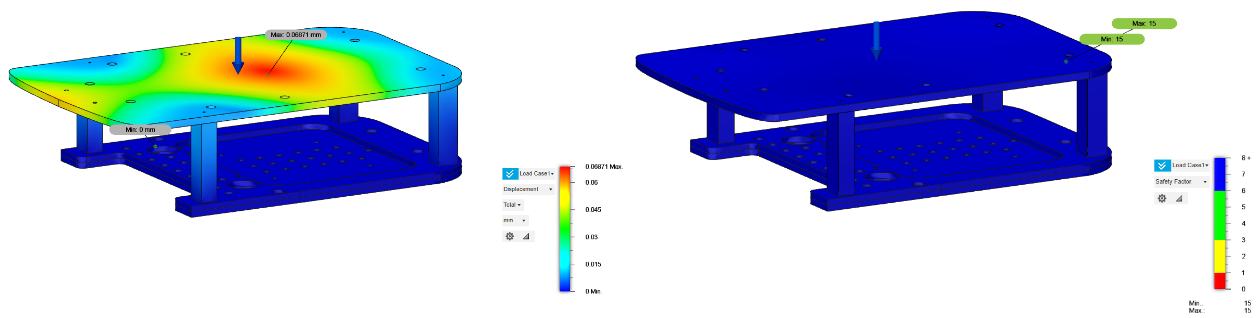


Fig. 5. The second configuration of the payload sleds.

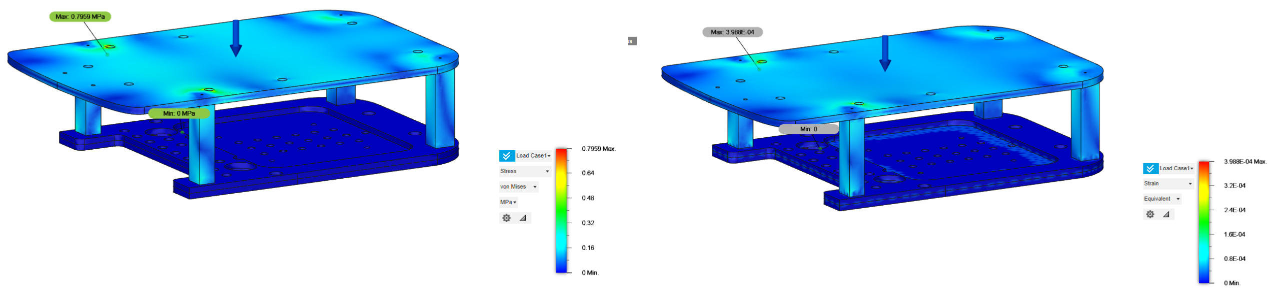
3.2 Stress Analysis

A stress analysis test was performed on the designed platform (payload sleds) to analyse how it might perform under real-life conditions and to predict any failures that might occur. Based on the manipulator and the depth camera weight in addition to the other designed components, a total of 1.85 kg or (18.142 N) was applied to the upper platform and simulated in Autodesk Fusion 360 CAD software as shown in Fig.6 and Fig.7 below. the martial of the plates was assigned as Acrylic whereas the pillars' martial was assigned as ABS plastic for 3D printing.



(a) Displacement **(b)** Safety factor

Fig. 6. Stress analysis results (displacement & safety factor)



(a) Stress **(b)** Strain

Fig. 7. Stress analysis results(Stress & Strain)

The stress analysis showed that the payload sled will be able to withstand the weight of the manipulator and the other sensors without any notable deformation, as Fig.6 above shows, the upper plate has a safety factor between 6 and 8 as well as a maximum displacement of 0.0687 mm.

The upper plate experiences a maximum stress of 0.7959 MPa and a maximum strain of 3.988 E-04 as shown in Fig.7.

3.3 Mechanical Drawing

The mechanical drawings of the Robot with the payload sleds as well as the base and upper platforms supported by the four pillars are shown in Fig.8 and Fig.9 respectively.

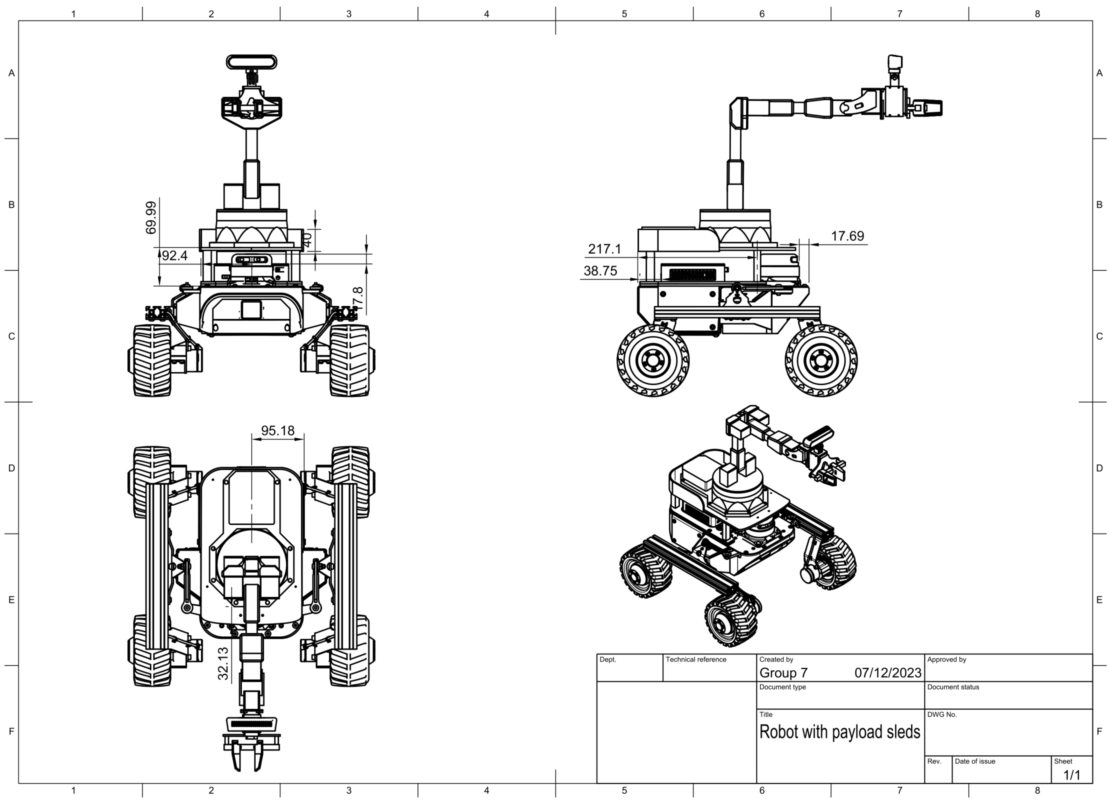


Fig. 8. Mechanical drawings of the Robot with the payload sleds

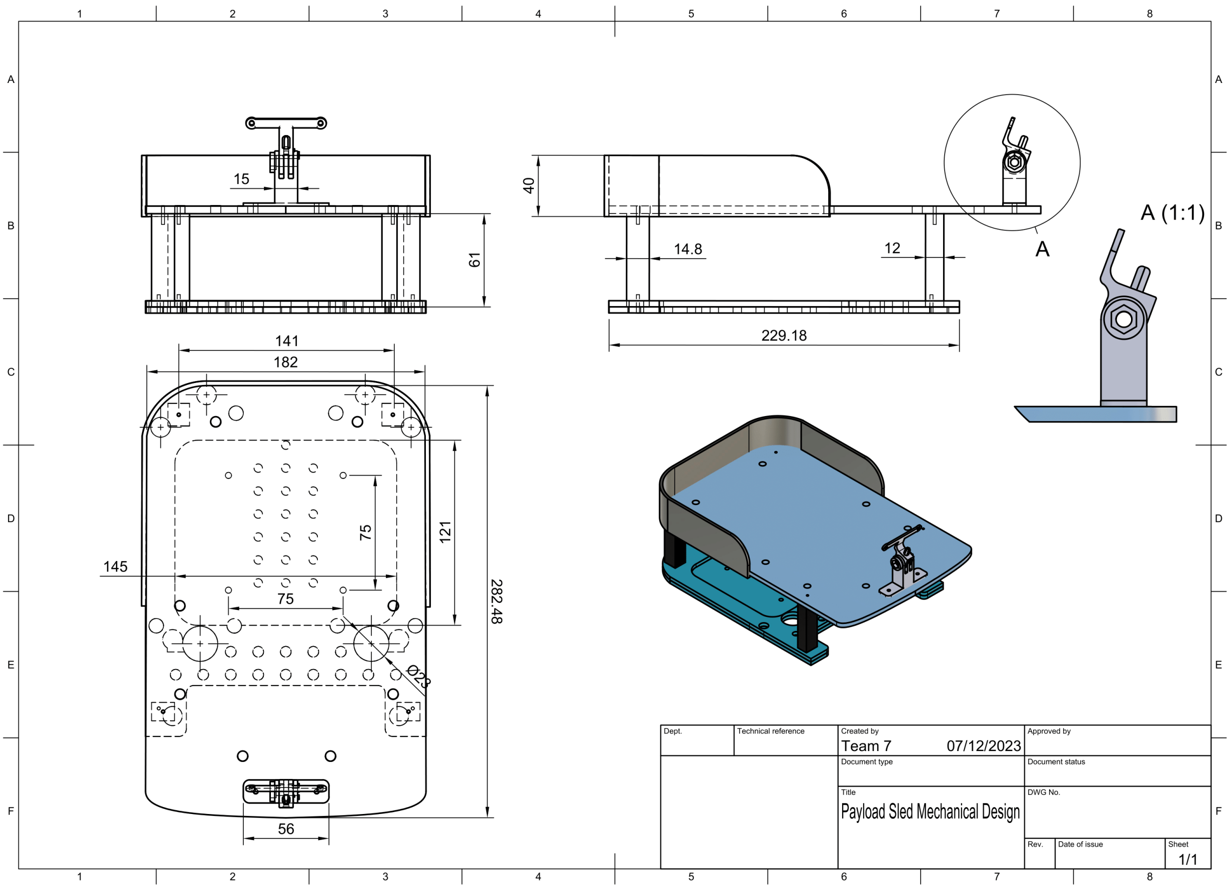


Fig. 9. Mechanical drawings of the payload sled platform

As for the mechanical drawings of the depth camera mount and the NUC Case, refer to Appendix C.

4 Electrical Design

The power connection diagram for the Leo Rover robotic system illustrates the distribution of electrical power across different components. It depicts the connections between the power sources, including the 11.1V Li-Ion battery, the PowerBox, and the various power-consuming devices, such as the Intel NUC, the Raspberry Pi, the robot arm, the LiDAR, the depth camera and the fisheye camera.

Power Sources:

1. 11.1V Li-Ion Battery: The primary power source for the Leo Rover is the 11.1V Li-Ion battery, which in turn supplies power to the PowerBox.
2. PowerBox: The PowerBox acts as the central power distribution unit, regulating the voltage and current from the 11.1V Li-Ion battery and providing power to the various components through either the 12V or 5V DC sockets.

Power Distribution and Data Transfer:

1. Intel NUC: The Intel NUC receives power from the Leo Rover’s PowerBox. The NUC takes in data from the rover, the manipulator, the LiDAR and the depth camera.

2. Raspberry Pi 4B: The Raspberry Pi 4B draws power from the LeoCore Controller through its GPIO pins. An RJ45 cable (Ethernet) is connected to the Intel NUC for the Raspberry Pi to publish the robot topics to the Intel NUC.

3. Robot Arm: The PincherX 150 Robot Arm receives power from the PowerHub Board which is connected to the Leo rover’s PowerBox. The ROBOTIS U2D2 Controller is used to send and receive data from the NUC and the arm.

4. LiDAR: The RPLiDAR A2M12 receives power from the Intel NUC, and it is connected through UART to a UART to USB adapter which in turn connects it to the Intel NUC. Data and power are transferred through this connection.

5. Fisheye Camera: The 5MPX Fisheye Camera is powered directly from the Raspberry Pi using a CSI/DSI cable, and this cable assists in sending camera data.

6. Robot Wheels: The Buhler BLDC Motors for the robot wheels receive power from the LeoCore Controller through 6-pin connections. The magnetic encoders attached to the motors provide feedback on their rotation.

Overall Power Management:
The Leo Rover’s power connection diagram as observed in Fig.10 effectively distributes electrical power across the various components while maintaining proper voltage levels and ensuring efficient operation. The PowerBox plays a crucial role in regulating power from the main battery and providing clean power to the system’s critical components.

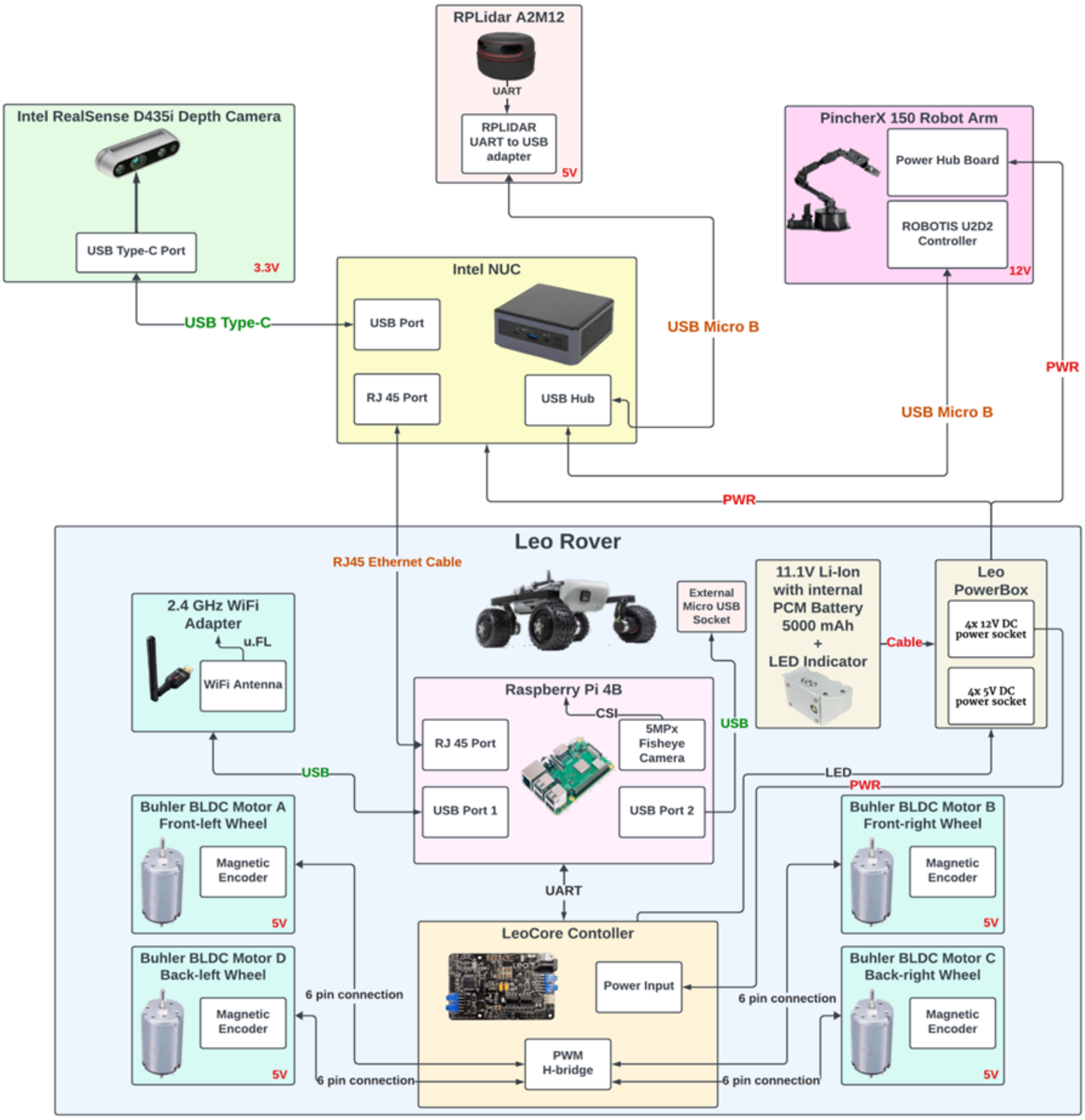


Fig. 10. Power Connection Diagram

5 Software Design

5.1 RQT Graph

In the Power Connection Diagram depicted in Fig.10, various connections have been established from the Intel NUC to different components of the robotic system, including the rover, manipulator, LiDAR, and depth camera. The communication and information exchange between these components are visualized in more detail through the representations in Fig.11 and Fig.12.

Fig.11 provides a comprehensive overview of the topics published by these connections to the NUC. Each connection corresponds to specific data streams, or "topics," that convey information about the state and operation of the respective components. The breakdown of topics is as follows:

- Rover topics: Under the **/firmware** node, the rover publishes information related to wheel states (**/firmware/wheel_states**), wheel odometry (**/firmware/wheel_odom**), inertial measurement unit (IMU) data (**/firmware/imu**), and joint states (**/joint_states**).
- RPLiDAR topic: The LiDAR component publishes scan data (**/scan**) through the **/rpLiDAR_node**.
- Manipulator topics: The manipulator component, represented by the **/px150** node, publishes joint states (**/px150/joint_states**) and robot description (**/px150/robot_description**).
- Depth Camera topics: The depth camera component, represented by the **/camera** node, publishes various image-related topics, including raw images (**/camera/image_raw**), monochrome images (**/camera/image_mono**), color images (**/camera/image_colour**), and additional information about the images (**/camera/image_info**).

Fig.12 further aids in understanding the relationship between these peripherals, the rover, and the NUC. The visualization highlights the distribution of topics on the **/param_events** parameter server. The left half of **/param_events** is covered with topics from the rover, while the right half is covered with topics from the manipulator, LiDAR, and depth camera. This spatial arrangement emphasizes the distinct data streams originating from each component and their contributions to the overall system.

In summary, the combination of Fig.11 and Fig.12 provides a detailed and organized representation of the communication patterns and data flow within the robotic system, enhancing the understanding of how information is exchanged between the Intel NUC and its connected components.

5.2 Git Repository

The team's weekly progress is recorded in our GitHub repository, which can be accessed through the following link: `https://github.com/Team-7-UOM/DocumentationForLeoRover`.

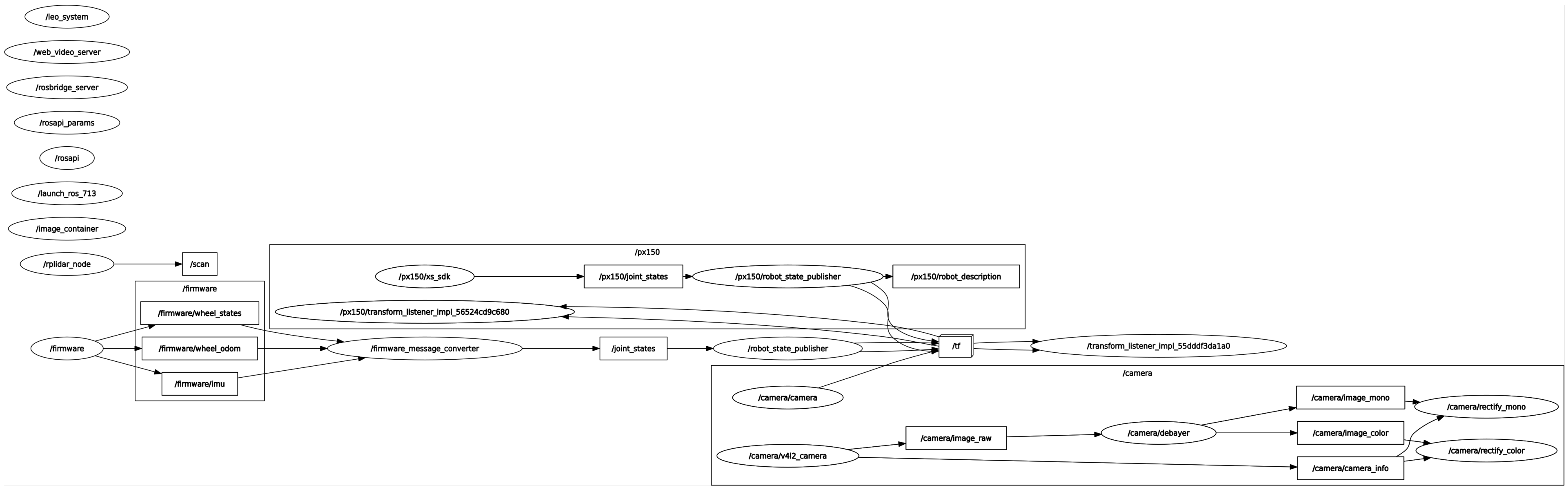


Fig. 11. RQT Graph

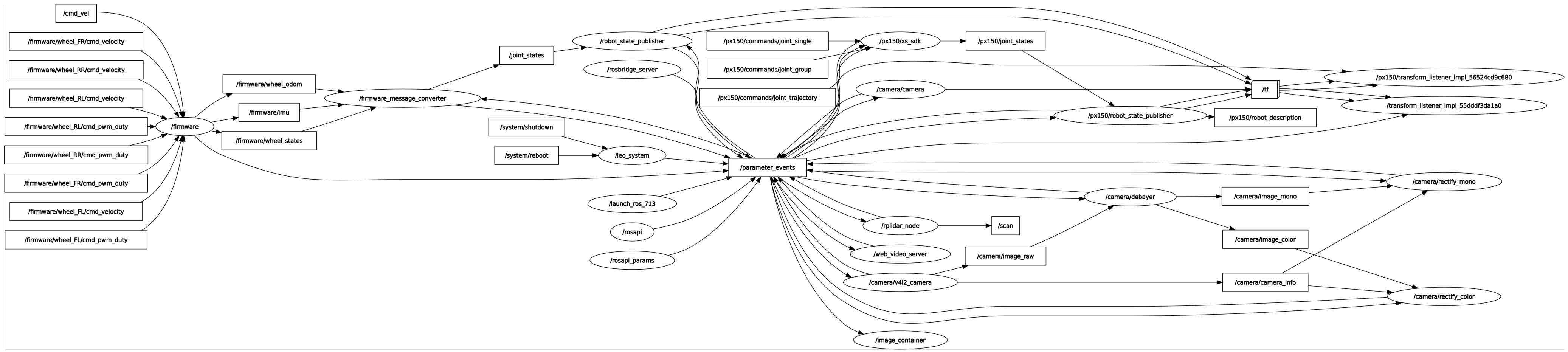


Fig. 12. RQT Graph with parameter events

6 Analysis

6.1 Requirements Verification Matrix

Requirements Verification Matrix as observed in [2] and Table 1 is a tool used to ensure that project requirements are met. This matrix helps the team track requirements, ensuring that each requirement has gone through the proper verification process and corresponds to the corresponding verification methods.

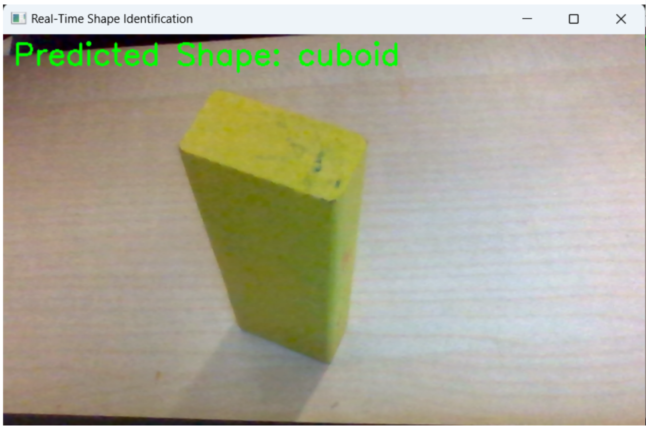
Table 1. Robot Requirements and Verification

Req. No.	Requirements Statement	Verification Success Criteria	Verification Method	Verification Status
1	The robot detects and distinguishes a target object.	The robot has a depth camera that can detect objects at a minimum distance of 28cm.	Inspection, Testing	Verified -The robot can distinguish different objects using a depth camera and contours on the object
2	The robot maps out a static unknown environment.	The robot has a LiDAR that can detect obstacles at a distance of 0.2m to 15m away from the LiDAR.	Testing, Simulation	Partially Verified - The LiDAR's range was verified with objects at different distances. It is also capable of effectively mapping out an environment in a simulation.
3	The robot navigates the unknown environment autonomously.	The robot can autonomously navigate with a degree of autonomy between 1 and 6 to reach the target object.	Testing, Simulation	Not Verified - The robot's feed was used to move around in an unknown environment using teleoperation.
4	The robot reaches, grasps, and securely holds the target object.	The manipulator can pick up the specified target object, has 5 degrees of freedom, a reach of 450mm, a working payload of 50g, and a transparent acrylic shield.	Inspection, Testing	Verified - The manipulator was tested with a maximum weight of 50g which it was successfully able to pick up and move around with no vibration. The Manipulator reach (full range) was tested using a measuring tape.
5	The robot traverses around obstacles.	The robot has 4 in-hub DC motors and wheels with a diameter of 130mm made of rubber with foam inserts.	Testing, Inspection	Not Verified - can only be tested once all the mounts and peripherals are set up on the robot.

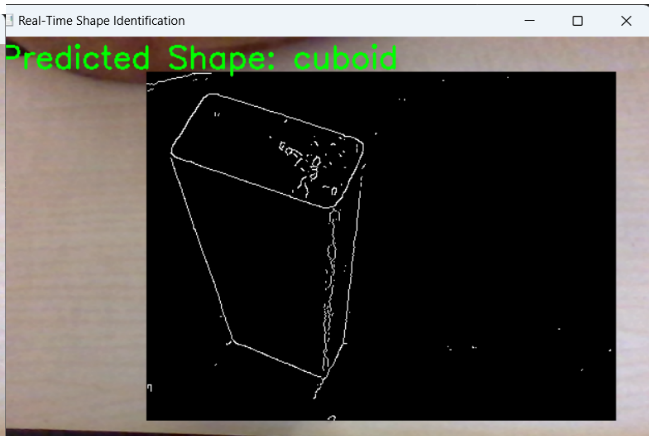
Req. No.	Requirements Statement	Verification Success Criteria	Verification Method	Verification Status
6	The robot is Wi-Fi enabled with a user interface.	The robot has Wi-Fi connectivity with a range of up to 100m for teleoperation and a user interface linked to the camera feed.	Testing, Inspection	Verified - The robot was teleoperated and the user kept moving away to test the strength of the connectivity, however, it was noted the presence of walls affected the distance of connectivity.
7	The robot can safely store the collected target object.	The base robot weighs less than 7 kilograms, has dimensions of 447x433x249 mm, can carry a maximum payload of 5 kilograms, and has a mounting platform of 299x183 mm.	Inspection, Testing	Partially verified - The robot weighs less than 7kg on a weighing scale, however, the maximum payload is yet to be tested.
8	The robot is safe to use for the customer.	The robot does not have sharp corners.	Inspection, Manufacturing	Verified - The designs were made to match the requirement, avoiding any sharp corners.
9	The robot is dust-protected and withstands vibrations.	The robot's components, structure, and joints can withstand vibrations caused by the robot during traversal.	Testing, Simulation	Undergoing Verification - The individual components are being evaluated for vibrations, however, testing is still pending for the entire robot
10	The robot can return to the starting position.	The robot can accurately return to the starting position after collecting the target object.	Testing, Inspection	Not Verified - Autonomous traversal is still left to be implemented
11	The robot logs data and generates reports.	The robot can log data and generate reports on its activities.	Inspection, Testing	Verified - The robot's log data can be viewed by subscribing to the topics on the robot as observed in Fig.12
12	The robot completes the mission without running out of battery.	The robot has a battery capacity of 5000 mAh.	Testing, Inspection	Not Verified - The robot is still not mission-ready.
13	Emergency-stopping procedures are implemented on the robot.	The robot has implemented emergency-stopping procedures.	Inspection, Testing	Not Verified - This feature has not been implemented yet for testing.

6.2 Design Analysis

1. The robot detects and distinguishes a target object: The depth camera successfully distinguishes objects using contours as seen in Fig.13, demonstrating effective object detection at the specified minimum distance. The combination of depth information and contour analysis enhances the robot's capability.



(a) What we see



(b) What the camera sees

(c) Cube detection

Fig. 13. Trained Model visualizations for the depth camera

2. The robot maps out a static unknown environment: The LiDAR's partial verification indicates that the obstacle detection and mapping functionality are promising. However, further testing and validation are required to ensure reliable performance in real-world scenarios.

3. The robot navigates the unknown environment autonomously: Teleoperation testing provides insight into manual control, but the implementation and testing of autonomous navigation remain pending. This is a critical aspect for real-world applications, and thorough testing is needed for reliable performance.

4. The robot reaches, grasps and securely holds the target object: Successful testing of the manipulator with a specified target object and compliance with design parameters (degrees of freedom, reach, payload capacity) demonstrate that the robot can effectively perform grasping tasks.

5. The robot traverses around obstacles: The potential obstacle traversal capability is acknowledged, but practical verification awaits the setup of additional components. Full testing is required to ensure obstacle avoidance and navigation in complex environments.

6. The robot is Wi-Fi enabled with a user interface: Successful teleoperation and Wi-Fi connectivity up to 100m highlight positive aspects. However, the impact of obstacles on connectivity suggests that environmental factors need consideration for robust performance.

7. The robot can safely store the collected target object: A storage section was designed as a part of the upper platform shown in Fig. 5 & 9. Weight compliance is confirmed, but pending testing of the maximum payload raises questions about the robot's ability to safely handle heavier objects. Further testing is crucial to ensure safety and functionality.

8. The robot is safe to use for the customer: Design considerations, such as avoiding sharp corners and controlling motor rotation speed, confirm the robot's safety features. This proactive approach in design is crucial for user safety.

9. The robot is dust-protected and withstands vibrations: The ongoing verification process indicates a proactive evaluation of components for vibrations. Full-system testing is necessary to ensure that the robot can withstand operational vibrations and environmental conditions.

10. The robot can return to the starting position: The pending implementation and testing of autonomous traversal, including the ability to return to the starting position, is a critical feature for mission success. This should be prioritized for comprehensive validation.

11. The robot logs data and generates reports: Successful verification of data logging and reporting is a positive aspect. The accessibility of log data through subscription demonstrates transparency and accountability in the robot's operation.

12. The robot completes the mission without running out of battery: The current status of not being mission-ready emphasizes the importance of completing battery testing. This is a fundamental requirement for the robot to perform its intended tasks reliably.

13. Emergency-stopping procedures are implemented on the robot: The pending implementation and testing of emergency-stopping procedures are critical for user safety and system integrity. This feature should be prioritized to ensure swift response in case of unexpected events following the guidelines provided in the risk assessment.

Appendices

A Updated Design Requirements

A.1 Terminology

Utilising the guidelines provided in [2] and [3], we can define the terminologies as:
“shall” – Normative or mandatory requirement
“should” – preferable to have (goal)
”will” – facts or declaration of purpose

A.2 Specifications

This section highlights the main functional and product design requirements to follow while designing the robot.

1. The robot shall detect and distinguish a target object.
    - The robot should have a depth camera that can detect objects at a minimum distance of 28cm.
2. The robot shall be able to map out a static unknown environment.
    - The robot shall have a LiDAR that can detect obstacles at a distance of 0.2m to 15m away from the LiDAR.
3. The robot shall navigate the unknown environment with a degree of autonomy between 1 and 6 to reach the target object.
4. The robot shall reach, grasp, and securely hold the target object using a manipulator mounted on top of the robot.
    - The manipulator should be able to pick up the specified target object on its own. In the case of it not being able to distinguish the objects, it should request human intervention.
    - The manipulator will have 5 degrees of freedom.
    - The manipulator shall have a reach of 450mm.
    - The manipulator shall have a working payload of 50g.
    - The manipulator will weigh within 2.5 kilograms.
    - The manipulator will be constructed from extremely rigid 20mm x 20mm extruded aluminum and all aluminum brackets.
    - The manipulator will have a transparent acrylic shield to keep the robotic arm’s electronics free from debris as well as impact from the arm itself.
5. The robot will be able to traverse around obstacles and not over them.

- The robot will have 4 in-hub DC motors
- The robot's wheels will have a diameter equal to 130mm.
- The robot's wheels will be made up of rubber with foam inserts.

6. The robot will be Wi-Fi enabled and have a user interface linked to the camera feed, to monitor and track the mission's progress.
    - The robot will have a connection range of up to 100m for tele-operation from a human user.
7. The robot should be able to safely store the collected target object when needed without disturbing the dynamics of the robot.
    - The base robot in itself will not weigh more than 7 kilograms
    - The robot without any fittings will be of the dimensions 447x433x249 mm.
    - The robot shall be able to carry a maximum payload of 5 kilograms.
    - The robot's mounting platform for peripherals and the robotic arm will have a dimension of 299 x 183 mm.
8. The robot should be safe to use for the customer.
    - The robot shall not have any sharp corners.
9. The robot should be dust-protected and withstand vibrations, and splashing of water to a certain degree.
    - The robot's components, structure, and joints shall be able to withstand vibrations caused by the robot during traversal.
10. The robot shall be able to return to the starting position after collecting the target object.
11. The robot should be able to log data and generate reports on its activities.
12. The robot shall complete the mission without running out of battery.
    - The robot will have a battery capacity of 5000 mAh.
13. Emergency-stopping procedures shall be implemented on the robot in case anything goes wrong.

B Updated EDIA Workplace Charter

B.1 Our Comments

1. Equality

   We will ensure that each group member has an equal opportunity to participate in the various stages of the projects. Whether in the decision-making process or task allocation, we will treat each member with fairness and equality and avoid discrimination.

2. Diversity

   We will respect and appreciate diversity within the group, including the cultural, academic background, and viewpoint of each team member. When faced with problems or conflicts, we encourage each member to share their unique insights to foster open communication.

3. Inclusion

   No matter how big or small the ideology is, members are always encouraged to share their input or even share their grievances. Our team members strive to ensure that every member can feel included, and the contribution of every team member is vital to achieve our common goals.

The above commitments are to ensure that each member of the team will not be subject to discrimination, bullying, harassment or victimization.

B.2 Team Rules

1. All members should be respectful and polite to each other, irrespective of gender, age, or ethnicity.
2. When performing a certain task, team members should share their task progress to ensure that each member can understand the progress of the entire task.
3. All members should participate in team activities, including meetings, project discussions, etc.
4. Members of the team should ensure the authenticity and validity of the results of their completed tasks so that academic misconduct is prohibited.
5. Encourage members to share opinions and suggestions to ensure diversity and inclusion within the team.
6. Each team member must ensure that the laboratory is tidy.
7. Encourage members to resolve conflicts positively and cooperatively. If necessary, some measures can be taken.
8. Every member of the team should have a collaborative and team spirit, and encourage members to work hard to achieve goals.
9. Members must respect each other's contribution to the team, and must not discriminate against one another based on qualification or experience.
10. In the event of a disagreement or conflict of opinion regarding a specific task, a vote between the team members will be conducted to collectively determine the resultant course of action. In the event of ties, professors can be invited to provide their perspectives, thereby influencing the outcome of the vote.

11. Team members are expected to adhere to prescribed working hours. If a member is unable to work at the scheduled time, the member must explain the reason to other team members in a timely manner and adjust work arrangements according to the situation. Team members are not expected to do any work outside of the agreed working hours already established by the team

B.3 Purpose of our policy

The purpose of the equality, diversity, and inclusion policy is to ensure that all team members are treated equally, to ensure that each member is treated fairly and there is a mutual respect for diversity within the team. In addition, this policy can also promote inclusion within the team. Another purpose of this policy is to eliminate stereotypes based on age, disability, gender reassignment, marriage or civil partnership, pregnancy and maternity, race, religion or belief, sex and sexual orientation discrimination, inequality and prejudice. The establishment of this policy can ensure that every member of the team has equal opportunity and can fully develop their potential, thereby ensuring that the assigned tasks and course objectives can be successfully completed.

The primary goal of the Equity, Diversity, and Inclusion (EDIA) policy is not to punish; Rather, it is designed to make it easier for individuals to understand their mistakes and create a harmonious and inclusive work environment.

B.4 Our disciplinary and grievance procedures

When a member of the team feels discriminated against, bullied, harassed, victimized, or encounters technical disagreements, the team's own internal grievance procedure is set to help resolve the conflict.

When team members feel discriminated against, bullied, harassed or victimized. The team should identify and acknowledge the existence of conflict and encourage open communication so that all members involved in the conflict can safely express their views and feelings. Group members not involved in the conflict can act as mediators thereby forming a panel, and after hearing both the parties in question, can propose a solution that de-escalates the situation.

If the disagreement is about technology, the team leader can hold a meeting and allow team members to discuss it freely. Team members should provide data and research to support their opinions, reviewing relevant data and evidence together to ensure that all decisions are based on evidence and objective information as well.

If both parties are not cooperative during the mediation, the panel will temporarily suspend the mediation and will take a short break. In this temporary suspension, the panel will discuss possible solutions to avoid further conflict during the mediation. When a new round of discussion starts, the panel will set a time period for the discussion to avoid it becoming endless and potentially creating more problems.

It is imperative that when discussing among members, one should avoid using an accusatory tone. Additionally, when each member of the team reaches a consensus, they are required to reflect on the conflicts that occurred within the team so that they can better handle similar situations in the future.

The designated team leader will make sure that each member of the team feels included in any discussion and during regular meetings, it is their duty to check in with the team members to address any issues they are facing.

On this basis, if team members encounter a conflict that cannot be resolved within the team, team members should be encouraged to escalate the issue or conflict outside the team, such as reporting it to senior academic staff or management, to ensure that the issue is handled fairly and professionally. This step is a last resort to ensure the well-being of team members, especially when conflict is severe. The specific flow can be referred to Fig.14.

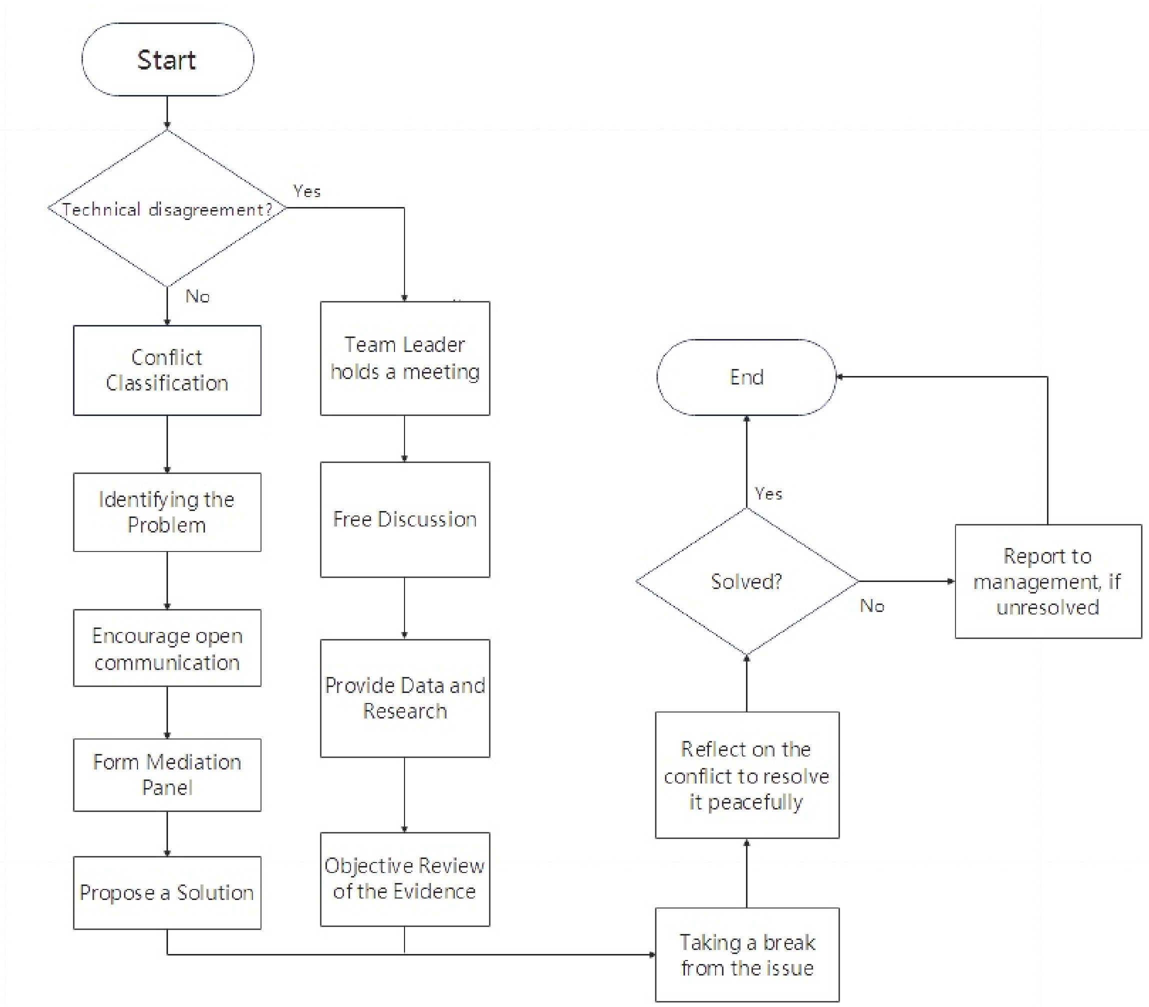


Fig. 14. Flow chart of disciplinary and grievance procedures

C Additional Mechanical Drawings

This section highlights the mechanical drawings for the death camera mount attachment for the Manipulator as well as the mechanical drawings for the NUC case.

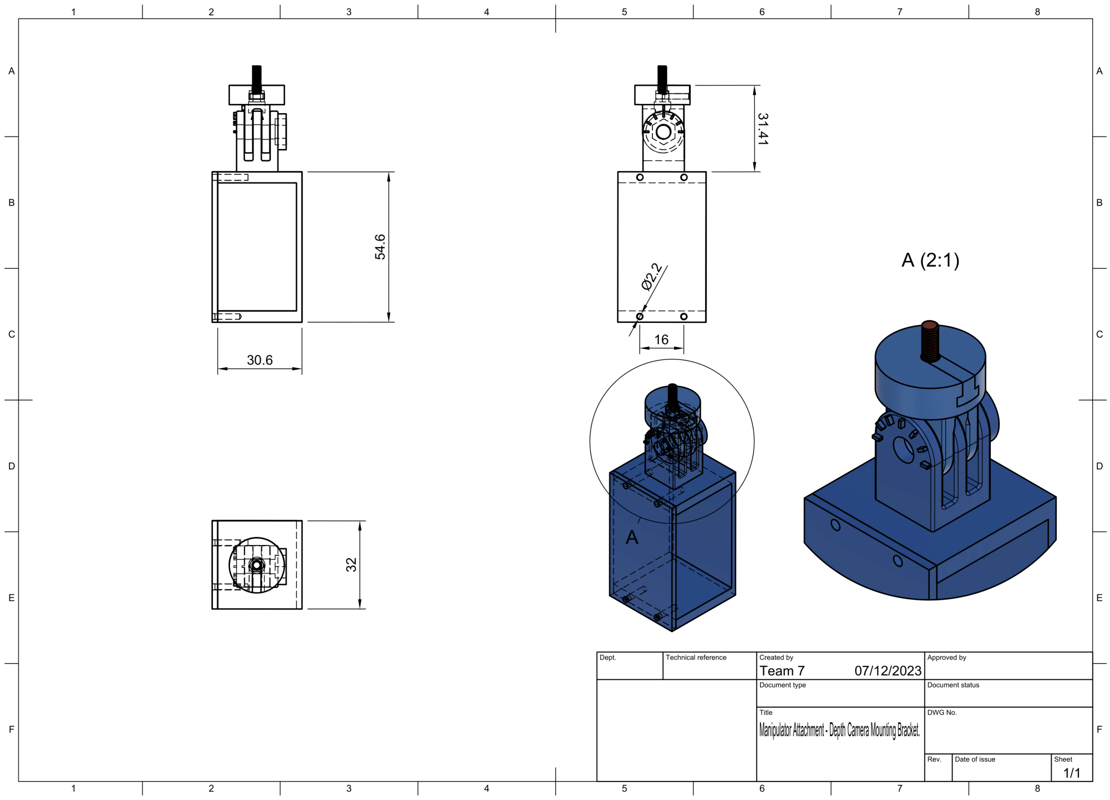


Fig. 15. Mechanical drawings of the depth camera mount for the Manipulator

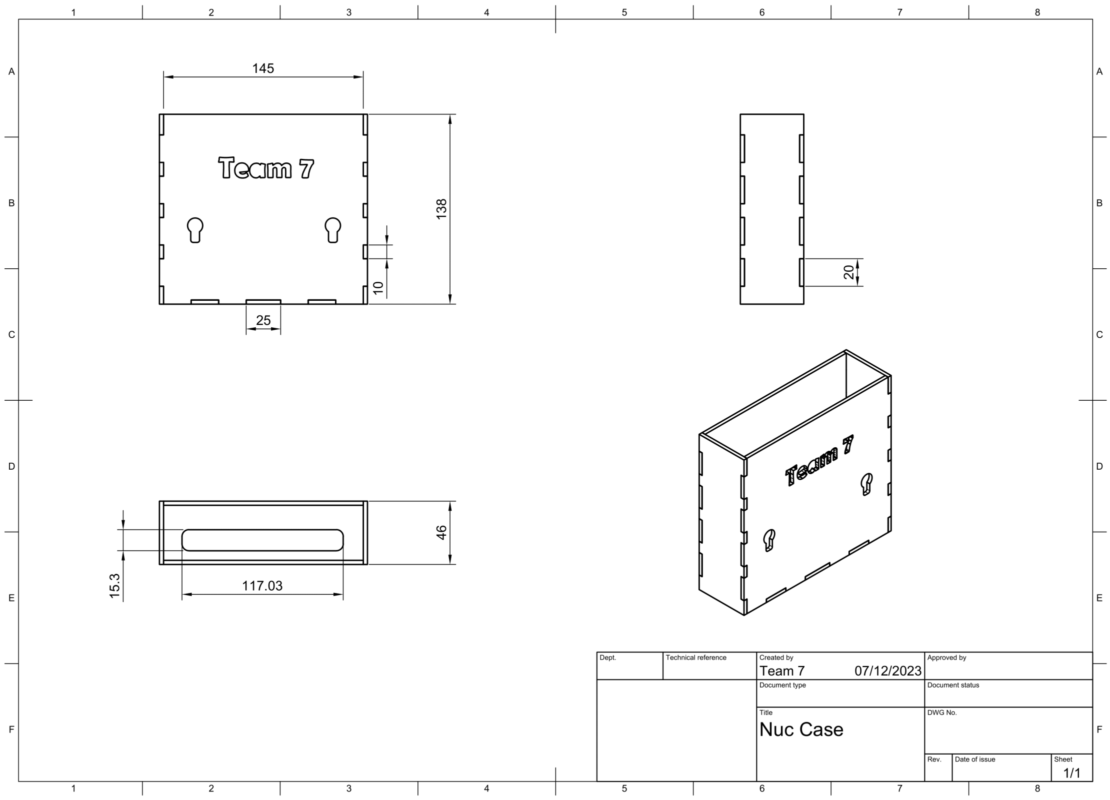


Fig. 16. Mechanical drawings NUC case

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