MANCHESTER 1824
The University of Manchester

# Design Requirements Analysis

AERO62520 - Robotic Systems Design Project

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**Student ID**
Team 9

School of Engineering

# Contents



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# 1 Stakeholder Engagement

Various questions were discussed with the customer (Dr. Simon Watson) to elaborate on the problem and gain a comprehensive understanding of the mission requirements. The table below serves as a record of this meeting.

| **Customer:** | **What?** What is the problem | **Why?** |
|---|---|---|
| Dr Simon Watson | Develop a robot which can autonomously retrieve an object from an environment. | This problem represents and simulates several real life situations, such as retrieving objects from radioactive facilities, or rescuing people from dangerous areas. |
| **Autonomy**<br>Limited to no human intervention. | **Environment**<br>Engineering Building A GA.033 - Net Area (Indoor Environment)<br>Light Conditions: Ambient Light | **Obstacles**<br>Avoid any obstacles. Obstacles are static, and could take various shapes and colours. |
| **Customer requirements:**<br>Develop an autonomous mobile robot that can:<br>• Navigate an unknown environment<br>• Avoid obstacles<br>• Locate a randomly placed wooden cuboid object<br>• Pick up the object safely<br>• Return the object to the starting point of the robot | | **Object Specifications**<br>• Wooden<br>• Cuboid<br>• Brightly coloured<br>• Light and small enough for the manipulator<br>**Future ambitions**<br>• Handling multiple objects<br>• Handling soft objects<br>• Handling uncommon object shapes |
| **Power and Maintenance:**<br>The robot should not run out of battery during the mission. | **Resources**<br>• Leo Rover kit<br>• Robotic manipulator, Lidar, depth camera, NUC<br>• 3D printer, laser cutter | **Constraints**<br>• The robot shall not leave the net area<br>• The robot shall not lose power during the mission<br>• The robot shall not collide with obstacles |

**Fig. 1.** Problem Framing Table

# 2 Problem Statement

The main aim of this project is to *"Design and develop an autonomous mobile robot capable of retrieving a randomly located wooden cuboid object in an unknown indoor environment, and returning it to the starting point of the robot."*

A set of objectives have been set to address the critical issues identified during the problem assessment:

1. Assemble the Leo Rover and upgrade its mechanical design such that it can fit a robotic manipulator, a LiDAR, and depth camera
2. Integrate the LiDAR and stereo camera with the system, allowing the Leo Rover to navigate through an unknown environment, avoid obstacles, and locate a wooden cuboid object autonomously

3. Integrate the robotic manipulator with the system, allowing the Leo Rover to pick up the object, and return it safely to the starting point of the robot
4. Develop the software of the Leo Rover to operate at the highest possible level of autonomy, ensuring limited to no human intervention during the mission
5. Build flexibility into the system to accommodate any additional issues that may be identified by the customer during the development process

# 3 Functional and Product Design Requirements

This section highlights the functional and design requirements of the robot, allowing it to achieve the objectives set out in the problem statement (Section 2 of this document).

## 3.1 Autonomy Requirements

1. The robot shall autonomously avoid obstacles observable by the robot, utilising the onboard 2-D LiDAR to detect and navigate around obstacles within its operational environment.
   (a) The LiDAR should be able to detect obstacles between the range of 0.15 m - 5 m, to be able to perform obstacle avoidance.

## 3.2 Environment Requirements

2. The robot shall be able to traverse the netting area in the lab (room GA.033 in MECD)
   (a) The robot shall be able to move at a speed of 0.35 m/s, to be able to complete the task within the robot's battery life.
   (b) The designed payload will not exceed the width of the robot, which is 450 mm.
   (c) The combined weight of the designed payload, LiDAR, NUC, and depth camera will not exceed 5 kg.
3. The robot should navigate the environment, perform obstacle avoidance, and pick up the object autonomously, with no human intervention.

## 3.3 Object Retrieval Requirements

4. The robot shall be able to pick-up lightweight wooden cuboid objects that are within the size and torque capability of the grippers
   (a) Robot arm shall be able to pick up cuboid wooden objects of sizes up to 0.04 m x 0.04 m x 0.04 m, with a maximum weight of 50 g.
5. The robot should be able to pick-up lightweight wooden spherical objects that are within the size and torque capability of the grippers

(a) Robot arm should be able to pick up spherical wooden objects of sizes up to a diameter of 0.04m, with a maximum weight of 50 g

(b) The payload will be no more than 0.25 m above the ground level to allow the robot to pick up objects from the ground comfortably, as the working area of the manipulator is a sphere with diameter 0.63 m.

### 3.4 Object Identification Requirements

6. The robot shall be able to identify the target object by colour.
7. The robot should identify the target object with limited human intervention (ex: inputting object colour and shape).
8. The robot will be equipped with a vision system that can identify objects by colour, distinguishing between a predefined range of colours under standard laboratory lighting conditions.
9. The robot should integrate a depth camera to assist in the accurate determination of object position and size.

    (a) Depth camera should be able to detect objects as small as 0.02 m x 0.02 m x 0.02 m between the ranges of 0.28 m - 5 m.

### 3.5 Task Requirements

10. The robot shall be able to bring picked up objects back to the robots original starting location.

### 3.6 Robot Safety and Debugging Requirements

11. The robot should include an emergency stop feature that can be activated by the operator to immediately cease all movement and operations.
12. The robot should provide a log of its activities, including objects picked up, paths taken, and any errors or obstacles encountered.

# 4 Requirements Verification Matrix

This section addresses the Requirements Verification Matrix, illustrating the methods for confirming whether the design aligns with the specified requirements. All the requirements outlined in the matrix are detailed in Section 3 of this document.

| Requirement No | Paragraph | Shall Statement | Verification Success Criteria | Verification Method | Phase |
|---|---|---|---|---|---|
| 1 | 3.1 Autonomy Requirements | The robot shall autonomously avoid obstacles observable by the robot, utilising the onboard 2-D LiDAR to detect and navigate around obstacles within its operational environment. | 1. The LiDAR will be tested with various objects of different colours and sizes placed within the specified range (0.15 m - 5 m) to see if the objects are detectable.<br>2. The LiDAR will then be placed on the robot ensuring the obstacles are detected then traversed around. This will be tested in various environments and against various obstacles. | Test | 2 |
| 2 | 3.2 Environment Requirements | The robot shall be able to move at a speed of 0.35 m/s, to be able to complete the task within the robot's battery life. | The robot's speed will be tested to see if the robot can maintain a speed of 0.35 m/s, by having measurements on the floor of the lab and timing how long it takes to traverse over a set distance. | Test | 1 |
| 4 | 3.3 Object Retrieval Requirements | Robot arm shall be able to pick up cuboid wooden objects of sizes up to 0.04 m x 0.04 m x 0.04 m, with a maximum weight of 50 g. | A wooden cube of various sizes ranging from 0.02 m to 0.04 m and various weights up to 50 g will be attempted to be picked up by the robot arm. | Test | 3 |
| 7 | 3.4 Object Identification Requirements | The robot shall be able to identify the target object by its colour. | The robot will return a message of the correct colour of the certain area from the image information. | Test | 2 |
| 10 | 3.5 Task Requirements | The robot shall be able to bring picked up objects back to the robot's original starting location. | 1. Starting from the foundation of the requirement 3 test.<br>2. The robot will then traverse the lab at a speed of around 0.35 m/s to verify that the manipulator can maintain control of the block over the course of the objective.<br>3. The robot and wooden block will then be placed in random locations in the environment, the robot will retrieve the block, then return to its starting location. | Test | 4 |

**Table 1.** Requirements Verification Matrix