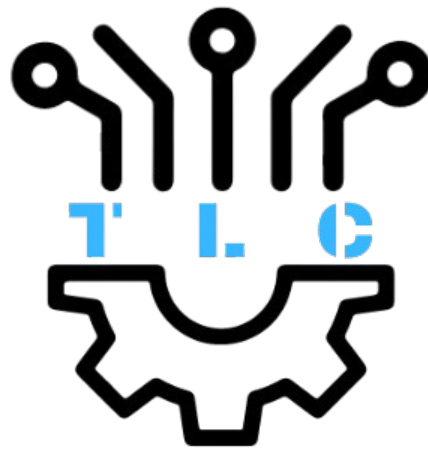# DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING
THE UNIVERSITY OF TEXAS AT ARLINGTON

ARCHITECTURAL DESIGN SPECIFICATION
CSE 4316: SENIOR DESIGN I
FALL 2024

TEAM TLC
ROAM_BOT

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REVISION HISTORY

Revision	Date	Author(s)	Description
0.1	11.05.2024	CD	document creation
0.2	11.19.2024	CD	added the introduction
0.3	11.19.2024	MG	created architecture diagram
0.4	11.20.2024	AH	added movement subsystems
0.5	11.24.2024	AK	added pathfinding subsystems
0.6	11.24.2024	RS	added interface subsystems
1.0	11.25.2024	CD, RS, MG, AK, AH	official release

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1 INTRODUCTION

The Roam_Bot should assist with learning to implement autonomous system software through real test simulations. This will be achieved using actual robotic systems. The overall design is controlled by a Raspberry Pi, which acts as the host connecting the different components of the rover. For now, the Raspberry Pi has three sections that connect to it. The first section describes the rover's motion and functionality. The second section entails the interface which allows users to upload their algorithm or manually control the rover. The third section is about the path-finding function, which dictates where the rover can move with the use of LIDAR and other sensors.
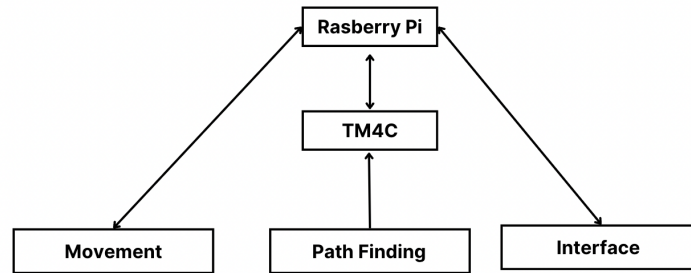
2   SYSTEM OVERVIEW

Figure 1: A simple architectural layer diagram

2.1   MOVEMENT - DESCRIPTION

The movement layer of the Roam_Bot is responsible for facilitating the rover's movement including the crash prevention feature, odometer, speed, and direction control. All instructions in this layer pass through Motor_Control using PWM and GPIO. The speed and direction subsystems both use PWM to achieve a user-provided speed and the algorithm determines the direction. The crash_prevention and odometer subsystems both use GPIO to let the rover know when to stop.

2.2   PATH FINDING - DESCRIPTION

The path-finding layer of the Roam_Bot is responsible for the navigation of the rover. This layer communicated with a TM4C to facilitate communication with the LIDAR. LIDAR will be used in the navigation to create a mapping of the room and communicate obstacles. The LIDAR and navigation will use UART.

2.3   INTERFACE - DESCRIPTION

The user interface layer is responsible for receiving user input. This layer is made up of 3 subsystems. The starting UI will display and redirect the user to algorithm upload or user control. User Control will use UART to accept rover commands. The algorithm upload uses UART to read a file into the system.
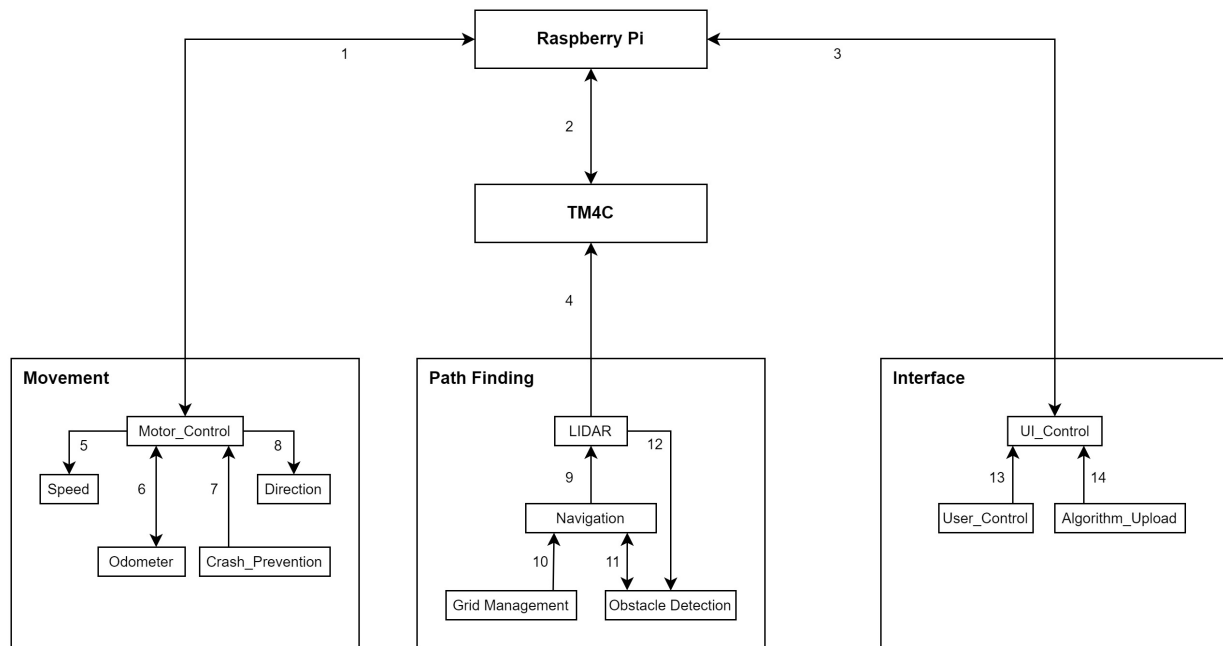
3 SUBSYSTEM DEFINITIONS & DATA FLOW

Figure 2: A simple data flow diagram

4 MOVEMENT SUBSYSTEMS

4.1 SPEED CONTROL

The speed control subsystem manages the power of each motor to maintain a specific set speed. It receives feedback from the odometer and crash prevention to ensure safe operation.
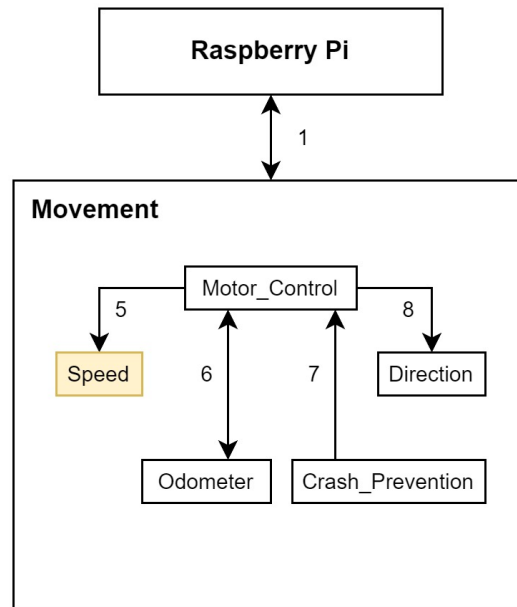
Figure 3: Movement Subsystem - Speed Control

4.1.1 ASSUMPTIONS

The motor driver supports PWM input to control motor speed. The odometer feedback is accurate within 10% from wheel encoder measurements [1]. Communication latency between the TM4C and Raspberry Pi isn't noticeable for real-time feedback.

4.1.2 RESPONSIBILITIES

Adjust motor PWM signals to match the target speed set. Monitor odometer feedback to ensure the actual speed matches the desired speed. Stop the speed if a collision is detected.

4.1.3 SUBSYSTEM INTERFACES

Table 2: Movement Subsystem - Speed Control

ID	Description	Inputs	Outputs
#5	Pulse Width Modulation (PWM)	Power In	N/A

4.2 DIRECTION CONTROL

The direction control subsystem manages the robot's steering by adjusting the motor signals for the left and right wheels. It receives feedback from the steering sensors and ensures the rover follows the correct path.
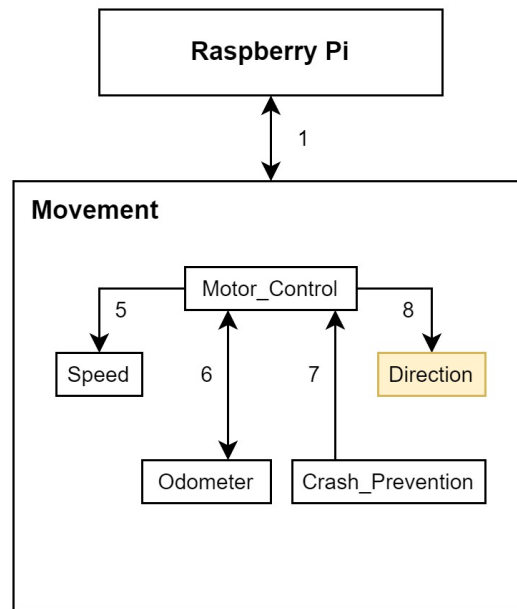
Figure 4: Movement Subsystem - Direction Control

4.2.1 ASSUMPTIONS

The motor driver supports PWM input to control motor direction. The steering feedback system is accurate within 5% from LIDAR measurements [2]. Communication latency between the TM4C and Raspberry Pi is minimal for real-time control.

4.2.2 RESPONSIBILITIES

Adjust motor PWM signals to steer the robot in the desired direction. Monitor steering feedback to ensure the robot is following the intended path. Correct any misalignment detected by the steering sensors.

4.2.3 SUBSYSTEM INTERFACES

Table 3: Movement Subsystem - Direction Control

ID	Description	Inputs	Outputs
#8	Pulse Width Modulation (PWM)	Power In	N/A

4.3 MOTOR CONTROL

The motor control subsystem manages the power supplied to the motors to achieve the desired movement. It receives feedback from the motor encoders and adjusts the motor signals to control both speed and direction.
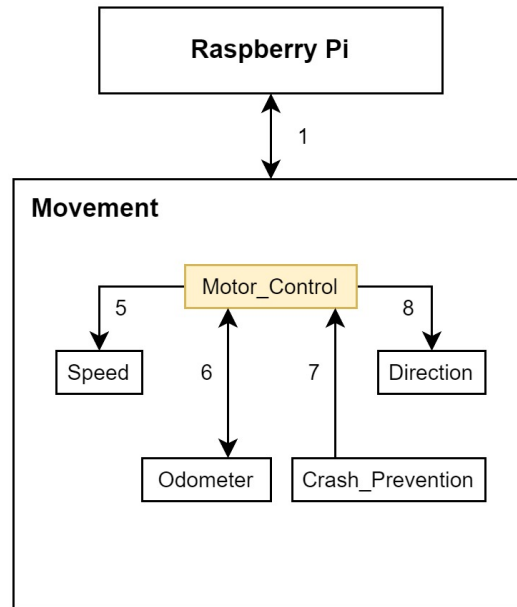

Figure 5: Movement Subsystem - Motor Control

4.3.1 ASSUMPTIONS

The motor driver supports both PWM and direction control signals to drive motor speed and direction [3]. The motor encoders provide accurate feedback to control speed and direction adjustments. Communication latency between the TM4C and Raspberry Pi does not impact real-time motor control.

4.3.2 RESPONSIBILITIES

Control motor power to achieve the desired speed and direction. Monitor motor feedback to ensure correct operation and make adjustments when necessary. Handle error states, such as motor stall or failure, and stop the motors if a critical fault is detected.

4.3.3 SUBSYSTEM INTERFACES

Table 4: Movement Subsystem - Motor Control

ID	Description	Inputs	Outputs
#5	Pulse Width Modulation (PWM)	N/A	Power Output
#6	General Purpose Input Output (GPIO)	Odometer Feedback	Odometer Control
#7	General Purpose Input Output (GPIO)	Crash Detect	N/A
#8	Pulse Width Modulation (PWM)	N/A	Power Output

4.4 ODOMETER

The odometer subsystem is responsible for measuring the distance traveled by the vehicle. It provides feedback to the motor control subsystem to help adjust the speed and ensure accurate movement over time.
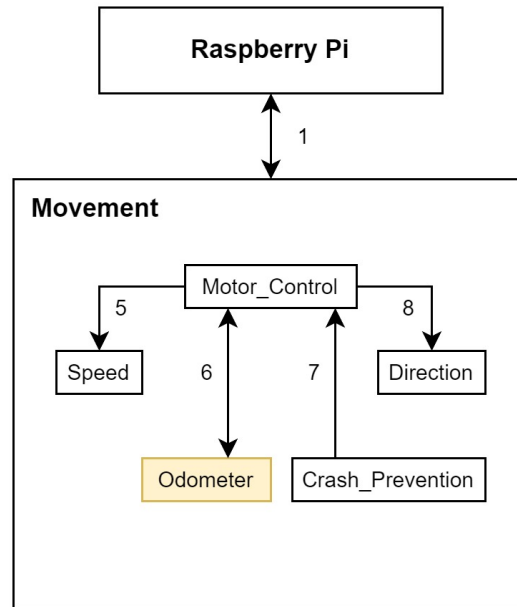

Figure 6: Movement Subsystem - Odometer

4.4.1 ASSUMPTIONS

The odometer system uses wheel encoders and LIDAR to measure the distance traveled. The feedback is accurate within 10% for distance measurement [1] [2]. The odometer data is updated in real time, with no significant communication delays between the TM4C and Raspberry Pi affecting its accuracy.

4.4.2 RESPONSIBILITIES

Measure the distance traveled by the vehicle based on wheel rotations. Provide real-time feedback to the motor control subsystem to adjust the speed accordingly. Alert the system if abnormal readings are detected, such as wheel slippage or encoder malfunction.

4.4.3 SUBSYSTEM INTERFACES

Table 5: Movement Subsystem - Odometer

ID	Description	Inputs	Outputs
#6	General Purpose Input Output (GPIO)	Odometer Control	Odometer Feedback

4.5 CRASH DETECTION

The crash detection subsystem is responsible for identifying any potential collisions or obstacles in the vehicle's path. It monitors sensor data to detect obstacles or sudden changes in velocity that may indicate a crash or near-crash event.
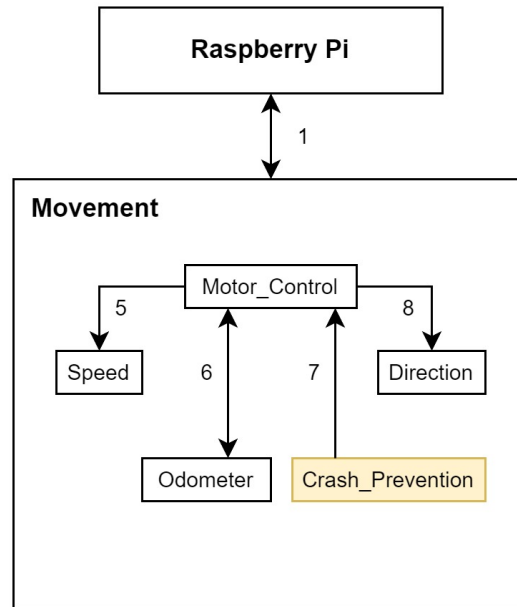

Figure 7: Movement Subsystem - Crash Detection

4.5.1 ASSUMPTIONS

The crash detection system uses a combination of proximity sensors and accelerometers to detect obstacles and sudden impacts [4].The sensor system is accurate within a range of 5 cm for obstacle detection, and the accelerometers can detect changes in velocity. Communication latency between the TM4C and Raspberry Pi is minimal and does not affect real-time collision detection.

4.5.2 RESPONSIBILITIES

Monitor sensor data to detect any obstacles or sudden changes in velocity. Alert the motor control subsystem to stop or adjust the vehicle's movement if a crash is detected. Ensure that the vehicle responds promptly to prevent further damage or injury in case of a collision.

4.5.3 SUBSYSTEM INTERFACES

Table 6: Movement Subsystem - Crash Detection

ID	Description	Inputs	Outputs
#7	General Purpose Input Output (GPIO)	Crash Detect	N/A

5 PATHFINDING SUBSYSTEMS

The pathfinding subsystem manages the components or modules within a larger pathfinding system that handles specific aspects of the

5.1 GRID MANAGEMENT SUBSYSTEM

The grid management subsystem allows the display of the LiDAR range as a grid of cells and allows them to be marked as either traversable or non-traversable, as needed.
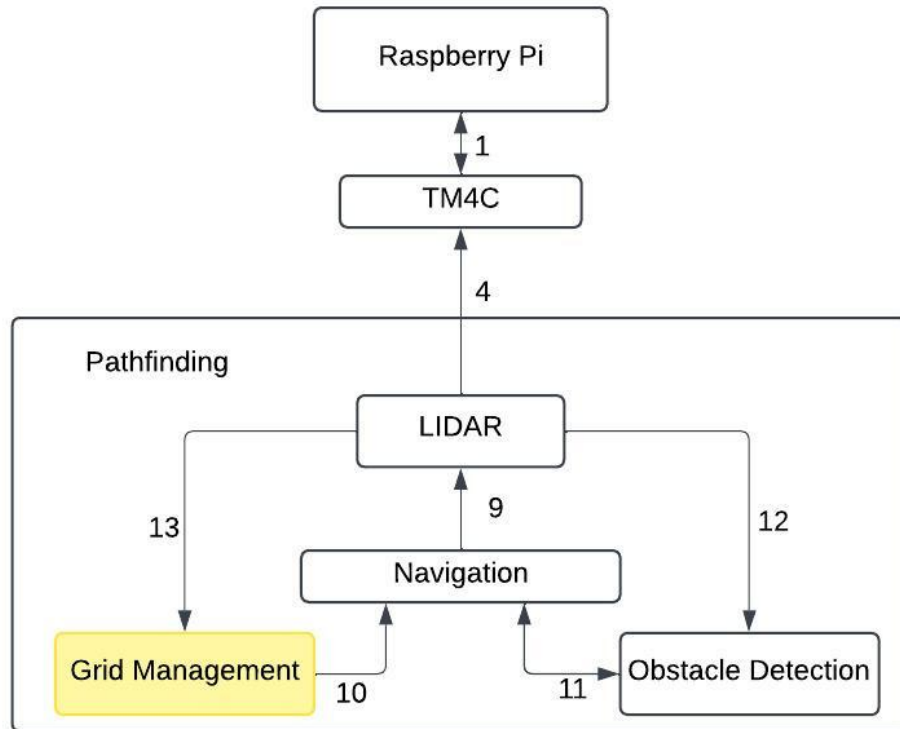

Figure 8: Pathfinding Subsystem - Grid Management

5.1.1 ASSUMPTIONS

Grid management allows for the environment within the LiDAR range to be modeled to a graph or grid. All cells within in the grid shall either be marked as traversable or non-traversable depending on if an obstacle is within the cell. The grid will dynamically update itself once it nears the outer area of the grid or when new obstacles are introduced.

5.1.2 RESPONSIBILITIES

The pathfinding algorithm creates a grid representing the environment with the LiDAR Range. The grid will contain nodes that contain properties such as:

- Traversability (true/false).

- Coordinates in world space.

The pathfinding algorithm will also covert world space coordinates to cells, and allow to update nodes during a terrain change.

5.1.3 SUBSYSTEM INTERFACES

Table 7: Pathfinding Subsystem - Grid Management

ID	Description	Inputs	Outputs
#10/13	Data that will create a cells within a grid	World Coordinates	Node Data

5.2 OBSTACLE DETECTION SUBSYSTEMS

The obstacle detection subsystem is designed to process feedback from the LiDAR, identifying objects within its range and marking them as impassable when necessary.
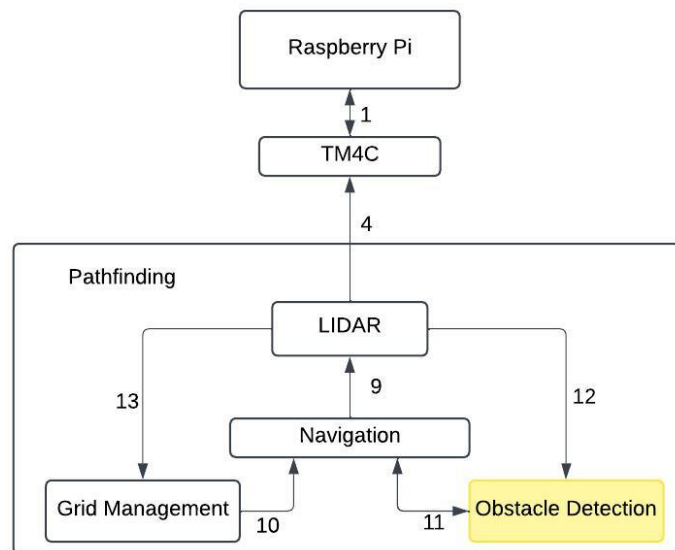

Figure 9: Pathfinding Subsystem - Obstacle Detection

5.2.1 ASSUMPTIONS

The rover will be able to register static and dynamic obstacles and be detected with LiDAR.

5.2.2 RESPONSIBILITIES

The rover will be able to detect obstacles and update the graph representation Subsystem by marking a cell as untraversable. The obstacle detection subsystem should also be able to be integrated with LiDAR and other sensors. If the close-range sensors get triggered the rover should halt movement and retreat a set distance before reactivating its pathfinding.

5.2.3 SUBSYSTEM INTERFACES

Table 8: Pathfinding Subsystem - Obstacle Detection

ID	Description	Inputs	Outputs
#11/12	Algorithm will send a signal to the Navigation sending marked obstacles	Input from LiDAR	Obstacle Update Signals

5.3 NAVIGATION SUBSYSTEMS

The pathfinding subsystem is designed to give the Roam_Bot the ability to traverse the terrain and reach the desired terrain.
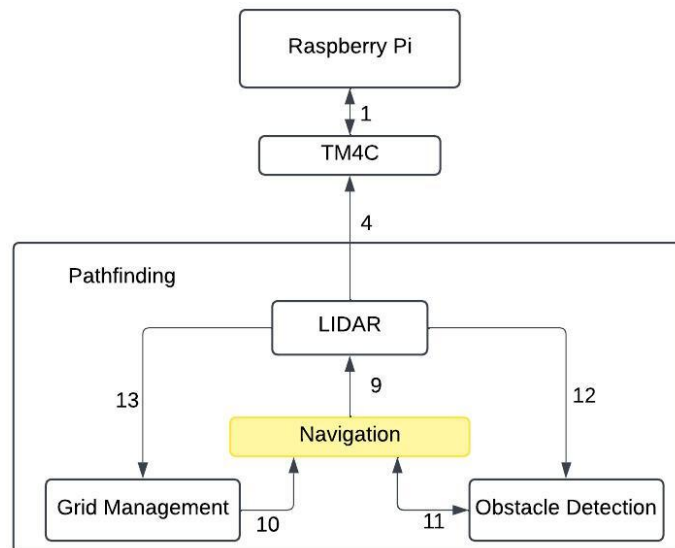
Figure 10: Pathfinding Subsystem - Navigation

5.3.1 ASSUMPTIONS

The pathfinding algorithm requires that the graph is already constructed, and LiDAR is active.

5.3.2 RESPONSIBILITIES

The pathfinding algorithm calculates either the optimal or heuristic-based path from a start to end node. The pathfinding algorithms should also allow for multiple algorithms such as A*, Djiksta's, Breadth-First-Search, etc. While also handling-handling static and dynamic obstacles.

5.3.3 Subsystem Interfaces

Table 9: Pathfinding Subsystem - Navigation

ID	Description	Inputs	Outputs
#9/10/11	Algorithm will feed pathfinding to Li-DAR Range	Navigation	Data to TM4C (Microcontroller)

5.4 LiDAR Subsystems

The LiDAR subsystem is designed to give the Roam_Bot the ability to see the desired terrain.
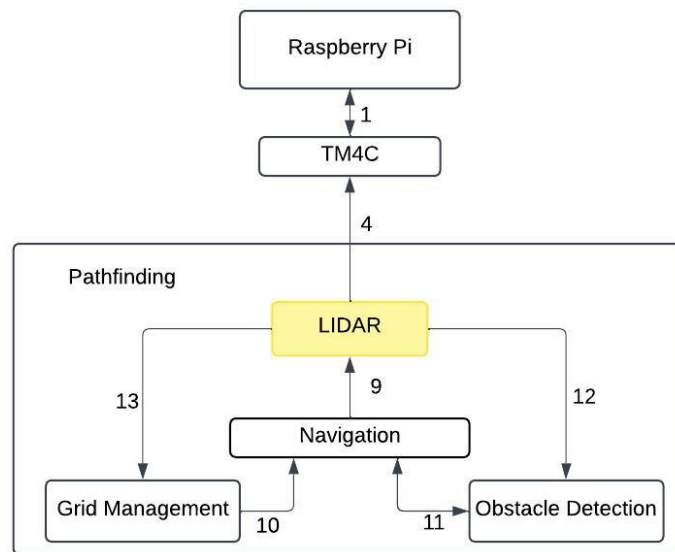

Figure 11: Pathfinding Subsystem - LiDAR

5.4.1 Assumptions

The LiDAR subsystem requires that the Roam_Bot be turned on.

5.4.2 Responsibilities

The LiDAR subsystem takes the input given by its senses and sends all relevant information to the Grid Management, and Obstacle Detection subsystems as well as the TM4C system.

5.4.3 SUBSYSTEM INTERFACES

Table 10: Pathfinding Subsystem - LiDAR

ID	Description	Inputs	Outputs
#13	The LiDAR subsystem will transmit video data to the Grid Management subsystem, which will process the input, convert it into a structured grid, and divide it into individual cells for further analysis.	Navigation	Data to TM4C (Microcontroller)
#12	The LiDAR subsystem will transmit video data to the Obstacle Detection subsystem, which will analyze the input to identify and classify areas as either obstacles or traversable terrain.	N/A	Data to TM4C (Microcontroller)
#4	LiDAR will feed accumlated infromation to TM4C (microcontroller)	Data from Navigation	Data to TM4C (Microcontroller)

6 INTERFACE SUBSYSTEMS

The interface subsystems are responsible for getting user input and translating it to the motion of the rover.

6.1 USER INTERFACE

This is the user interface, where users will be able to input which path-finding algorithm they want the rover to utilize, and control the motion of the rover.
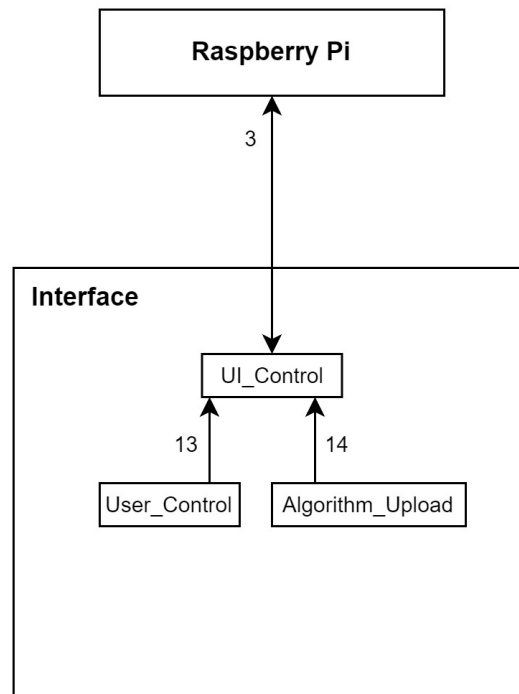

Figure 12: Interface Subsystem

6.1.1 ASSUMPTIONS

We are assuming that the user will be able to utilize the UI. We will be printing out specific instructions, and cover for any possible cases.

6.1.2 RESPONSIBILITIES

It should be user-friendly and easy to use, so that users can simply run the program and send commands to the rover.

6.1.3 SUBSYSTEM INTERFACES

Table 11: Interface Subsystem

ID	Description	Inputs	Outputs
#3	UI	N/A	Screen
#13	User Control	Speed Direction	Motion
#14	Algorithm Upload	Algorithm Name	Path-finding

REFERENCES

[1] X. Zhang, Y. Li, and L. Zhang, "A new method of angle measurement error analysis of rotary encoders," *IEEE Access*, vol. 8, pp. 74 539–74 549, 2020.

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