University of Toronto
Faculty of Applied Science & Engineering

MIE444: Mechatronics Principles

Request for Proposal

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Group 2:
Yuanshan Du 1001324541
Hongzheng Xu 1001772904
Yixiao Hong 1001311145
Ziqi Zhang 1001374684
Stephen Huang 1001165099

Project Requirements

The goal of this project is to build a rover that can navigate through the 4 x 8 maze, avoid obstacles, and relocate a load from the loading zone to the drop-off zone. Several sub-categories are required to be considered in order to achieve the objective.

First of all, the rover should be able to identify its own location in the maze and the direction it is heading. Second, the rover should be able to drive in a straight line during movement and perform corrections. Third, the rover should be efficient when choosing the route, which means the rover should travel the shortest distance.

There are several important constraints that the design must meet. First, the cost of the entire project has to be less than 250 Canadian dollars. Second, the rover must be able to identify the wall and avoid contacting the wall. Third, the rover must be able to identify the location of the load in the loading zone. Last, the rover must be able to perform collect-and-release operations to move the load.

Detailed Rover Design

The layout of the rover components is shown by the CAD model in Figure 1 to Figure 3

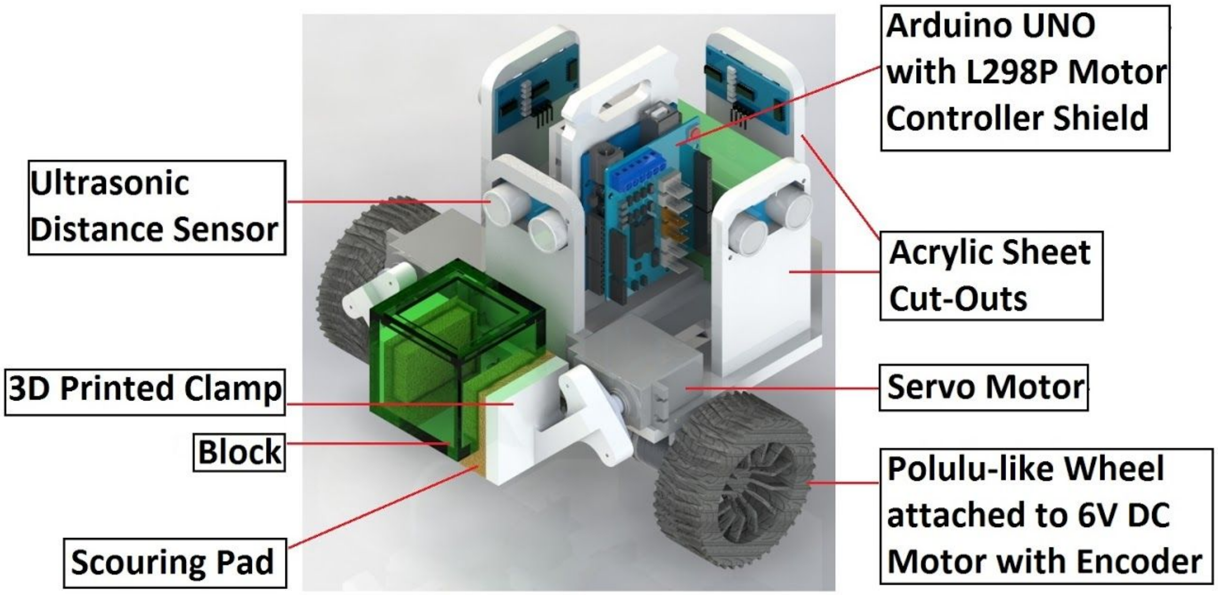


Figure 1. Isometric View of Rover

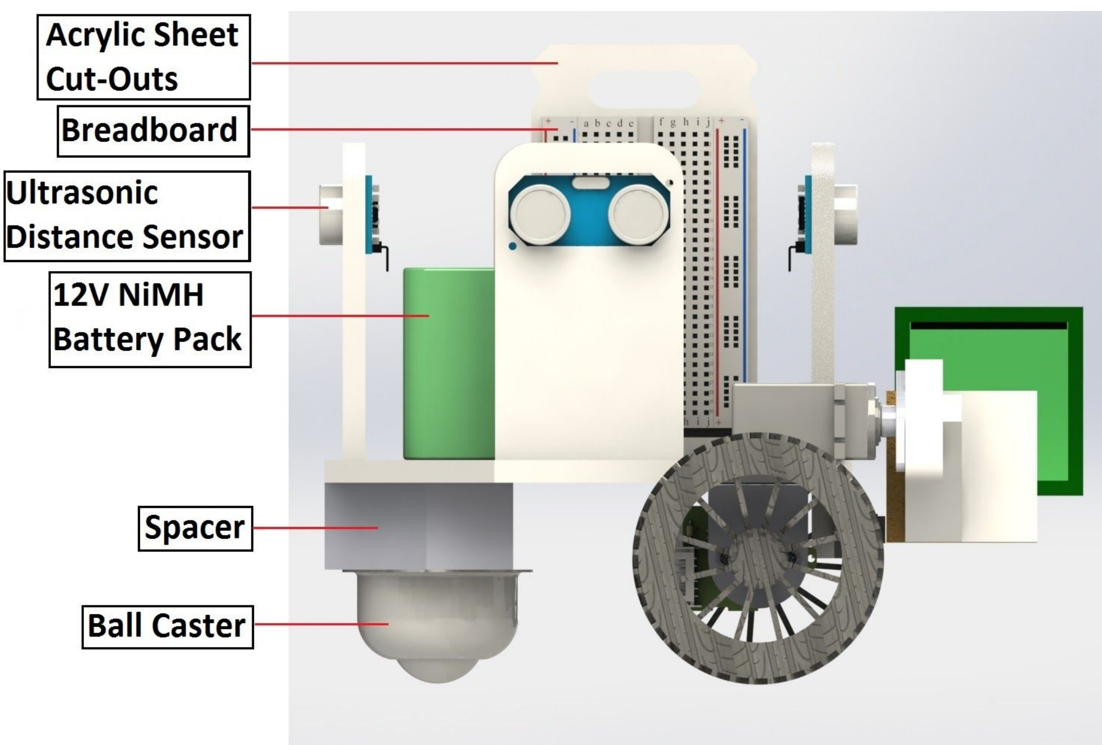


Figure 2. Side View of Rover

G

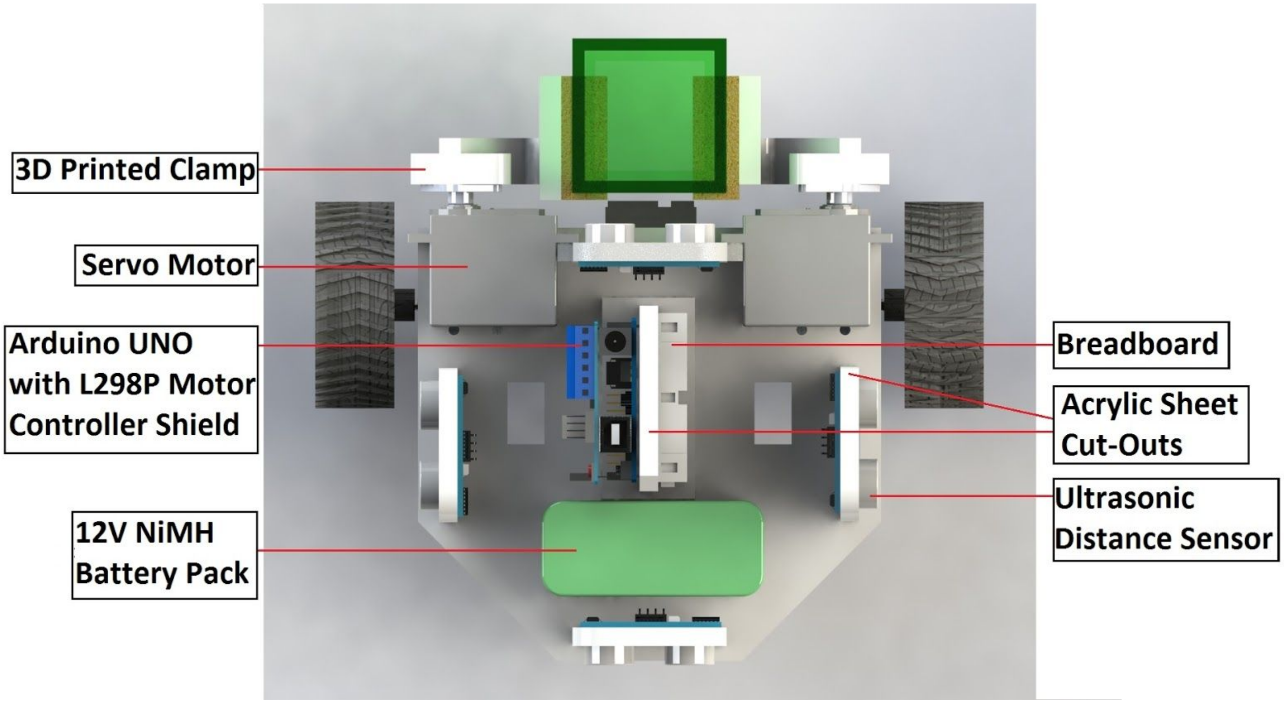


Figure 3. Top View of Rover

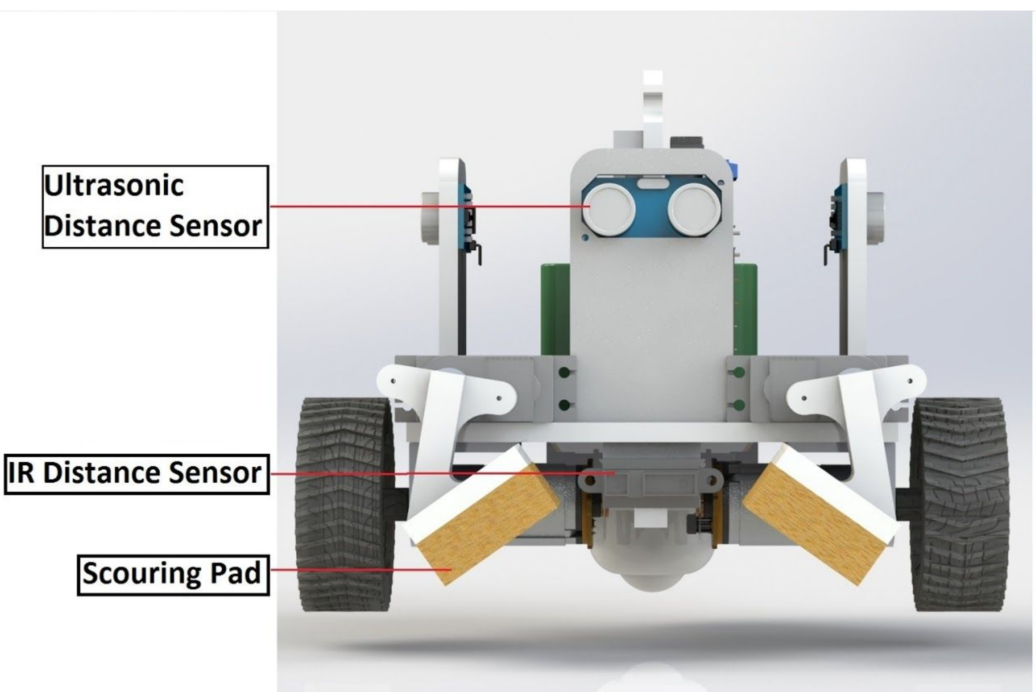


Figure 4. Front View of Rover

Maneuvering:

The rover is driven by two side-wheels that are powered by 6V DC motors. The rover moves forward when two wheels spin in the same direction, turns when two wheels spin in the opposite directions. A ball caster is placed at the back of the rover to support its body weight. Four ultrasonic sensors on each side obtain the distance from the wall.

When moving forward, the rover straightens itself by maintaining the readings of the side sensors. If the reading from either side sensors drops suddenly, the rover will know it’s approaching an intersection. Then it will perform turning operations as per Figure 5.

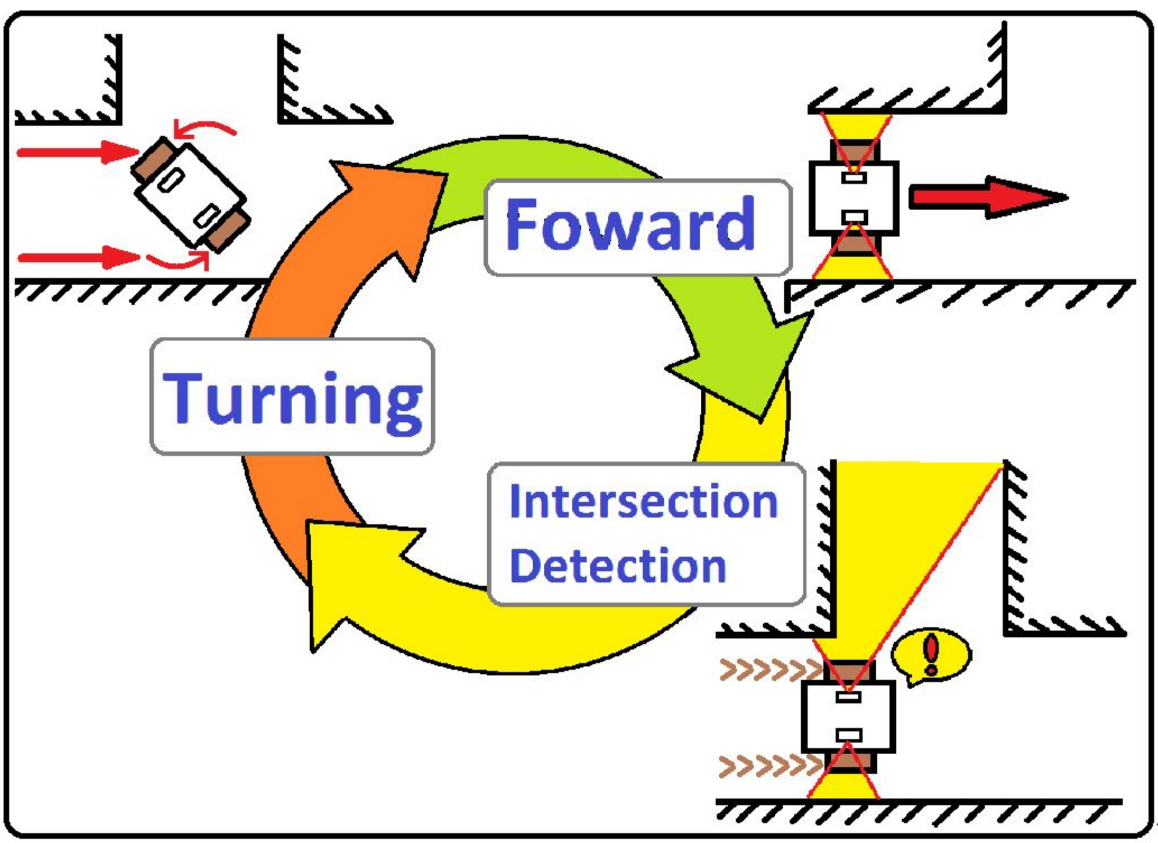


Figure 5. Forward, Intersection detection, and Turning

Loading:

The loading mechanism consists of two clamping arms that pick up the block by pitching it on both sides, shown in Figure 4. A layer of high friction soft material (eg. scouring pad) is attached to the inside of the clamping arms for both lifting and holding purposes, as per Figure 6 and 7. The rover will detect the block when the IR sensor's distance reading is significantly smaller than the front ultrasonic sensor's reading, shown in Figure 8.

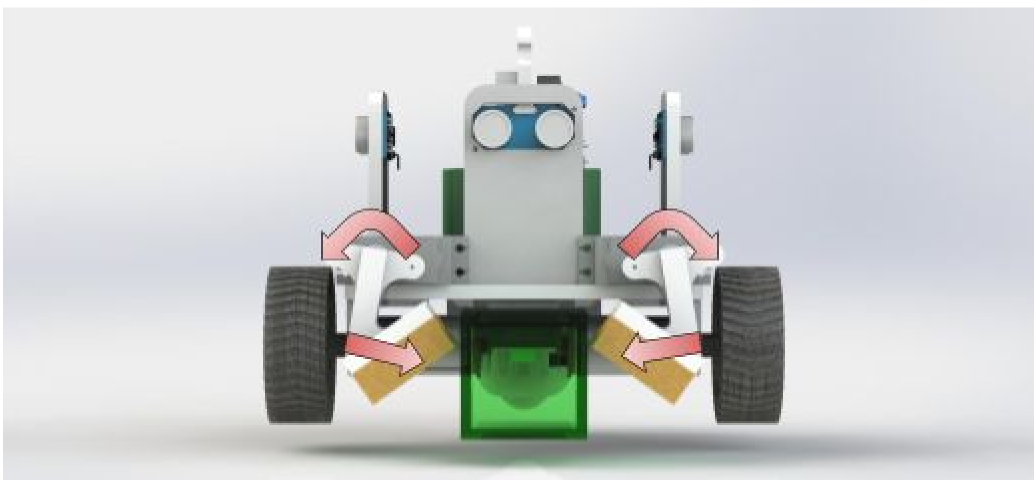


Figure 6. Rover Clamp Closing

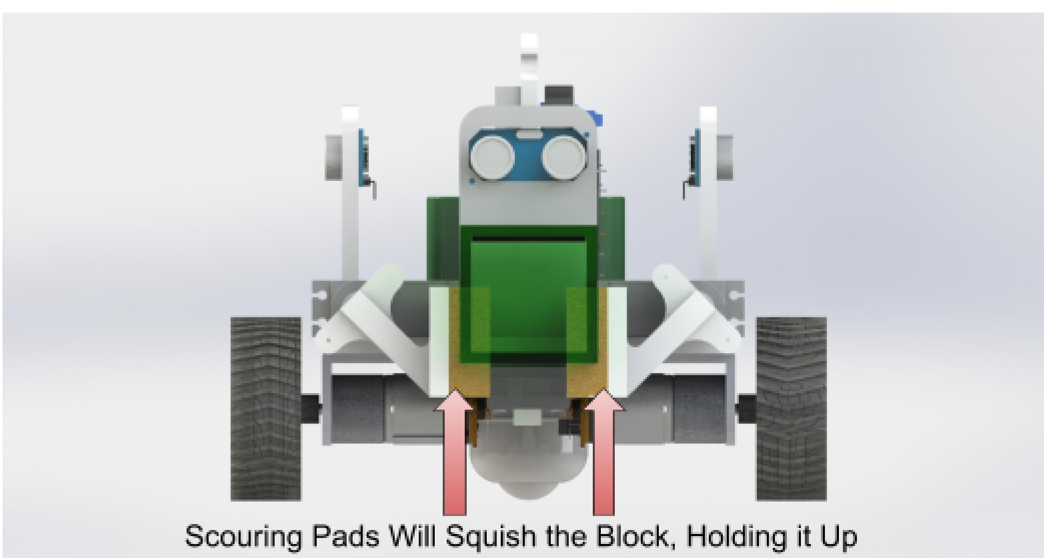


Figure 7. Rover Clamp Fully Closed

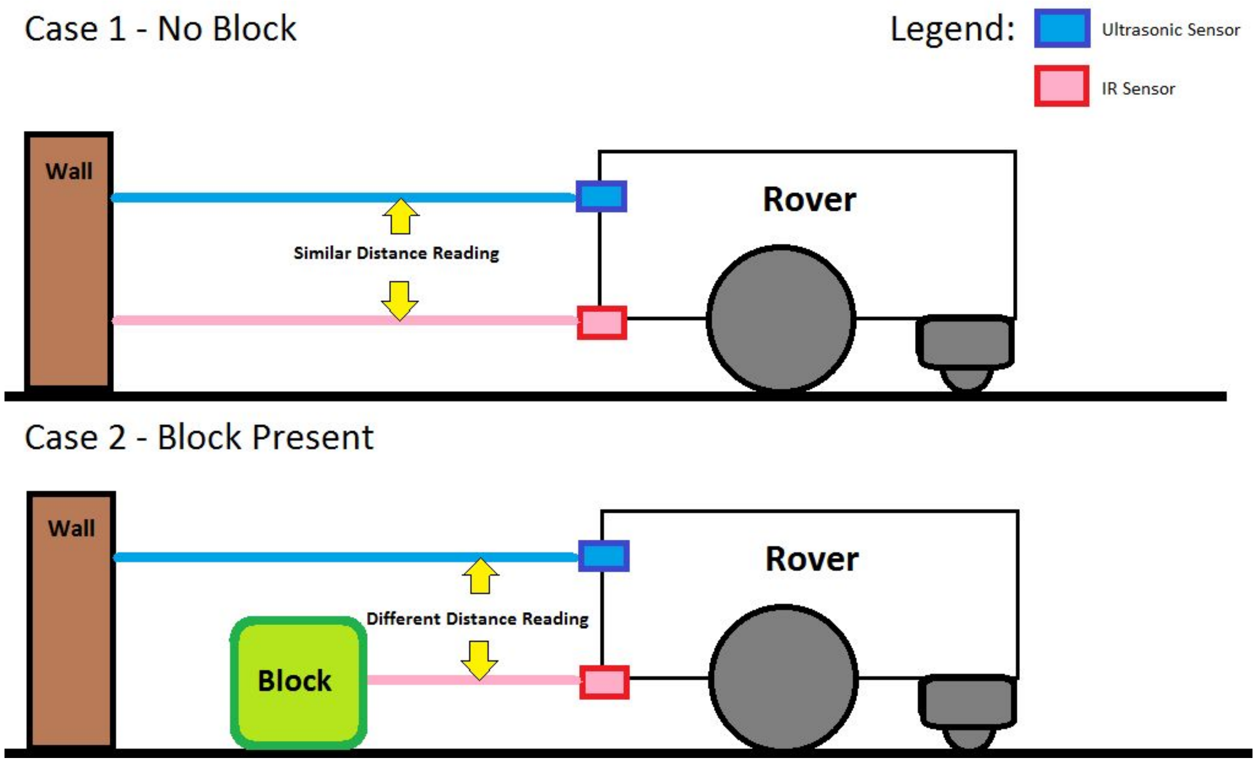


Figure 8. Sensor Block Detection

Bill of Materials

The following table lists the components required to build the rover:

Component	Comment	Quantity	Price (USD)
6V DC motor with encoder		2	$23.44
Pololu-like wheels		2	
Servo motor	Screw mounted and glued to the rover frame	2	$7.32
IR distance sensor		1	$3.37
Ultrasonic distance sensor		4	$15.16
Digital compass		1	$0.77

L298P motor controller shield	Control the motors	1	$4.19
Arduino UNO		1	$3.88
USB Programming Cable		1	$1.00
12V NiMH Battery Pack	Step down to 6V for all the motors	1	$30.26
12V Battery pack connectors		1	$5.00
DC-DC converter		1	$0.78
Ball caster (large)		2	$6.14
Breadboard		1	$1.00
Acrylic Sheets (~12" x ~12")	Laser cut	1	$11.93
Wifi ESP8266	Logic operations performed on a separate computer. The rover communicates with the computer through the Wifi module.	1	$5.26
jumper wires		30	$1.22
Screws (multiple sizes)	Secure main components (motors, ball casters, Arduino board, sensors, etc.)	18	$2.00
Portable power bank (5200mAh)	Supply 5V input voltage to Arduino board	1	$15.99
Total	**$134.99 (CA$174.89)**		

Maze Solving Strategies

Localization Strategy:

As shown in Figure 9, the internal map's orientation (up down left right) is predefined to be aligned with the maze in terms of the compass cardinal direction.

Each 1' x 1' grid of the map is then characterized into different types of zones based on their surrounding walls. See Figure 9 for locations of characterized grids and zones. "☆" grids are unique zones while Type1-5 grids are non-unique zones.

Once the rover is placed in the maze, it will re-orientate itself using the compass to face the "Up" direction. Then, ultrasonic sensors will scan the surrounding walls to identify the rover's current location. The rover will be localized if it is in any "☆" grids. Otherwise, the rover will be able to identify which type of zone it's currently in and proceed to further localization procedures described in Figure 9.

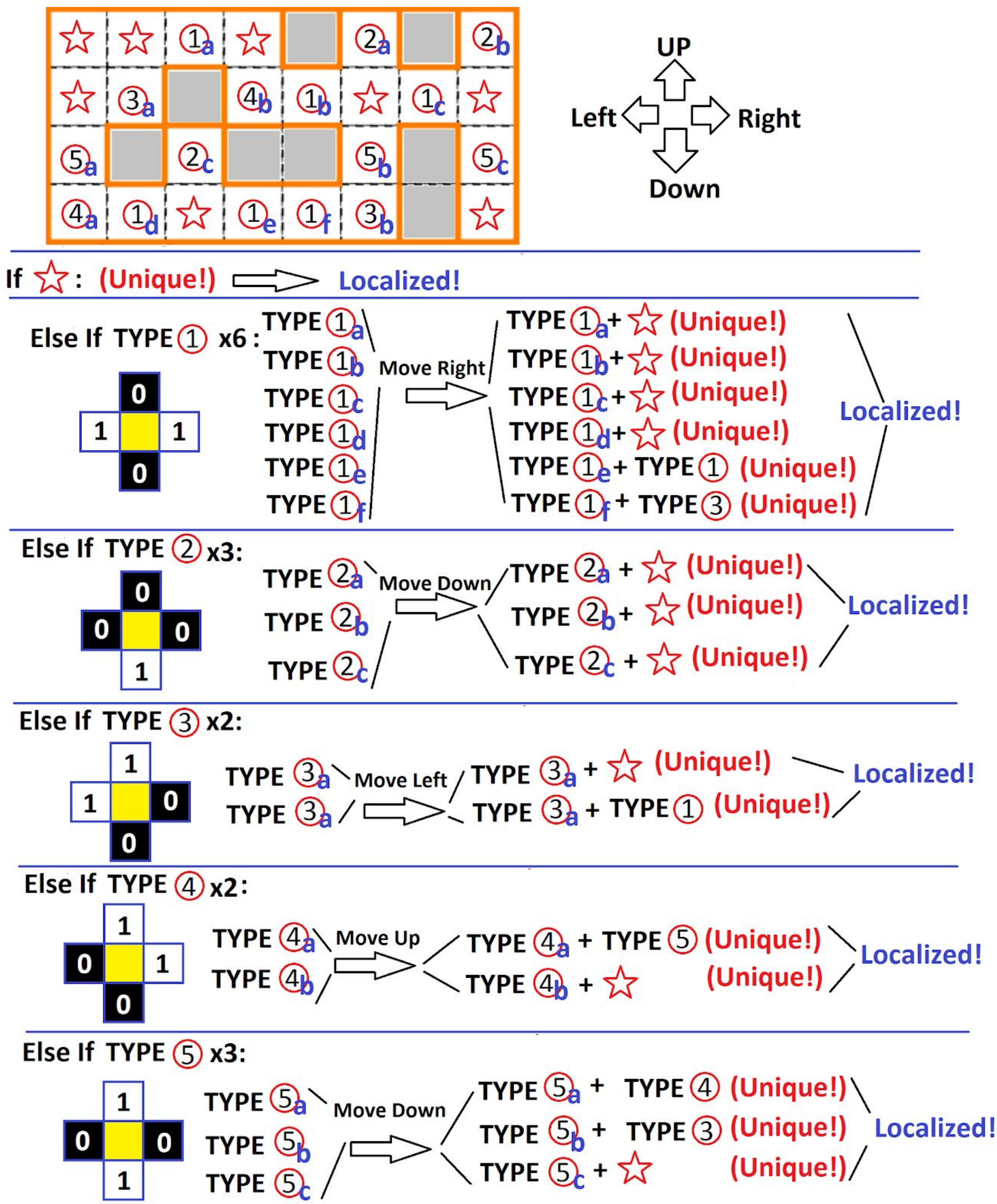


Figure 9. Localization Strategy

Target Location Navigation:

A 6*10 navigation map is shown in Figure 10 below. The target location(s) are given values of 0. All other locations are assigned with a value which represents the least number of steps needed to reach the target. Once the rover localizes itself, it will start to compare its current location with the surrounding grids and move to a lower-valued grid until it reaches the grid with the value of 0 (Target location).

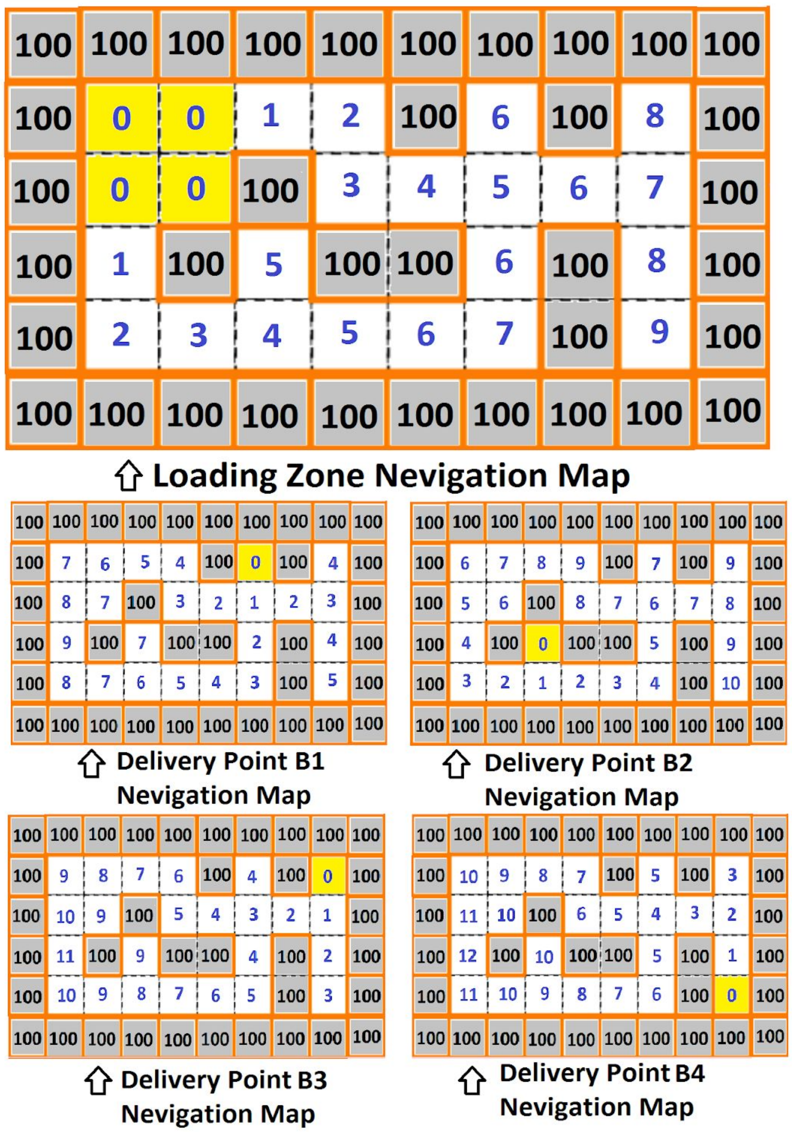
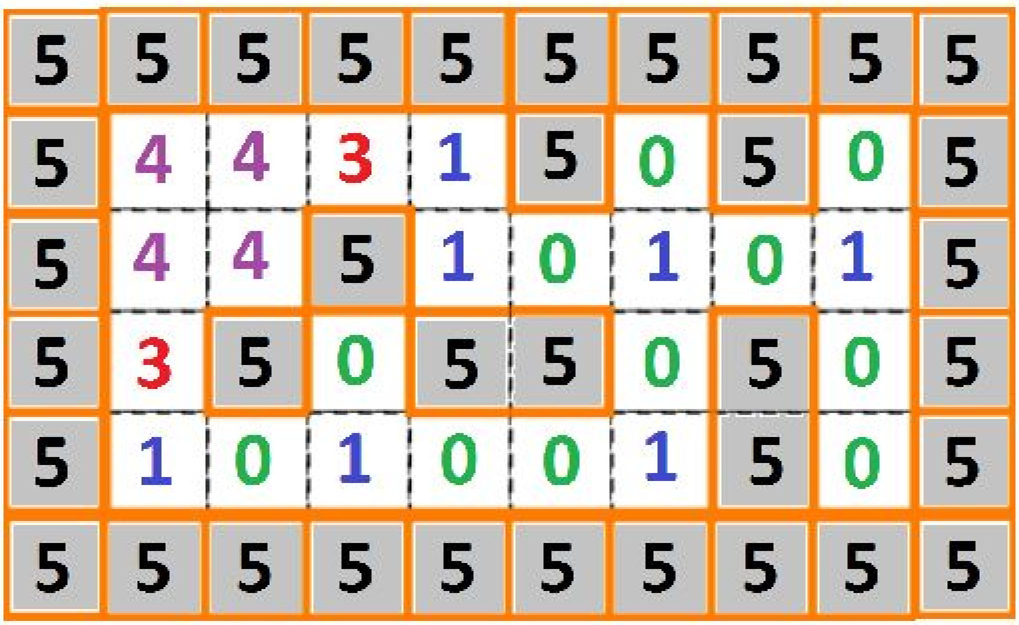


Figure 10. Navigation Maps

Maneuvering & Real-Time Location Display Strategy:

Following strategies will be applied depending on which zone the rover is in as per Figure 11. The rover will confirm its current location every time it passes a turning zone. Other non-turning zone locations will be calculated based on the tracked distance of the encoder from the last confirmed turning zone. The rover's location will be displayed on a laptop through Wifi connection.



Zone	Name	Strategy
0	Straight Zone	Forward
1	Turing Zone	Intersection Detection, Turing
3	Loading Zone Entrance	Pause and proceed to 4
4	Loading Zone	Block Searching, Block Pick-up
5	Wall	Never make contact

Figure 11.Strategies Matrix

Summary of individual tasks

The individual assignments' responsible personnel, specific goals, and timelines are listed in the table below:

	Task	Responsible Person	Goals	Timelines
1	Achieve localization with a random starting orientation, and track & display orientation during the operation.	Stephen Huang	• Identify the initial orientation • Identify the orientation after turning, which way the rover is facing. • Implement a display showing the current moving direction.	To be completed before the first milestone, obstacle avoidance
2	Provide a sound effect based on the location and task.	Yuanshan Du	• Provide sound effect to show the moving direction after each turning operation. • Provide sound effect on loading and unloading operations.	To be completed before the second milestone, localization.
3	Build a circuit which can recharge NiMH battery	Hongzheng Xu	• Build a circuit that allows charging the battery from a standard 110V Voltage source.	To be completed 1 week before the first milestone, obstacle avoidance, to support testing.
4	Robot Aesthetics	Yixiao Hong	• Ensure all the electrical connections are secured, no loose wire. • Group or identify the wires for tidiness. • Ensure no visible glue residues on the rover	To be performed before each test run and milestone showcases.

5	Program Arduino over Bluetooth	Ziqi Zhang	● Create communication between the Arduino board and the computer via a Bluetooth/Wifi module ● Be able to remotely change the Arduino code ● Oversee the rover operations on the computer. Read the data for location, direction, loading, and unloading.	To be completed 1 week before the second milestone, localization, for ease of adjustment and troubleshooting.

Contribution List:

Summarize the distribution of work. (5 points)

	Ziqi Zhang	Yuanshan Du	Yixiao Hong	Hongzheng Xu	Stephen Huang
Project Requirement	ET	FD,FP	ET	ET, MR, FP	ET
Detailed Rover Design	ET, FP	MR,FP	FD	ET, FP	FD,FP
Bill of Materials	FD, FP	ET		FP	ET,FP
Maze Solving Strategy	MR, FP	ET,FP	MR,FP	FD, ET, MR	MR,ET,FP
Summary of Individual Task		FD	ET	FP	ET

FD - First Draft

ET - Edit

MR - Major Revision

FP - Final Proofreading