RAFIK HARIRI UNIVERSITY

Intelligent Lawn Machine

A ROS Powered Autonomous Lawn Machine

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ABSTRACT

We live in a world where time is the real valuable currency. People now search for machines that can do daily routines on their own so that people can spare extra time. From this we came up with the idea of creating an autonomous lawn machine that does all the mowing responsibility on its own. To allow the machine to work on its own with minimum need of human interface, the robot is given the capability to identify its working area and avoid obstacles it might face. This machine also keeps the lawn beautifully looking by having the mower to adopt movement patterns that allow it to cover all the area. In addition to having a blade that cuts the grass in a mulching system so that it keeps the grass tidy. Because this machine works autonomously, many safety measures were applied where the costumer doesn't have to worry about any kind of danger. This machine also includes a web application for human-machine interface where you can manually control the mower through the web app.

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INTRODUCTION

Cutting grass in the past, and present, in public places, industries, fields, etc. was done using a cutlass. Because this method necessitates human effort, it is a time-consuming procedure. In addition to that, inaccuracy was observed in cutting level when manually cutting the grass. Throughout the course of history, mankind has always been evolving and advancing the tools and equipment around him, and to keep up with this advancement, we decided to build an autonomous lawn machine. and as engineering students, we are interested in such advancement and innovation, so we aimed for a project that fits our vision and ambition. And because an autonomous lawn mower machine has never been manufactured in Lebanon, we decided to take on this challenge and invent an autonomous lawn mower from our vision. Autonomous lawn mower is an intelligent robot that moves with a specific type of algorithm while cutting the grass. Robotic lawn mowers are becoming more advanced, with, some cases, self-docking capabilities, rain sensors, reducing the need of human input interaction.

This report will mention several techniques for autonomous lawn mowers. In order to reach our aim and cut the grass at the RHU campus, ROS was used to operate all the algorithms. We looked over the actions we took to attain our goal in detail in five chapters in our report.

The first chapter is a literature review that covers our past BE1 study. After that, in Chap ter 2, all of the hardware utilized in this project is detailed, as well as how it was developed, and i n Chapter 3, the ROS simulation for the Intelligent Lawn Mower is discussed. Implementation on the actual robot is discussed in Chapter 4. Finally, Chapter 5 discusses the user interface and the communication done with the robot.

CHAPTER 1

LITERATURE REVIEW

1.1 General Introduction on Lawn Mower

A lawn mower is a machine for cutting grass on a lawn. The lawn mowers blades are usually propelled forward by pushing the mower ahead. Different criteria are used to classify lawn mowers. For example, reel lawn mowers (with a horizontal axis) and rotary lawn mowers (with a vertical axis) are two types of lawn mowers (in which the axis is vertical). The reel (cylindrical) lawn mower has been discovered to be superior. They achieve a crisp cut via scissors action and are made from of blades on a revolving cylinder. The whirling blades of the mower come into contact with a stationary bar called the bed knife, which is parallel to the ground as the mower travels ahead. The mower may be set to a variety of cutting heights. Rotary mowers are typically powered by internal combustion engines or electric motors, and are mowed by hand, with the engine only spinning the cutting blades. Cutting grass is usually mulched by the rotary mowers through an opening on the side of the housing or cut where the grass is gathered in a collector connected to the outflow point. The blade only slices the grass, leaving brown tips behind. The horizontal blades, on the other hand, are simple to remove, sharpen, or replace. We can have a gasoline-powered, electric-powered, or hand-powered lawn mower, depending on the energy source. There have been several advancements in lawn mower technology throughout the years. However, as technology advances, it becomes necessary to assess the influence of robots on both the environment and humans. With a traditional gas-powered lawn mower, pollution is a serious problem. Another factor that needs to be reduced is human effort. In this study, we examine several techniques that have been developed to improve the efficiency of lawn mower operation, as well as ongoing research and development work in the respective designs (Konwar, 2016).

1.2 Motivation

Today, we live in an era in which time is the matter that everyone cares most about. People tend to look for machines that can execute daily tasks on their own so that they can save time. As a result, we came up with the thought of developing an autonomous lawn mower that acts on behalf of all the mowing chores. This would allow people to save both time and effort and put them in other tasks that matter them.

1.2.1 Goal.

An automated machine that mows the lawn on its own. The machine should cut the grass in a 20 m2 field in Rafik Hariri university

1.3 Lawn Mower Timeline

The invention of the lawn mower was on January 1, 1830. The lawn mower was created in 1830 by Edwin Beard Bunning, who patented it on August 31, 1830. He created it primarily for usage on golf courses and other similar venues. It was designed to be an alternative to using a scythe to mow grass. Edwin Beard Bunning was born in the United Kingdom. Moving blades encircled a cylinder on his lawn mower. On January 28, 1868, the reel lawn mower was patented. Amariah Hills was the one who came up with the idea. It was equipped with a spiral blade cutter. It was partly constructed of iron. In its first year on the market, it earned its creator about $100,000. A mower with improved rotating blades was patented on May 9, 1889. John Albert Burr was the one who came up with the idea. Lawn clippings were less likely to clog it up. With it, it was easy to mow near margins. It was equipped with traction wheels. A gas-powered lawn mower was created in 1919. Colonel Edwin George was the one who came up with the idea. It was more efficient than a mower powered by a steam engine. They didn't take off immediately away after being created around the time of the Great Depression. They became more popular after World War II. C.C. Stacy, a farmer, began experimenting with the rotating idea in the 1930s. He devised a blade suspension mechanism that would allow his electric lawn mower to cut equally throughout the whole grass. A self-propelled random motion lawn mower was patented on October 17, 1972. It runs on batteries. A rotary blade is used. Lawrence Bellringer was the one who came up with the idea. It detects limits and then comes to a halt. It features both front and back wheels. Several businesses produced robotic lawn mowers in 2000 that can trim a lawn without the user needing to do anything and can drive themselves to a charging station.

1.4 Reel Lawn Mower Technology

Manual reel mowers, sometimes known as cylinder mowers, were the first lawn mowers. Simply pushing one across the lawn caused the wheels to rotate, spinning a cylinder of sharpened grass-cutting blades. Manual reel mowers have a number of crucial benefits over their gas-guzzling and rotary decedents, despite the fact that the core technology hasn't evolved much in more than a century. Manual reel mowers are less expensive than gas mowers.

• They're safer than rotary mowers.

• They require low maintenance.

• They are friendly to the environment.

• Make as little noise as possible.

• They're lightweight and easy to store.

• Avoid kicking up dust or releasing toxic smells.

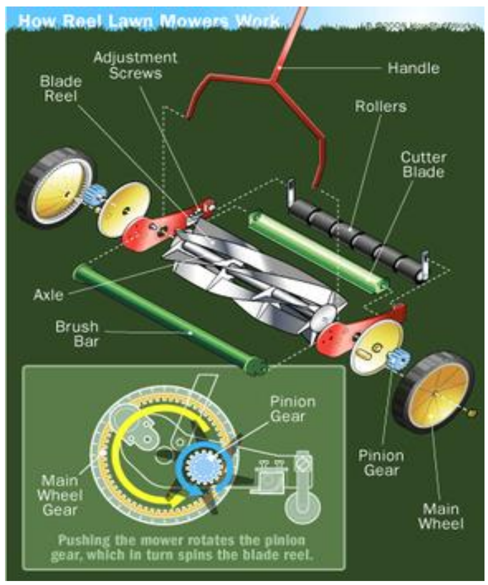

Figure 1: Reel Lawn Machine [1]

Manual reel mowers are very simple machines with only a few working parts. The mower's overall structure is best described as a miniature cart with a long handle. Most reel mowers have two major wheels on a single axle at the back, with either a bar of rollers or a series of smaller auxiliary wheels. The back rollers or wheels serve just to maintain balance, while the primary wheels provide the motion required to turn the bladed cylinder of the mower.

Following the passage of force through the mower is the easiest approach to learn how reel mower parts function.

A forceful push is applied to the handlebars. The exerted power pushes the mower forward on its wheels as it goes down the handle. The rotation of the axle causes a pair of gears to rotate. The first gear is bigger in diameter than the pinion gear, which is smaller. The torque increases as a bigger gear transfers its rotational force to a smaller gear. As a result, the reel mower's blades spin significantly quicker than the wheels (Lamb, 2008).

1.5 Gas Powered Lawn Machine

Manual and powered reel mowers are available, but rotary mowers, which have a horizontally rotating blade, require an engine. Most lawnmowers employ a variation of Briggs & Stratton's lightweight aluminum blade, which was created specifically for lawnmowers. These engines work on the same principles as automotive engines, and they fail when the key components for combustion, air, fuel, and a spark, are not balanced appropriately.

Engine operation: Unlike certain reel mowers, a rotary mower does not require chains, belts, or gears to link the blade to the crankshaft of the engine. In a two- or four-stroke combustion cycle, a single piston drives the crankshaft. The combustion of the gasoline pumped into the combustion chamber and ignited by a spark plug drives the piston down, and the piston's cyclical movement spins the blade since it is attached to the crankshaft. The engine works on a simple premise, but it requires enough fuel and spark as well as adequate air movement into the combustion chamber to function properly.

Fuel and air: The carburetor spray a combination of air and fuel into the combustion chamber through its intake port, bringing fuel and air into the combustion chamber. To increase engine performance, the carburetor may be changed to modify the strength of the mixture. In addition to the intake port, the combustion chamber features an exhaust port for releasing the combustion products. Before entering the carburetor, air, and gasoline both travel through filters, and exhaust normally flows through a spark arrestor before entering the muffler. Most lawnmower engines include a choke that improves starting by increasing the fuel-to-air ratio (Deziel, n.d.).

Some of the advantages of gas-powered lawn machines is that they are far more powerful than electric mowers. In addition to that, there is no need for wires or batteries, and is more durable, and parts for gas mowers are frequently less costly than those for electric mowers (Maxwell, 2021).

Figure 2: Gas Powered Lawn Machine[2]

1.6 Electric Lawn Mower technology

Electric lawn mowers are cost-effective, environmentally friendly, and simple to use. Their batteries last a long time, and they require far less effort than gas mowers to start up for the first mowing in the spring. Every lawn mower, of course, need a power source. Push mowers are propelled by us, whereas gas mowers are powered by gas. Electric lawn mowers, on the other hand, are powered by electricity. In today's lawn-and-garden sector, there are two types of electric lawn mowers: corded and cordless. Despite the fact that they are both powered by electricity, the distinction between them is all in the power source. Corded mowers have cords, which implies they may run for an indefinite amount of time. We can trim grass with corded mowers if the electricity goes via that socket. The cord must, of course, be longer the larger the yard. As a result, corded electric mowers are often the best choice for small lawns. Batteries power cordless mowers. Naturally, this implies that their batteries must be adequately charged to allow them to cut grass for as long as the user desires.

The electric mowers' controls include the following:

• Control Levers: These are normally hand-operated devices that are used to determine the cut level of the grass.

• Rear Rollers: Rear rollers are meant to assist flatten longer grass, and they're a great item to have around since it helps us trim our lawns when there are imbalanced grass levels. These rollers also help to keep the mower stable.

• Safety Cutoff Switches: A cutout switch is required on every electrical item to safeguard individuals who use it.

• Batteries: Cordless electric mowers are powered by batteries that must be recharged on a regular basis (Rawlins, 2020).

Figure 3: Cord [3]

Figure 4: Cordless [4]

1.7 Introduction on Robotic Mowers:

For more than two decades, autonomous and semiautonomous robotic lawnmowers have been on the market. The Husqvarna Automower was the first fully solar-powered robotic mower, and the second-generation versions of these machines, introduced in 2004, could cut a large area by following a boundary or guide wire, as well as locate their charging stations via radio transponders and automatically return to charge when they were finished. A basic mapping system is used by autonomous mowers. The user places a boundary wire around the perimeter of the area they wish to trim, which may also be extended to cover obstructions in the lawn's centre. When the robot senses that it is approaching the wire, it changes course in a random direction to avoid it, as well as avoiding leaving unattractive track marks in the lawn by crossing many times. Advanced models incorporate 360-degree laser or radar sensors to detect obstructions or oncoming threats in their route. While almost no robot mower design is large enough to harm a person or animal it collides with (aside from a possible mild bruise as the perplexed machine bumps gently against your ankles), this system (along with an integrated automatic shutdown and alarm feature if the mower collides with something) makes these machines safer. Even the cheapest models feature a front bumper collision sensor that spins them around if they collide with something. A random-mow mechanism is used by most automowers. When their batteries run out, they'll travel in a straight path until they strike something, then spin around and drive in a new route, finally covering the entire lawn before returning to their charging station. Robot mowers mow continually to keep the grass at a manageable length, therefore they don't normally mow the entire lawn at once. Some versions include random-walk algorithms into a more planned grid-mow pattern, leaving your lawn nicely aligned while yet allowing the mower to overcome all obstacles and reach all corners of the mowable area. Some even have GPS systems that may be used to create custom routes and patterns. Most others, at the very least, have on-board control panels. Husqvarna's auto mower comes with an app that allows you to monitor the mower and set cutting times. The majority of robot lawnmowers are geared for home usage, but technology is improving, and larger versions are on their way, providing 24-hour cutting over broad areas in all weather situations. Some people will never want to give up the simple pleasure of mowing the lawn, and there will always be a market for human-operated machines, but for those looking for something more convenient, robot lawnmowers are now competitive enough that, while expensive, they are comparable to a regular petrol lawnmower in terms of labor savings, fuel costs, and cut quality for the same medium-sized gardens (How on Earth do Robot Mowers Work, n.d.).

1.8 Robotic Mowers in the Industry:

1.8.1 Husqvarna

Husqvarna is a renowned manufacturer of robotic lawn mowers. Here are some of the characteristics offered by their robot:

• It can cover the whole work area: The guide wire ensures that Automower® reaches even the most remote work locations. It also assists it in determining the quickest route back to the charging station, so conserving energy and eliminating noticeable traces.

• Fits into tiny spaces: The Husqvarna Automower® detects narrow openings and navigates through even the tiniest gaps.

• Works in the rain: Husqvarna Automower® provides excellent cutting results in all weather conditions. Its important components are protected from rain, dust, and grass clippings.

• It charges automatically: Automower® returns to the charging station on its own. It recharges for roughly 60 minutes before returning to mowing – all without your intervention.

• It's quiet: You'll be astonished at how fast you forget about your Husqvarna Automower®. As it rolls around your garden, performing its work fast, quietly, and effectively, you'll scarcely notice it.

• Handles slopes: The Husqvarna Automower® can handle inclinations of up to 45 percent thanks to its optimized design and intelligent behavior.

• GPS navigation: An integrated GPS system builds a map of the garden, including the location of the boundary and guide wires. Husqvarna Automower® will then keep track of which areas of the garden it has mowed and alter its mowing pattern accordingly. This will provide optimal grass coverage as well as a superior cutting outcome. (On a limited number of models)

• Remote object detection: Automower® detects things in the cutting path using ultrasonic technology. Slowing down to gently bump against the thing, the mower turns and continues its job (DM CHAINSAWA, n.d.).

1.8.2 Honda Miimo

HONDA is another well-known manufacturer of robotic mowers. The Honda Miimo is a self-driving lawn mower with the following features:

• 3 Cutting Patterns: To maximize its performance on varied lawn sizes and shapes, Miimo provides three major programmed cutting patterns: Random, Directional, and Mixed.

• Distinctive Blades: Miimo's three special blades are long-lasting, sturdy, and efficient. The blades rotate between clockwise and counterclockwise spinning automatically, reducing wear and extending blade life. If a hard item is struck, the blades swing back into the blade disc, limiting damage.

• 360° Awareness Sensors: Miimo detects obstructions using powerful sensors and a floating cover. Miimo detects any contact and switches course instantaneously. And because Miimo detects that it is being lifted or tilted, the blades are instantly stopped. Miimo – and its surroundings – are kept secure thanks to these clever sensors.

• Recharging System: Miimo's long-life lithium-ion battery is not only a silent power source, but also a very cost-effective power source. Miimo is also clever, so when it runs out of power, it returns to its docking station to recharge.

• Quiet Operation: Because Miimo is an electric mower, it is quite quiet. If you need it to be even more stealthy at night, simply switch to silent mode. Miimo has the ability to minimize noise even more.

• Handles Slopes and Obstacles: Miimo can tackle even the most difficult lawns. Miimo is capable of mowing steep slopes of up to 25 degrees. It can easily go through ponds, flower beds, tiny corridors, swimming pools, trees, and other obstacles.

• Simple to Adjust Cutting Heights: With the turn of a knob, Miimo's cutting heights may be adjusted from 0.8" to 2.4".

Miimo's regular, little cuts produce tiny grass bits that enrich your lawn. Miimo's frequent mowing also makes it difficult for weeds to establish themselves. As a result, your grass is becoming healthier and more attractive every day (California prop 65 information. Honda Power Equipment, n.d.).

1.8.3 WORX Landroid

Worx Landroid is another another robot mower on the market, with the following features:

• Cutting pattern: Landroid patterns are determined by an algorithm, which may appear random at first glance, but this approach assures that your whole lawn gets mowed, even in the tightest of areas.

• Mowing time: The biggest advantage of robot mowers is that they mow your lawn more frequently than you do and maintain it properly groomed all year. Worx's landroid can mow 85m2 per hour.

• Mowing area: Worx Landroid provides three robot mower types that cover areas ranging from 500 to 1500 square meters (Worx Landroid, 2022).

1.8.4 Segway Navimow

The Segway Navimow's most striking feature is its Exact Fusion Locating System. Segway has included GPS locating in its mower, which eliminates the need for a perimeter wire. With GPS location, you can achieve an even trim all the way to the lawn's margins with no extra effort.

• The Segway Navimow's most notable feature is its Exact Fusion Locating System, which uses GPS navigation. Segway has included GPS locating in its mower, which eliminates the need for a perimeter wire.

• Cutting-edge algorithm: This robot mower is always analyzing the optimum path that removes any repetitive patterns so that no region is repeated needlessly, thanks to a cutting-edge algorithm.

• Versatile: Depending on the layout of your yard, you can simply create multiple zones with the Segway Navimow. The mower quickly adapts to various terrains and may be programmed to avoid "off-limits" zones and build speedy transit between them.

• Safe: With five safety sensors, you can be certain that your mower will stay on track and won't cause any damage, such as bumping or lifting.

• BladeHalt technology: BladeHalt technology is also available on Navimow. The blades will immediately cease rotating if the sensor region is touched.

• Auto Charging: The Navimow garage includes an integrated charging station as well as an overhead roof that provides additional protection from the elements such as rain and sun (Jason, 2022).

Specification and Feature																
Working area	up to 400	m^2	up to 1,100	m^2	up to 700	m^2	up to 900	m^2	up to 1,600	m^2	up to 2,000	m^2	500	m^2	800	m^2
Charging time	45	min	60	min	60	min	90	min	60	min	90	min	65	min	65	min
Working capacity	29	m^2/h	32	m^2/h	32	m^2/h	26	m^2/h	38	m^2/h	32	m^2/h	35	m^2/h	38	m^2/h
Cost	995	£	1599.95	$	1190	£	1199	$	1199.99	$	1299.96	$	1,425	$	1,781	$
Weight	8	kg	20.7	lbs	7.6	kg	42.5	kg	20.7	lbs	46.8	kg	N/A		N/A	
Mowing time per charge	50	min	60	min	75	min	65	min	60	min	75	min	60	min	75	min
Battery type	Li-on	18 v	Li-on	18 v	Li-on	18 v	Li-ion	20v	Li-on	18 v	Li-on	20v	Li-on	20v	Li-on	20v
Battery capacity	2.5	Ah	2	Ah	2.5	Ah	4	Ah	2	Ah	4	Ah	5.2	Ah	5.2	Ah
Noise level	63	db	60	db	63	db	60	db	60	db	60	db	54	db	54	db
Maximum incline mowing area	15	degree	15	degree	15	degree	20	degree	20	degree	20	degree	20	degree	25	degree
Length x width x height	445x364x202	m	23.2x17.7x10.6	in	445x364x202	m	21.7x15.91x8.07	in	23.2x17.7x10.6	in	24.8x17.2x8.86	in	N/A		N/A	
Cutting diameter	190	mm	8.7	in	190	mm	7	in	8.7	in	9	in	8.26772	in	8.26772	in
Blade width	19.05	in	35.56	cm	19	cm	17.8	cm	14	in	23	cm	21	cm	21	cm
Blade material	steel titanium coated blades	H44TN1	carbon steel	SAE 1018	steel titanium coated blades	H44TN1	stainless steel	304	carbon steel	SAE 1018	stainless steel	304	stainless steel	304	stainless steel	304
user interface	Touch screen		Touch screen		Touch screen		Touch screen		Touch screen		Touch screen		Touch screen		Touch screen	
Type of drive	Four-wheel drive		Four-wheel drive		Four-wheel drive		Four-wheel drive		Four-wheel drive		Four-wheel drive		Four-wheel drive		Four-wheel drive	
Range of communication	58	m	58	m	58	m	152	m^2	58 +	m	152	m	152	m	152	m
Awareness Sensors	included		included		included		included		included		included		included		included	
Cutting Patterns	Random /spiral		Sytamic		Random /spiral				Sytamic				Sytamic		Sytamic	
Tilt Sensors	Included		Included		Included		Included		Included		Included		Included		Included	
Collision Sensors.	Obstruction sensor		Anti-Collision Sensor		Obstruction sensor		Anti-Collision Sensor		Anti-Collision Sensor		Anti-Collision Sensor		Anti-Collision Sensor		Anti-Collision Sensor	
Theft Protection		Included		Included	Included		Included			Included		Included		Included		Included
cutting type	mulching		mulching			mulching		mulching	mulching		mulching		mulching		mulching	
schedualing mowing time	Included		Included		Included		Included		Included		Included		Included		Included	
Boundaries setup	Boundary wire		virtual boundary		Boundary wire		Boundary wire		virtual boundary				virtual boundary		virtual boundary	
Automatic charging	Included		Included		Included		Included		Included		Included		Included		Included	

Table 1: Table of Competitors

1.9 Standards

The standard used in all these robotic mowers already in the market is ANSI/OPEI 60335-2-107-2020: Particular requirements for robotic battery powered electrical lawnmowers. This standard specifies safety requirements and their verification for the design and construction of robotic battery powered electrical rotary lawnmowers and their peripherals with the rated voltage of the battery being not more than 75 V d.c. This Standard deals with all the significant hazards presented by battery powered robotic lawnmowers and their peripherals when they are used as intended and under conditions of misuse which are reasonably foreseeable.

1.10 Algorithms

Autonomous and Manual are the two different operational modes.

• Autonomous mode: Path planning is critical to the cleaning robot's efficiency. Path planning is focused on four different algorithms (Path planning algorithm development for autonomous vacuum cleaner robots, 2014):

i. Random walk
ii. Spiral
iii. 'S' shape pathway
iv. Wall follow

1.10.1 Random Walk

The robot goes ahead until it detects an obstruction, at which point it comes to a complete halt. Then it turns by comparing sensor data from the left and right directions, and finally it chooses how much to turn by creating a random number. The robot's front bumper features two bumper sensors, which detect when it collides with an object. A random stroll does not necessitate the exact execution of a route plan.

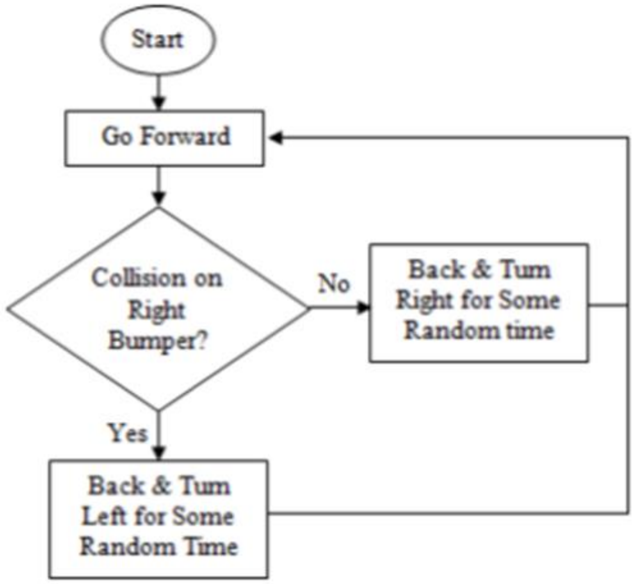

Figure 5: Random Walk Block Diagram [5]

1.10.2 Spiral Algorithm

This method enables the robot to form a larger circle. First, the robot determines whether there is sufficient space to begin spiraling. The robot then moves in a left-hand-side (LHS) direction, expanding its radius from the center point until it detects an obstruction. This method aids in the rapid covering of the room's surface area.

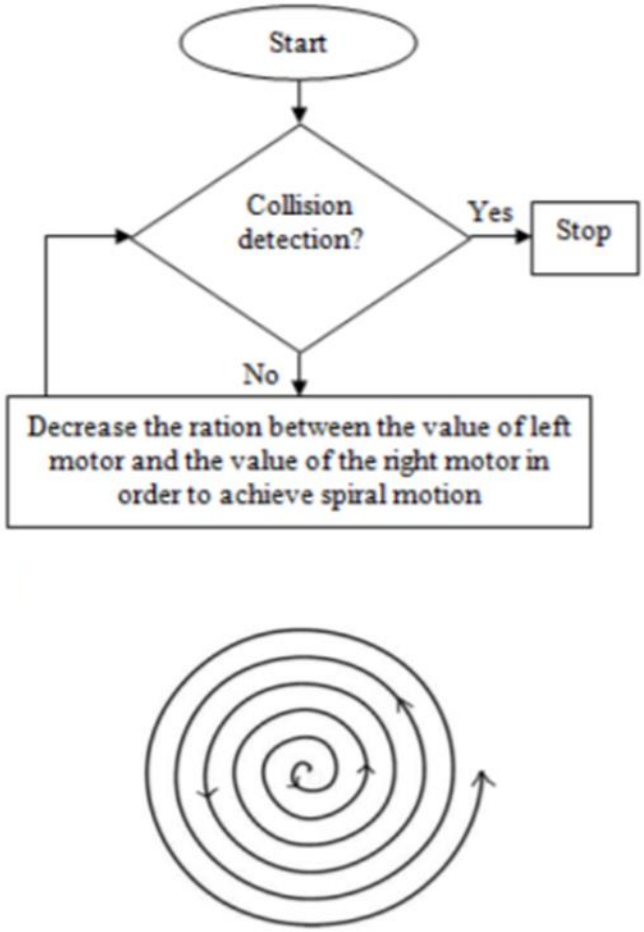

Figure 6: Spiral Algorithm Block Diagram [5]

1.10.3 ‘S’ Shaped Pathway

This algorithm's route map resembles the letter 'S.' This is the quickest way to cover a room's full surface area. Under this mode, the robot's turning direction changes with each encounter with an object.

The robot's body is shaped like a circle. The robot has a sequence of moves following each collision in this method. They are as follows:

a. Back

b. 90 Degrees (Left/Right)

c. Go

d. 90 Degrees (Left/Right)

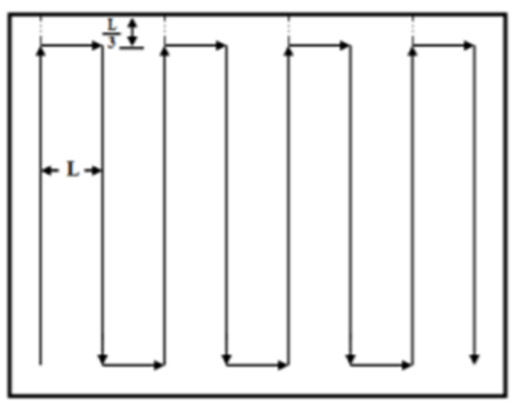

Figure 7: 'S' Shape Pathway [5]

1.11 Specifications

These are the specifications for our robot. These specifications are chosen based on what competitors found best. In addition to what the team concluded is best after concluding the survey findings.

Dimensions:	
Length	50 cm
Width	35 cm
Height	15 cm
Mass	10-12 kg
Working Area	100 m^2 Bounded Area

Operating Time &	
Operating time	1 hour
Charging system	Manual

Cutting specs:	
Cut height	5-6 cm fixed
Cut width	15 cm
Max slope	20 degrees
Cutting blades	1 rotating blade
Blade Type	Mulching and hard enough not to break while cutting
Blade rotation	Very high RPM to ensure cutting
Max grass length	15 cm

Control	
user interface	Web app + Manual control
Communication	Stable for streaming in a relatively far range

Features
Autonomous
Obstacle Avoidance
Video Streaming

Safety Features
Lift Detection
Tilt Detection
On Robot Emergency Button
Wireless Emergency Button

Figure 8: Specifications

1.12 Constraints

- Camera Vision had several constraints. Coding the algorithms using camera vison wasn't as correct as planned. In addition, there were issues have to do with time and functionality. Thus, it was opted to use lidar instead of camera vision.
- 100m2 area was huge for a proof-of-concept project, hence the target area cutting size is set to be 20m2. To operate on 100m2 operation time will be much huger thus battery sizing will differ in addition to the dimensions thus the weight and therefore we'll need bigger motors. The cost will be much higher.
- If area had too many tight areas manual mowing might be needed. Thus, manual mowing option was added to the robot.

Chapter 2

Design and dimensions

In this chapter, the design phase of our robot is displayed

2.1 Shape and dimensions

- To have a lawn mower small enough to fit in tight areas and not be too heavy, yet big enough to get a good cutting diameter while operating, the following design and dimensions are taken.
- It is a rectangular robot.
- Front side is inclined giving the robot a beautiful yet simple design. The Camera for Video Streaming will be implemented in the front part of the robot.
- The Lidar will be placed on top of the robot
- The dimensions are 50X35X15 cm in length width and height as mentioned in specifications.

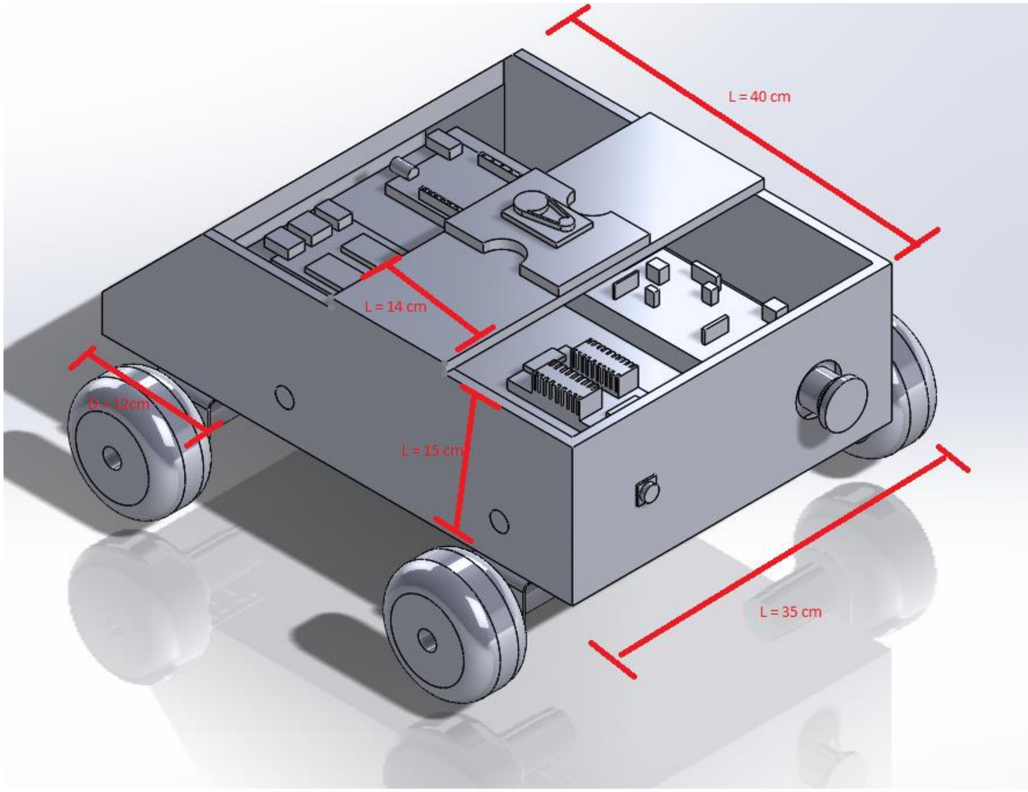

Figure 9: Cad Drawing of Machine

2.2 Drivetrain

For the drivetrain we had multiple options at hand, differential wheels continuous track, or 4 wheels drivetrain system which had different wheel types aswell. Each had its pros and cons. For example, the differential 2 wheels are less precise, Mecanum and omni wheels are bad for operating on grass, and the continuous track needs relatively high power for turning and is less accurate. Eventually the most suitable drivetrain for our robot is the standard 4 wheels.

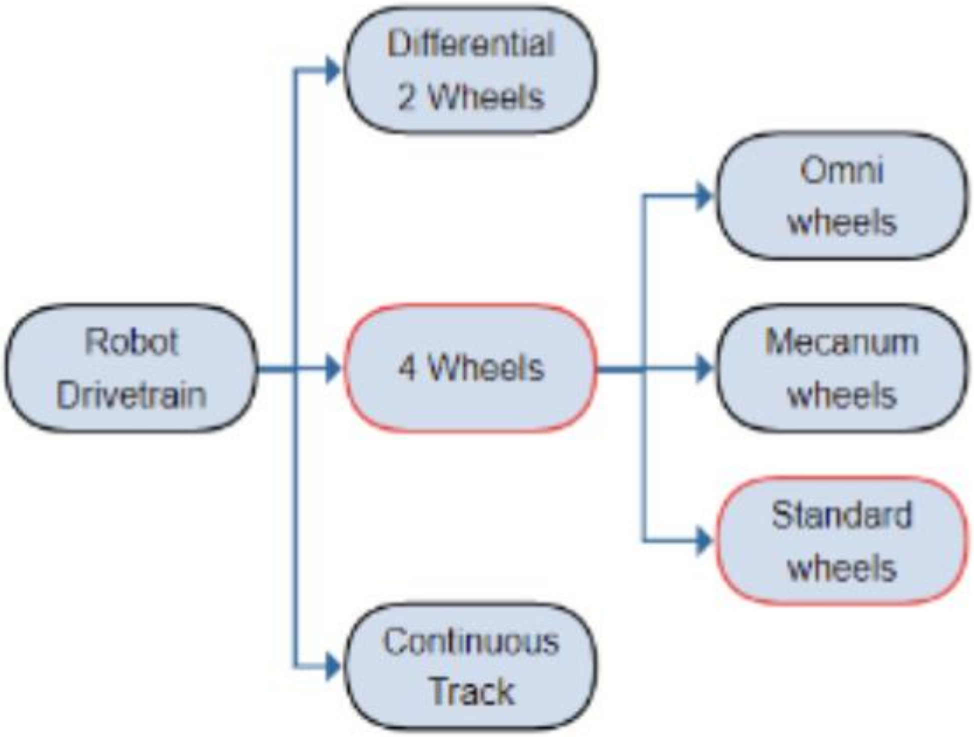

Figure 10: Drive Terrain Flowchart

2.3 Design Of wheels and Motors Position

The wheel motors are connected below the lower sheet in the robot as seen in the figure. This helps the robot gain additional height off the ground so that the blade sits on a suitable height. To form symmetry each motor was set 8 cm away from each corner. The total height of the robot from the ground is 8 cm. As for the wheels themselves, they are rubber wheels of 12 cm diameter.

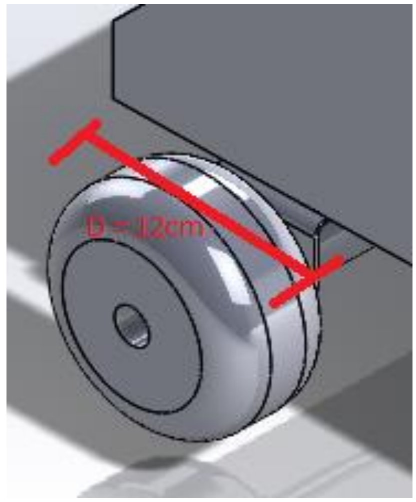

Figure 11: Diameter of wheel

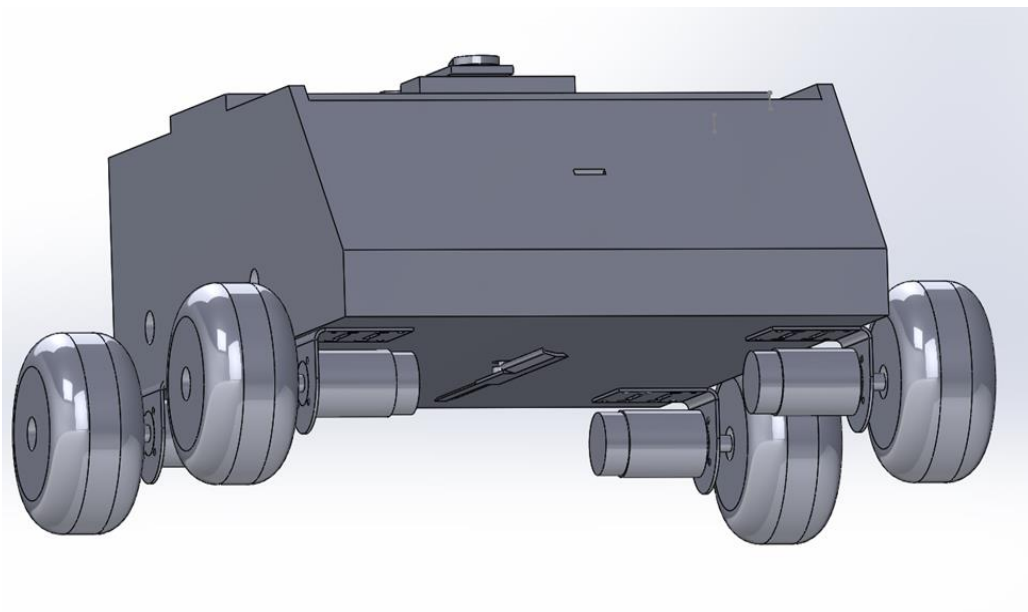

Figure 12: Front view of machine

Figure 13: Real wheel used

2.4 Weight of the system

Now moving on to an important design issue which is the weight of the system. The chosen material for constructing the body of the robot is aluminum 3003. The material is found good for its weight in general and because its not very difficult to cut, bend or screw the sheets to manufacture the body we want. After adding the weights considered the robot was within target specification.

Table 2: Table of Weights

one lower aluminum sheet 35 x 50 cm	**1.4 kg**
one Back view aluminum sheet 15 x 35	**0.45kg**
Two side view aluminum sheets 15 x 50	**1.2kg**
one front view aluminum sheet 25 x 35	**0.7**

Five motors. 4-wheel motors and 1 for the blade	**~ 2 kg**
Four wheels	**~ 0.5kg**

Electronic components weight is negligible. Total weight of system is approximately 6.2 kg (still less than target specification)

2.5 Torque calculation

1. We take gravitational force to be 10
2. Wheel is 12 cm diameter.
3. Total weight of the chassis with the components a total congruent to 10 Kg.

$$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$$

Equation 1: Torque Equation

Grass coefficient is 0.35 when the condition of the grass is clean and dry (Friction Coefficients and Calculator, 2004).

Total torque = Force*Radius = Mass*Gravitational force*friction coefficient*Radius

=10*10*0.35*0.06= 2.1 N.m

since we have 4 motors so total torque is divided by 4, thus Total torque needed on 1 motor is 2.1/4=0.525 N.m

Safety factor = 0.525*1.5 = 0.78 N.m per motor Per motor.

2.6 Wheel motors:

Figure 14: Wheel motor [14]

Performance Range	
Voltage:	12VDC
Speed:	1~120rpm
Torque:	~1 N.m

Table 3: Motor Performance Range Table

As stated above in the performance table the torque that is said to be used fits our designated value that is calculated above which is ~ 1 N.m. rated power (24 W).

2.6.1 Arduino DC Motor Drive 12A

According to the chosen motor the designated maximum current would be:

$$I = \frac{P}{U}$$

Equation 2: Current Equation

Power is equal to 24 W and the voltage is 12 V, so by substituting the numbers to equation 1, the current will be:

$$I = \frac{24}{12} = 2\ A$$

Equation 3: After substituting in Equation 1

Figure 15: 412 Arduino DC Motor Drive 12A [15]

2.7 Blade

2.7.1 Blade design

Moving on to the blade, the blade should be strong not to break and also sharp to cut the grass properly there are different types of blades that could be used. To avoid the need of collecting the grass, we need a mulching blade. Mulching cuts the grass into miniscule pieces. For mulching to occur. The blade should be manufactured as shown in the image. This way the grass would be cut into miniscule pieces. The blade is going to be manufactured using stainless steel to match specifications.

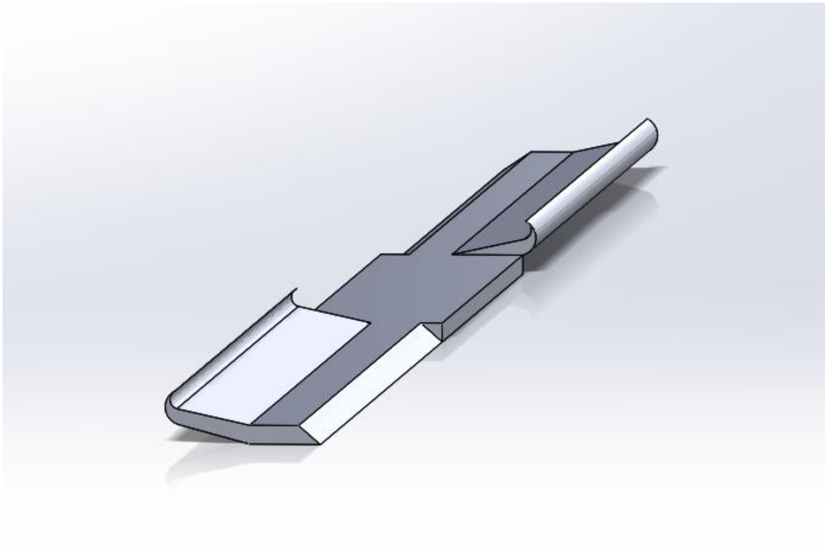

Figure 16: CAD Drawing of Blade

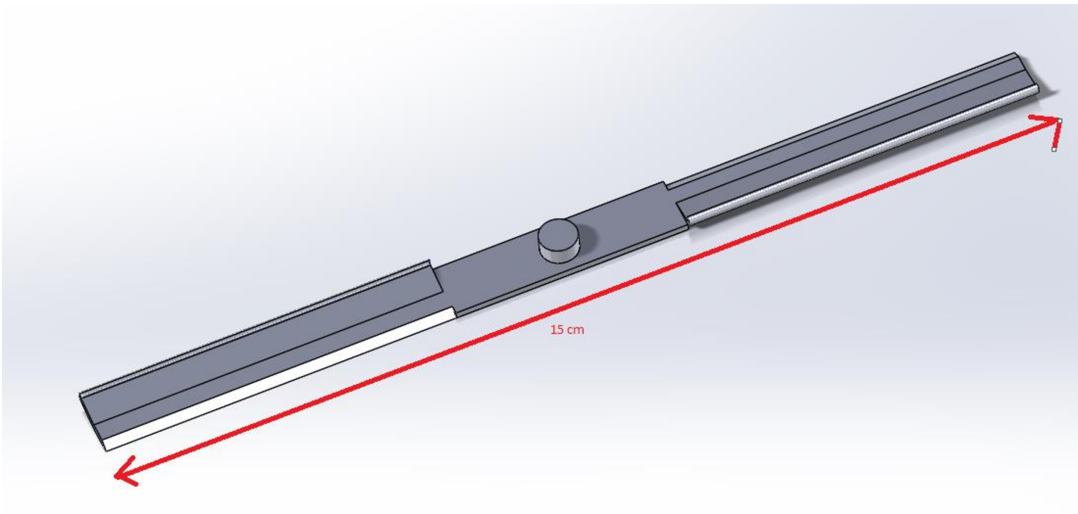

Figure 17: CAD Drawing of Blade

2.7.2 Blade motor

Specification:

1. Voltage: 12V DC
2. No-load speed: 550/1000 rpm
3. No-load Current: 0.55A

Figure 18: Blade's Motor [16]

2.7.3 Cutting height

In the design of the robot, it is crucial to know the cutting height needed. This has to do with how high we want to place the blade from the ground. After searching for ideal grass length, the targeted height of the grass after cutting is set to be 5-6 cm. Thus, the blade must be 5-6 cm above the ground.

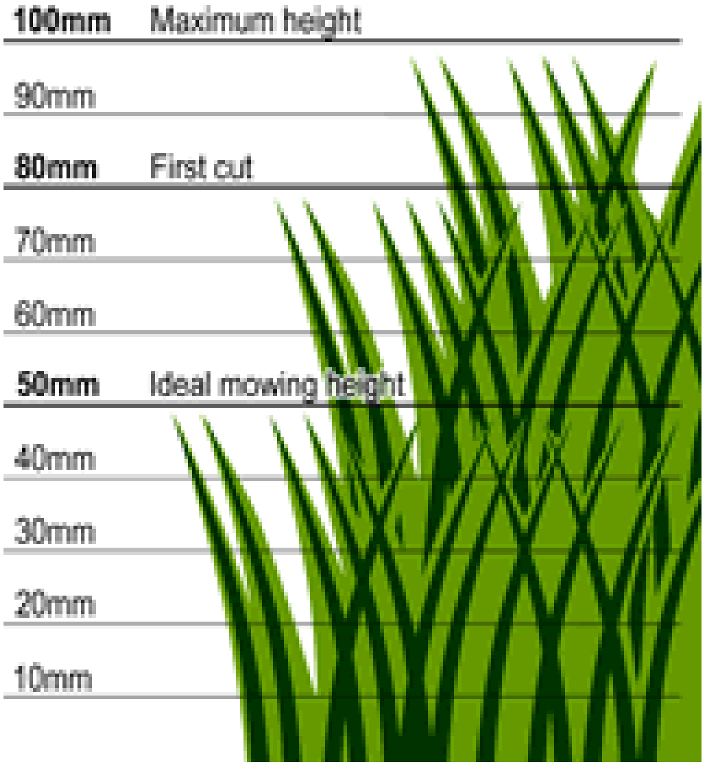

Figure 19: Grass Height

2.8 Battery

2.8.1 Power Consumption

Component	Voltage Level	Current Level
Lidar	5v	400mA 0.4A
ADXL345 3-axis Accelerometer Sensor:	5v	5uA~ 0.0000049

RASPBERRY Pi CAMERA RPI 5MP	5v	250mA ~0.2A
DC INA219 SENSOR	5V	0.61A
Raspberry Pi 3 B+ Model	5v	2.5A
Buck Convertor LM2596S DC-DC 24V/12V To 5V 5A	5V	~2.77A (-5*5+5*5/0.9)
4x 120 rpm Planetary Gear Motor Full Load	12v	0.6A x4
L298n motor drive	12v	36mA=0.036A
412 Arduino DC Motor Drive 12A	12v	1A
Total Power	U*I	71.7W

Table 4: Power Distribution Table

Total power:

$$P(total) = P * Safety\ Factor$$

Equation 4: Power Equation

$$71.7 * 1.5 = 107.55\ W$$

Equation 5: After substituting equation 3

2.8.2 Battery Type

According to the power table that is stated above the designed power is said to be 71.7W after multiplying it with the safety factor the required total power would be 107.55W
So, the required battery should supply 107.55W after researching for the best battery we had come across the Li-Poly Battery.

To know how much Watt Hours the battery provides, we simply use the equation Wh=Ah*V thus this battery provides 5Ah*22.2V=111Wh which allows the mower to function for an hour. The C Rating is simply a measure of how fast the battery can be discharged safely and without harming the battery. Calculating the C-Rating of our battery: 50 x 5 = 250A

The resulting number is the maximum sustained load you can safely put on the battery. Going higher than that will result in, at best, the degradation of the battery at a faster than normal pace. https://rogershobbycenter.com/lipoguide#:~:text=50C%20%3D%2050%20x%20Capacity%20(in,a%20faster%20than%20normal%20pace.

Figure 20: Li-Poly Battery [17]

2.9 Camera

A camera is included in our robot for video streaming. The camera will be placed in the front side of the robot so that you get a first-person perspective while driving the robot.

Figure 21: Camera

2.10 Safety features

Our machine could easily be considered dangerous, therefore we should design safety features for the robot. Several safety features are included such as on robot emergency button, tilt/lift sensors, and wireless push button. The emergency push button powers off the whole system. Whereas the wireless button and the tilt/lift sensors would only turn off the robot's motors.

2.11 Flow Chart of components

This here is the flow chart of components: Battery gives power to the raspberry pi. Which has the lidar and the Rpi camera connected to it via usb port and csi camera port respectively. The raspberry pi is connected to an arduino mega via usb port which sends commands to the motordrives therefore motors. As you can see the safety features are all added: The emergency push button is placed right after the battery, the relays are connected so that the wireless push button shuts off the motors. The accelerometer(to detect lifting tilting)is connected to the arduino. A buck converter is added to establish power correctly for the system.

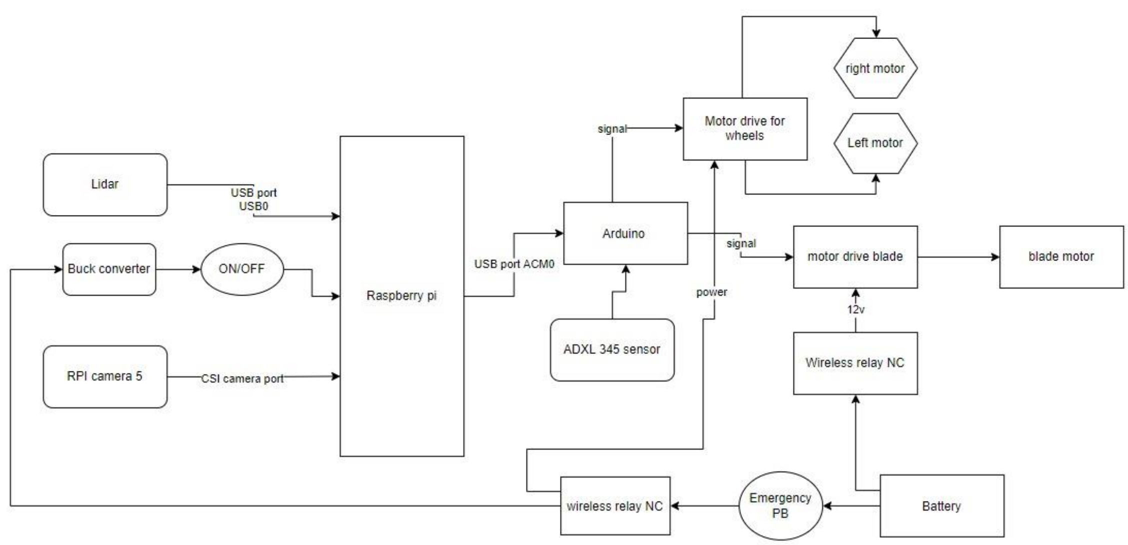

Figure 22: Flow chart of compionents

2.12 BOM (Bill of Material)

Component	Cost
Lidar LDS-01	**X**
ADXL345 3-axis Accelerometer Sensor:	2$
RASPBERRY Pi CAMERA RPI 5MP	5.5$
DC INA219 SENSOR	4$
Raspberry Pi 3 B+ Model	73$
Buck Convertor 36 DC Convertor DC to DC PCP down 75 W	2.5$
4x Gear Motor	46$
L298n motor drive	2.75$
Blade DC Motor	10$
Steel Sheet	21$
Li-Poly Battery 500mAh	50$
Total	216.75$

Table 5: Bill of Material Table

Chapter 3

Simulation

To make sure the robot is to cover the full area, simulating the work on the PC is a Must. Simulation was the hardest part in this project because many algorithms had to be tested. First An environment on gazebo is to be made. Then The Teleop Function was tested on simulation in a sense where the robot is controlled using PC. After making sure the Teleop function works several algorithms such as S-shape, Random, and our own Multi-patterned Algorithm were tested on the Turtle Bot. Right after, the algorithm chosen was tested on multiple different areas so that it is assured that it works regardless of the shape of the Area.

3.1 Creating an environment on Gazebo

The targeted area set is a $20m^2$ box. 4 walls were constructed in a sense were the area inside is equal to the targeted area. A green ground was added to for a realistic view. Decorative items outside the area such as a table, trashcan, and mailbox were added to the mimic environment so that it feels more like a real home environment. (The added decorative items are not obstacles inside the targeted area.) Inside the walls a turtlebot 3 is added.

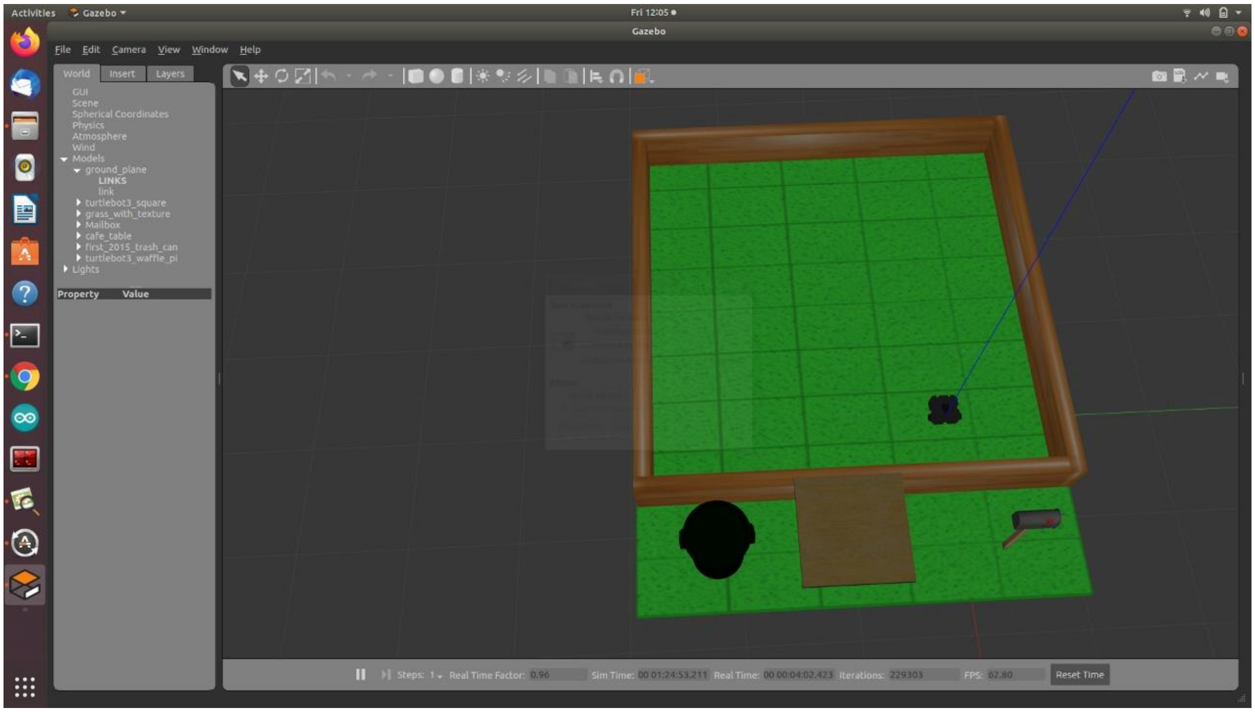

Figure 23: Environment

To bring up the environment, the following commands are to be placed:

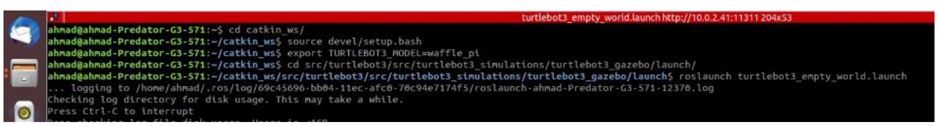

Figure 24: Terminal for the Environment

3.2 Simulating Teleop

Teleop function testing was an instant success. Where the WASDX keyboard keys were used to test the speed and direction of the robot. Pressing a key multiple times increases the Robot's speed in a certain direction (ex: W moves forward, D increases angular speed right) till it reaches the maximum speed set in the code.

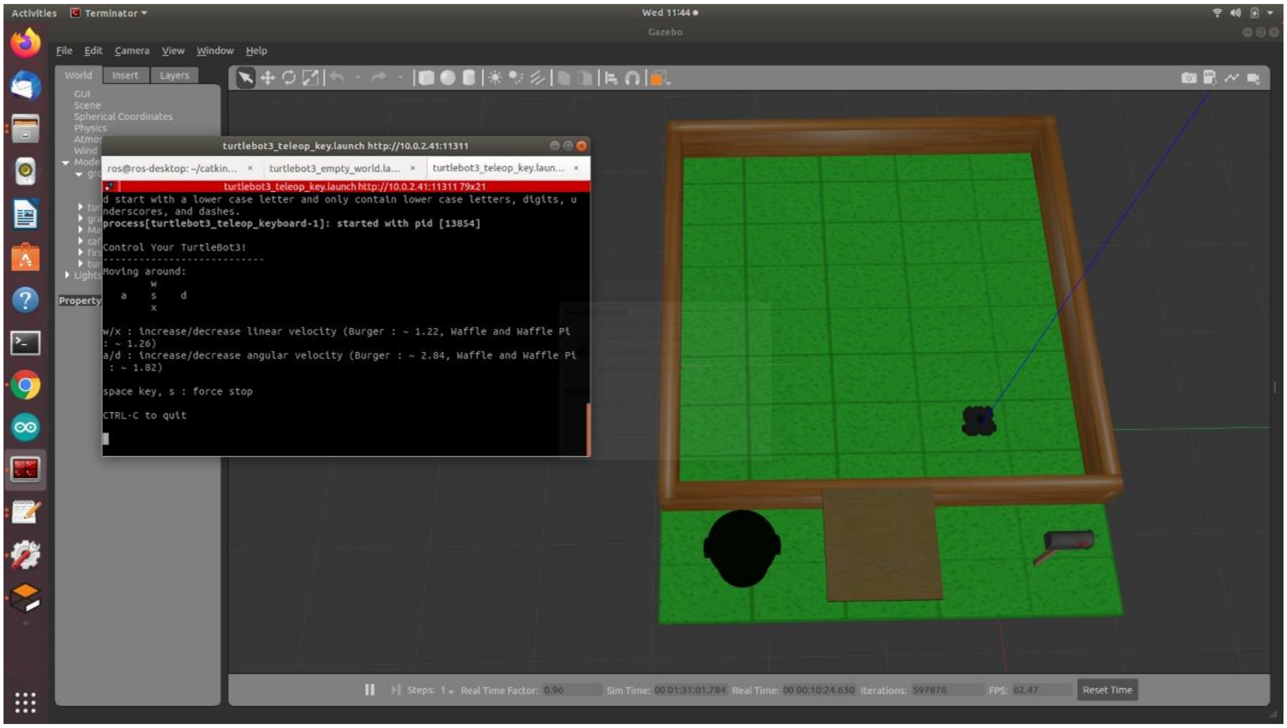

Figure 25: Environment Teleop

3.3 Boundary Detection in Simulation

Before performing any algorithm, boundary detection, the primary function of the robot was tested. A simple task where the turtle bot stops when it detects a boundary was performed. Then when this was established, the turtle bot was programmed to have a certain angular speed so that it rotates away from the boundary. Multiple tweaks in the angular speed were made so that we understand how it rotates (Ex: angular speed should be set for 0.93 with 0 linear speed so that turtle bot rotates 90 degrees.)

3.4 Forming Algorithms for Path Covering

This here is the hardest part of the project. To program an algorithm that covers the entire area without having any need for localization and is fully autonomous. The tested Algorithms are S-shape Algorithm, Random Pathway, and the Multipatterned Pathway that we came up with. Each algorithm had its advantages.

Tracking the Robot's progress in simulation:

To track the robot's progress and where it is going, several functions have to be made.

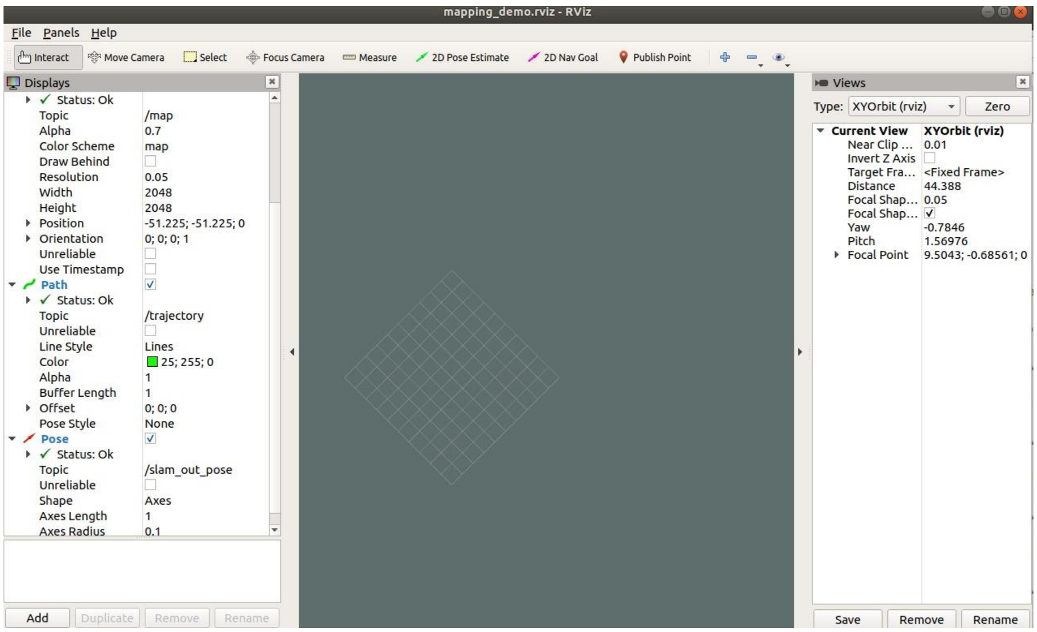

Figure 26: Open Rviz

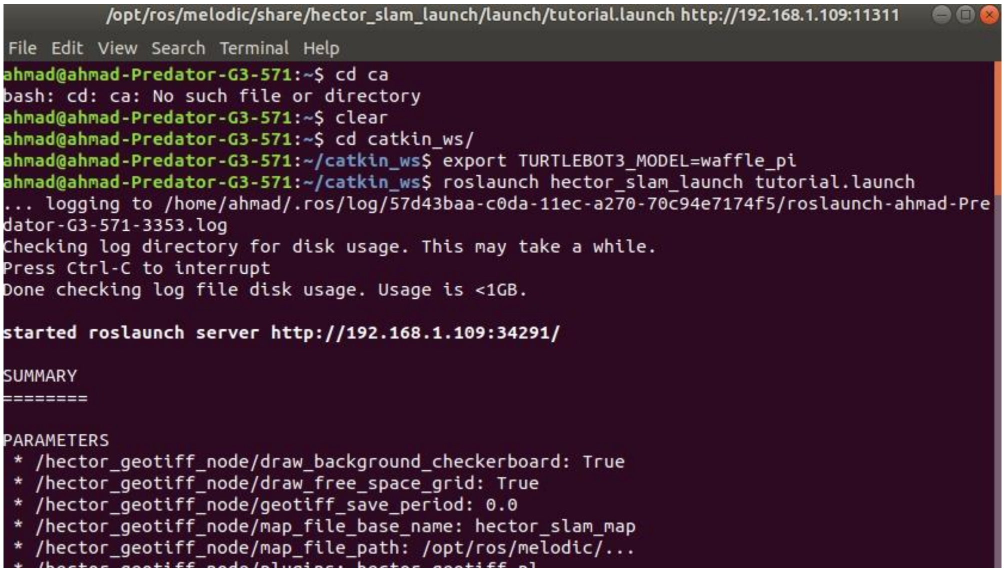

Figure 27: Terminal for roslaunch hector slam

3.4.1 S-Shape Algorithm

The S shaped algorithm moves in a sense where it goes forward till it reaches the upward boundary, turn right 180 degrees, move forward till it reaches downward boundary, turn left 180 degrees.

3.4.1.1 Advantages of S-shaped Algorithm:

1. No mapping of the yard is necessary
2. Moves in a systemic way so that it doesn't miss any spot
3. Completes entire area
4. Doesn't go over mowed area multiple times

3.4.1.2 Computing Time needed to complete entire Area using S-shape:

Approximately 55 seconds to mow 15 cm vertically.

Number of vertical lines to cover all area 400/15= 26.6 approximately 27.

27*55=1485

Rotation time approximately 5 seconds

5*27=135

Approximately needs 1620 second to cover 4*5 rectangle area

Thus needs 27 minutes to complete all area.

3.4.2 Random Pathway

The Random Pathway algorithm moves in a sense where the robot moves in a random direction every time it reaches a boundary. The angle of rotation when a boundary is detected is usually somewhere between 20 to 120 degrees.

3.4.2.1 Advantages of Random Pathway Algorithm:

1. No mapping of the yard is necessary
2. The lawn receives continuous maintenance
3. Unexpected obstacles are dealt with better
4. The lawn is mowed evenly from all sides

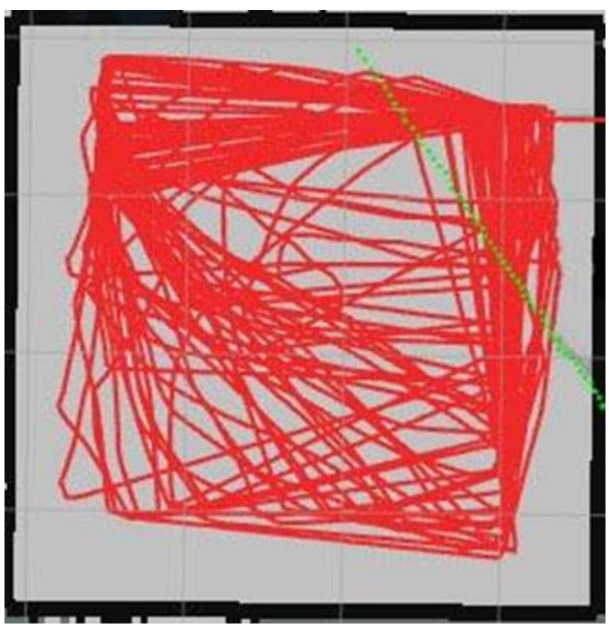

Figure 28: Area Cover

3.4.2.2 Time to cover full area:

The Random algorithm was used for more than an hour. However, the area wasn't fully covered. As seen in figure above the robot covers certain parts of the area much more frequently than other parts. The time needed to cover the full area will be set as >60 minutes and undefined.

3.4.3. Multi Patterned Algorithm

The multipatterned algorithm is an algorithm the team has come up with. This algorithm works in a sense where for first few minutes the robot moves in a Linear Pattern where it covers all the edges and corners (figure 29). Right after that the robot starts having an angular velocity where it moves in a curved way to cover the area in a pattern as shown below in figure 30. After this pattern is fully covered in a sense where the robot has operated for multiple minutes, it then moves with an increased angular velocity so that it covers the pattern as shown in figure 31.

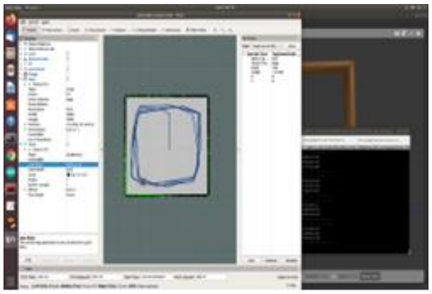

Figure 29: First Algorithm

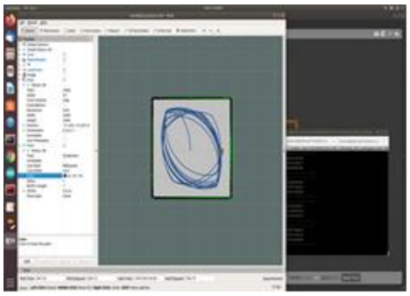

Figure 30: Second Algorithm

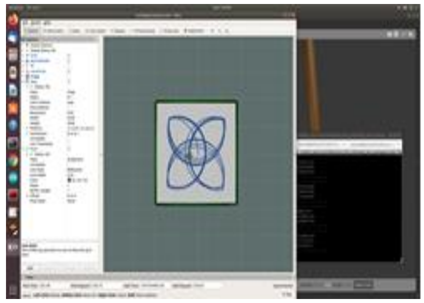

Figure 31: Third Algorithm

3.5 Flow Chart for Multipatterned Algorithm:

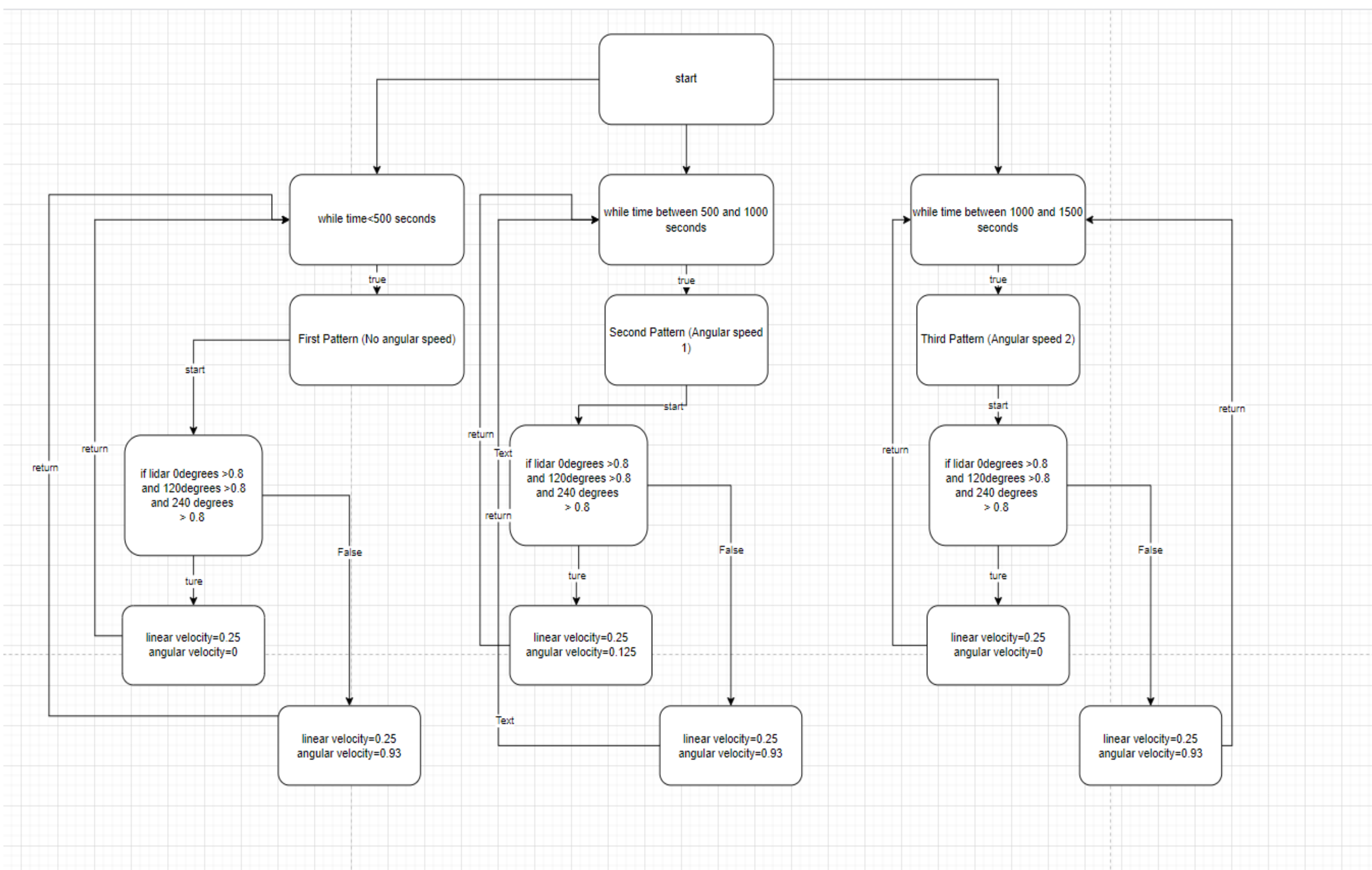

Figure 32: Flowchart of Multipatterened Algorithm

3.5.1 Advantages for Multipatterned Algorithm:

1. No mapping of the yard is necessary
2. Moves in a various systemic pattern to make sure all lawn is mowed
3. Completes entire area
4. Very good for edges
5. Faster than previous approach
6. Ensures all area is cut well by covering the area more than once
7. No specific Starting Point

3.5.2 Time Needed to fully complete Area:

The time needed to fully complete the area by testing was 25 minutes.

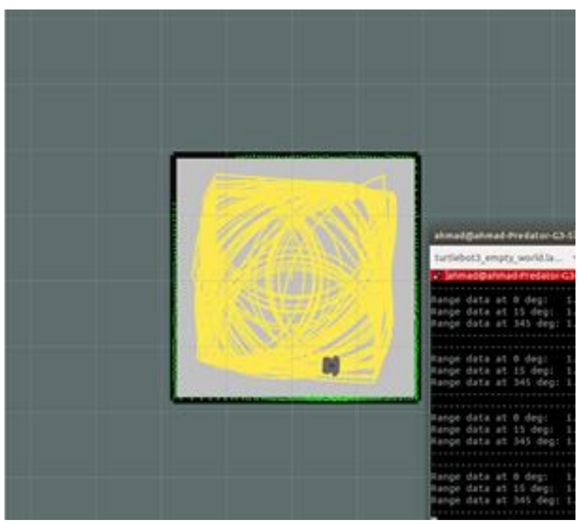

Figure 33: Three algorithms together

3.5.3 Comparison of all algorithms

Table 6: Comparison of Algorithms

Comparisons	**Random Algorithm**	**S-shaped Algorithm**	**Multi-Pattern Algorithm**
Covers All Area	Almost	Yes	Yes
Time To Cover Area	>60 minutes	27 minutes	25 minutes
Starting Point	Not Needed	Needed	Not Needed
Progressive Cutting	Yes	No	Yes

Note: All Algorithms are tested using the same linear speed. Spiral algorithm was not tested since it cannot be implemented on our real robot. This is due to the high accuracy needs of the algorithm to function properly

After Comparing the algorithm and taking into consideration all the points mentioned above. It is observed that the multi-pattern algorithm is the best option to go to. It includes the advantages of the random algorithm which are Progressive Cutting and not needing a specific starting point. It also includes the speed advantage of the S-shaped algorithm. Most importantly, it covers the entire area perfectly.

3.5.4 Testing Multipatterned Algorithm on different Areas

Now that the Algorithm is chosen, we want to make sure that this algorithm can operate on different areas, not just the 20m^2 mimic environment we created. Thus 2 additional areas, one triangular and another rectangular, were added. Figure **X** shows the extra areas created.

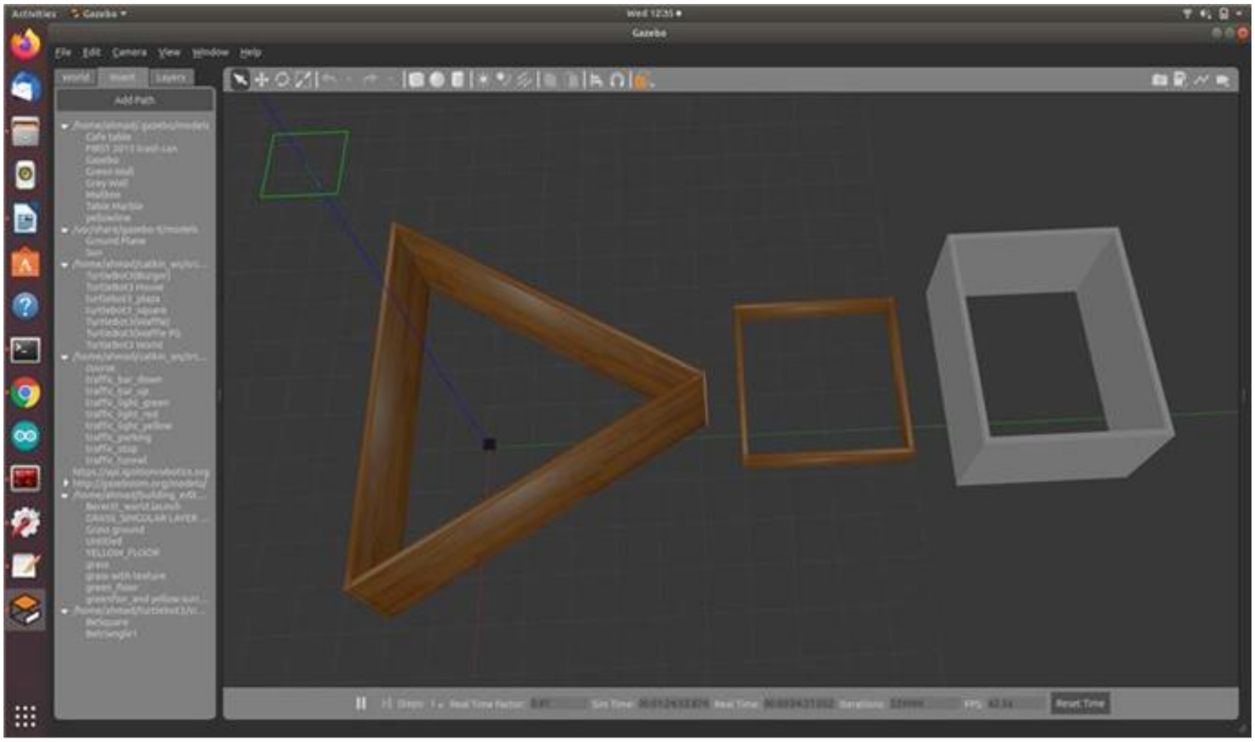

Figure 34: Different Shapes

As for the results on those areas, it is as follows:

Note: The line that is tracking the movement of the turtlebot is widened to be simulating the width of the blade on the real robot. This is done to have more accurate results. This way we can monitor how much the robot is cutting grass while it moves.

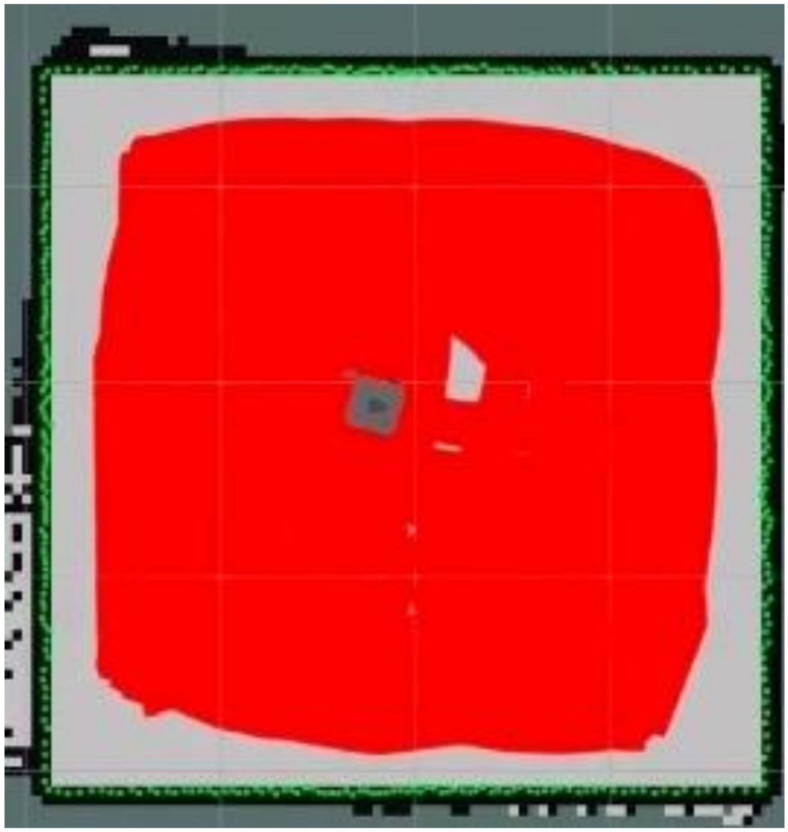

Figure 35: Cover of Area

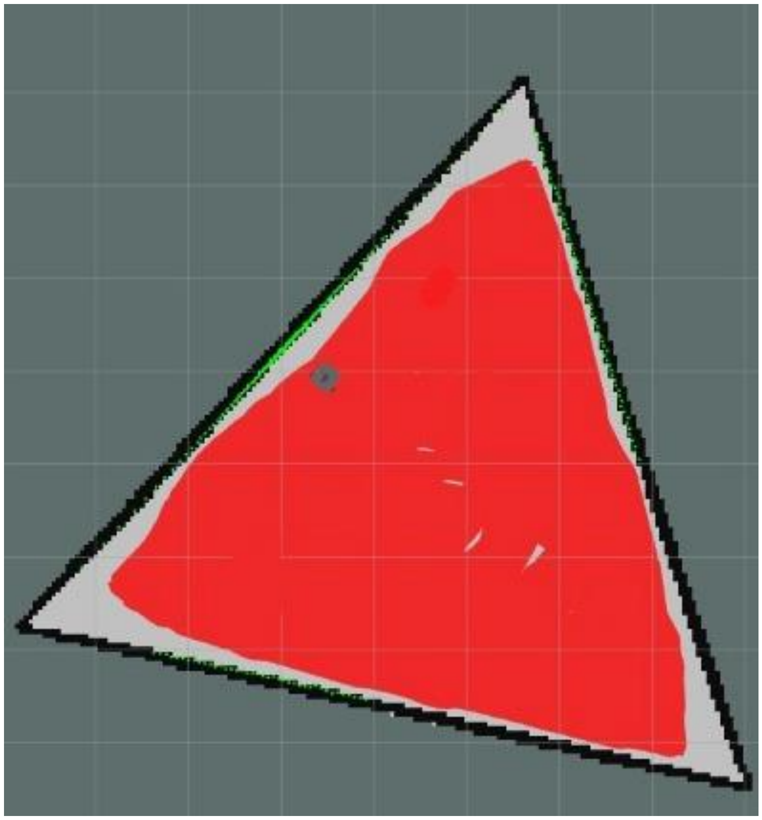

Figure 36: Cover of Area

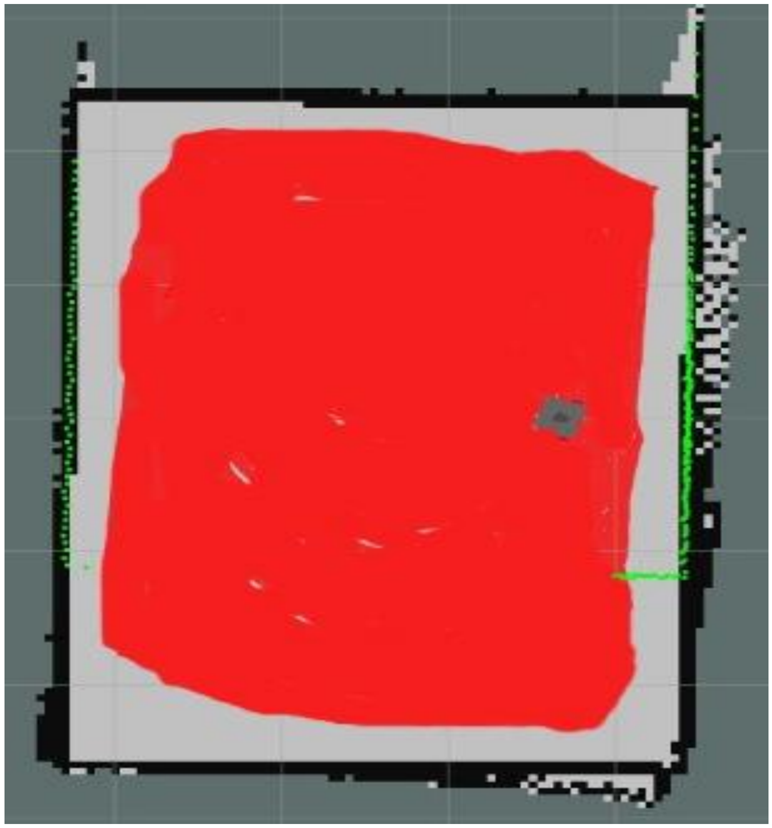

Figure 37: Cover of Area

Chapter 4

Implementation

In this chapter, the construction process of the mower robot is shown. This chapter will include the construction of the chassis, the manufacturing of the blade in addition to the implementation of all the motors and the wheels, the full circuit of the robot, the implementation of the lidar on the robot, and the addition of safety features.

4.1 Construction of Body

After deducing the design, dimensions, and the weight, it is time to start constructing the robot. Aluminum sheets are cut and bent to come up with the targeted shape. Then the aluminum sheets are screwed together. A hole in the middle of the lower sheet is formed so that the blade motor is fixed to it. Additional holes are added to put up the buttons and the camera in the front for video streaming. An additional sheet is placed on the top of the robot so that the lidar sits on it.

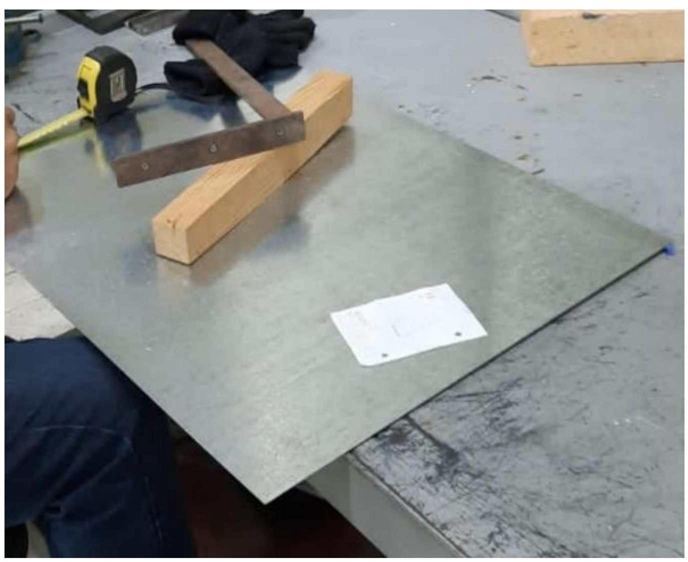

Figure 38: Metal Sheet

Figure 39: Metal Sheet

Figure 40: Body Form

Figure 41: Body Form

Figure 42: Body Form

4.2 Manufacturing of Blade

As designed, the blade was made in a mulching system and was placed 5-6 cm above the ground

Figure 43: Blade

Figure 44: Blade Height

Figure 45: Blade Under Robot

4.3 Implementation of motors and wheels on Robot

After the body is built. It is time to implement the wheels and the wheel motors. The wheel motors are connected below the lower sheet in the robot. This way the robot can gain extra height so that the blade sits on a perfect height. Each motor is set 8 cm away from each corner of the robot and the distance between the wheel centers is 34 cm. As for the height, it is 8 cm.

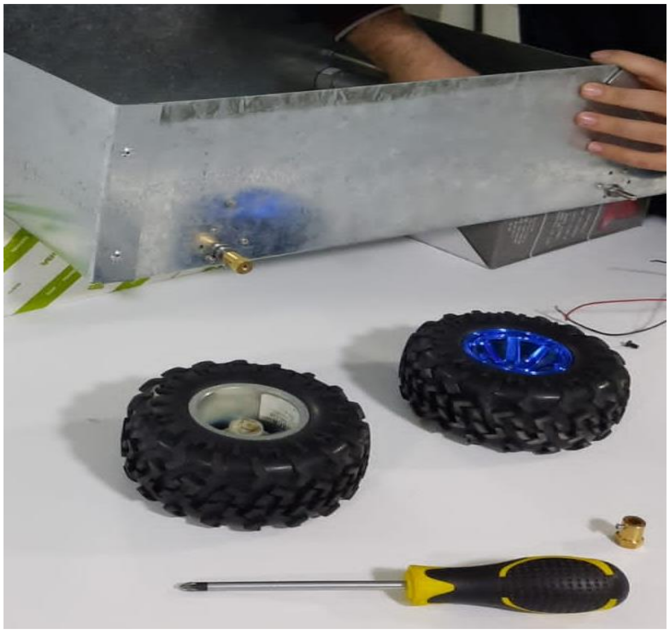

Figure 46: Wheels Upside Down

Figure 47: Wheels on Machine

Figure 48: Distance Between Wheels

Figure 49: Height of Machine

4.5 Safety Features

Our lawn mower is a dangerous machine, especially for having a sharp blade spinning multiple hundreds of turns per minute. Baring this in mind, safety features play a vital role in our robot. Several safety factors have been established including emergency push buttons both wireless and on robot in addition to lift/tilt sensors.

4.5.1 Emergency push Button on Machine

This emergency push button is a manual stop button that shuts down the functions of the robot. In case of any hazardous event, if the user wants to shut down the robot immediately all he must do is press the emergency button. The robot will

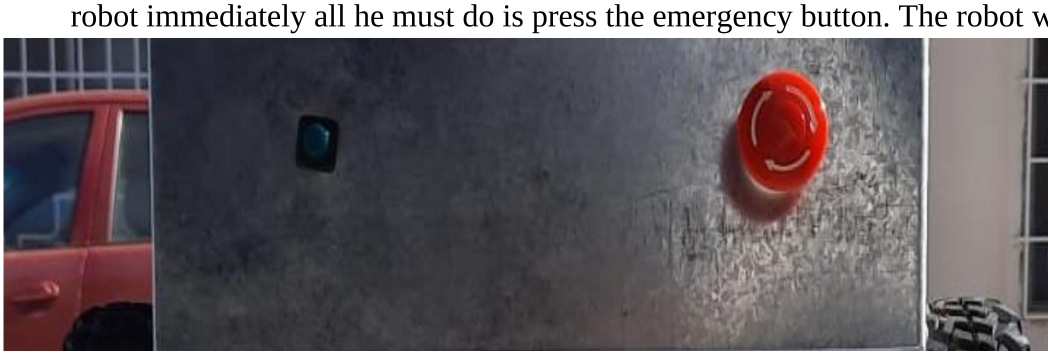

Figure 50: Buttons

then directly stop moving and the blade will stop rotating. To connect the emergency push button: it must be placed between one terminal of the battery and the motor drive.

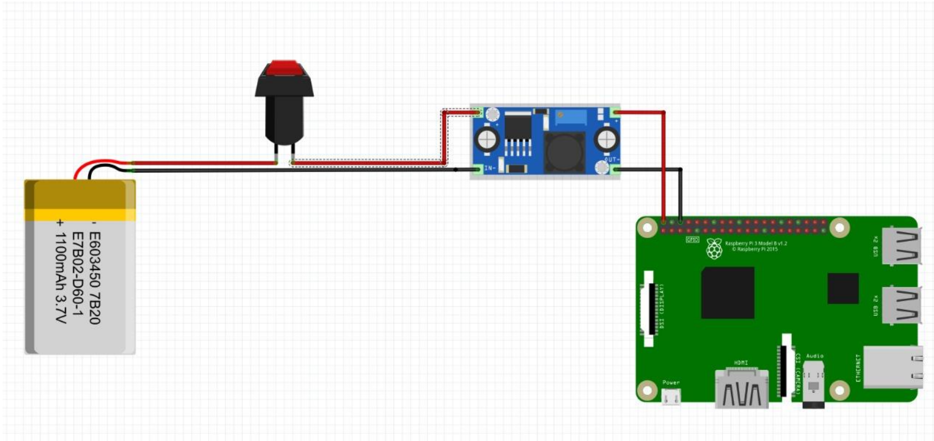

Figure 51: Circuit of Emergency Push Button

4.5.2 Wireless Stop Button

In short, a wireless stop button is implemented through a remote control that energizes and de-energizes the coil of a relay. As for the connections of this feature, a wire is connected from the positive terminal of the battery to the com input of the relay. Another wire is connected from the NC state contact of the relay to the blade motor.

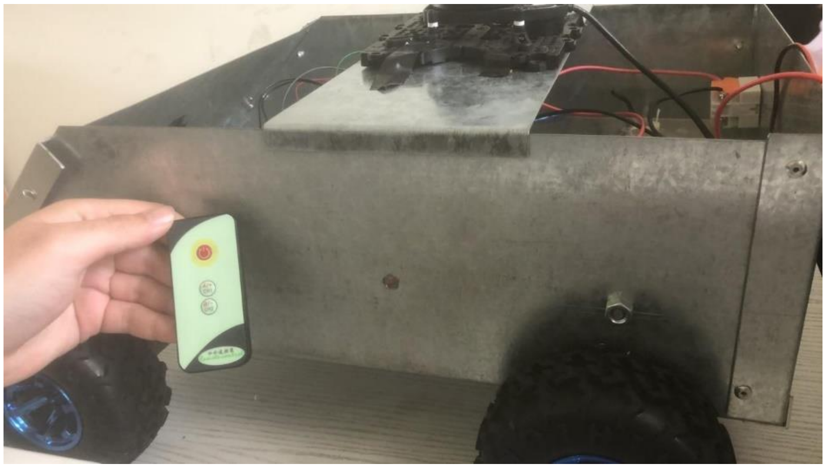

Figure 52: Wireless for Blade

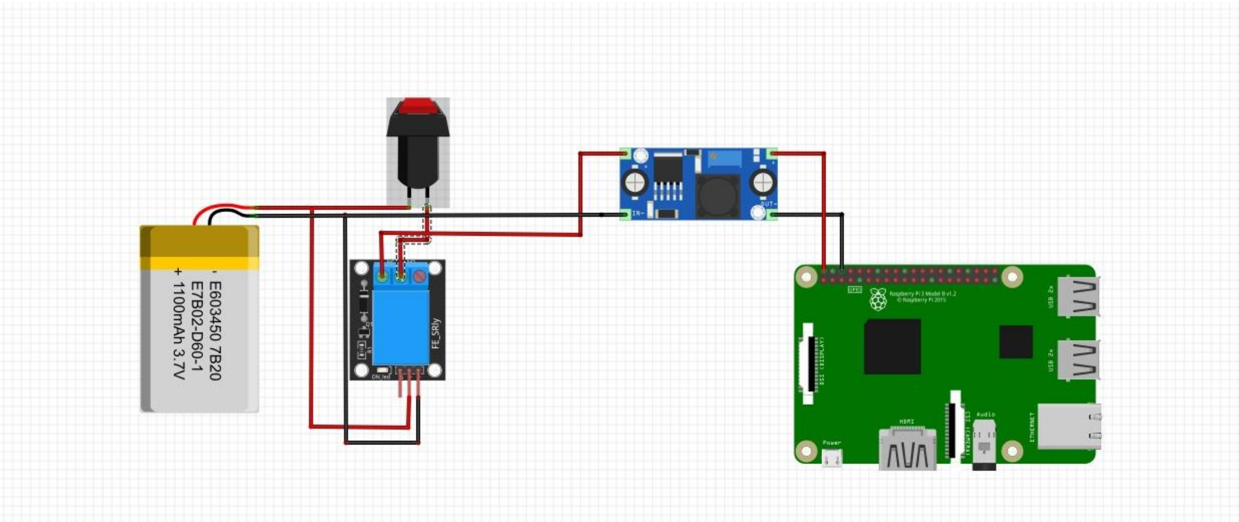

Figure 53: Circuit of Wireless Stop Button

4.5.3 ADXL Accelerometer Sensor

Taking into consideration that the robot is subjected to tilt due to steep areas or lifted for any reason, a sensor that detects such matters is needed so that the robot stops functioning when they do. Thus comes the ADXL accelerometer.

4.6 Camera Implementation

The camera is placed in the front side of the robot. It is intended to be used for livestreaming thus it must be capturing what's in front of it in a good angle.

Figure 54: Machine with Camera Implementation Infront

Chapter 5

User interface

Now, it's great for the robot to be able to moves autonomously, but it is not ideal. As we have seen from the competitor robots, they are great in mowing your lawn but sometimes they do not cover 100% of the allocated area and have tough times to be able to cover hard angles therefore, we decided to solve this problem by creating a manual control which you can be able to navigate your lawn mower however you like. To have these commands we created a web application which makes our robot more versatile for having 2 features instead of one.

Wifi communication

- It is important that the user has accessibility to Wi-Fi so that he can access the web app.
- The type of communication is chosen to be via wi-fi because wi-fi communication has relatively better range.
- The presence of video streaming makes wi-fi the best possible communication

Requirements for building the web app:

- Rosbridge
- HTML
- JavaScript
- Vue.js Framework
- Bootstrap

5.1 Rosbridge

The rosbridge protocol specifies how to communicate JSON-based commands to ROS. The standard is language and transport neutral. The concept is that any language or transport that can communicate JSON can talk the rosbridge protocol and connect with ROS. The protocol addresses subjects like as subscribing and publishing, service calls, getting and setting parameters, and even compressing messages, among other things.

5.2 HTML 5

HTML5 (Hypertext Markup Language Revision 5) is a markup language used to structure and convey World Wide Web information. HTML5 includes classic HTML and XHTML syntax, as well as additional features in its content, New APIs, XHTML, and error handling.

The specification of HTML5 is now overseen by three organizations:

The Web Hypertext Application Technology Working Group (WHATWG) developed the HTML5 standard and is in charge of HTML5 development, which allows browser vendors and other interested parties to collaborate openly.

The HTML5 specification is being delivered by the World Wide Web Consortium (W3C).

The HTML5 WebSocket API is being developed by the Internet Engineering Task Force (IETF).

5.3 Javascript

Javascript is a programming language that is used by programmers all over the world to generate interactive and dynamic web content such as programs and browsers. JavaScript is the most popular programming language in the globe, with 97.0 percent of all websites using it as a customer programming language. Client-side languages are ones in which the activity occurs on the user's machine rather than the server.

JavaScript is adaptable enough to be utilized in a wide range of applications, including software, hardware controls, and services. Because it is native to the web browser, JavaScript is best recognized as a web-based language. The web browser understands the language in the same way that a native English speaker understands English.

5.4 Vue.js Framework

VueJS is most commonly used to create web interface and one-page applications. However, because the HTML extensions and JS base working in parallel with an Electron framework, it can also be used for both desktop and mobile app development, making it a popular frontend tool.

Vue accomplishes this by employing classic Model View Controller (MVC) architecture to view an app's or website's user interface, with its core library serving as that of the primary view layer. It's adaptable in that it can work with Component Based Architecture, or CBA, exactly like React.

5.5 Bootstrap

Bootstrap is a powerful front-end framework for building modern webpages and web apps. It's open-source and free to use, but it includes a plethora of HTML and CSS templates for UI elements like buttons and forms. JavaScript extensions are also supported by Bootstrap (Bootstrap 5. (n.d.). W3schools).

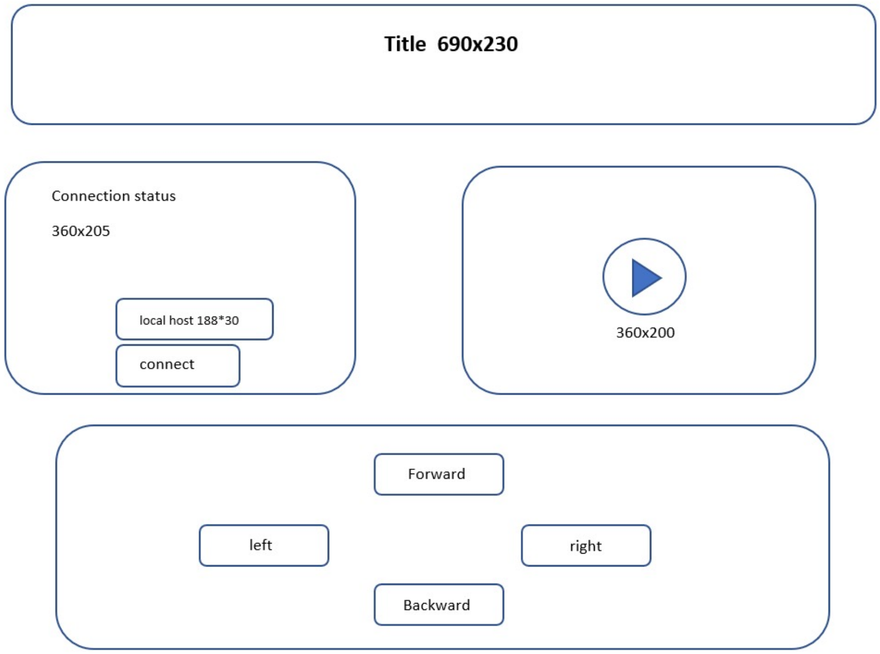

Figure 55: Sketch of User Interface

5.6 Implementation of webapp

5.6.1 Rosbridge Implementation:

The rosbridge suite package is a group of packages that implements the rosbridge protocol as well as provide a WebSocket transport layer.

The bundles include the following:

rosbridge library - The rosbridge core package. The rosbridge library oversees parsing the JSON text and transmitting commands to ROS, as well as vice versa.

rosbridge server - While rosbridge library handles the JSON->ROS translation, the transport layer is handled by others. Rosbridge server establishes a WebSocket connection, allowing browsers to "speak rosbridge." Roslibjs is a JavaScript library for the browser that can communicate with ROS through the rosbridge server (RobotWebTools).

5.6.2 Adding styles to the ROS control web page

For our HTML file we are going to add some styles by using the bootstrap framework. After creating the index.html file we import libraries that we would like to use, and we add them in the <head> section of the index.html.

```
<link rel="stylesheet" href="https://stackpath.bootstrapcdn.com/bootstrap/4.3.1/css/bootstrap.min.css"integrity="sha384ggOyR0iXCbMQv3Xipma34MD+dH/1fQ784/j6cY/iJTQUOhcWr7x9JvoRxT2MZw1T"crossorigin="anonymous">

<script type="text/javascript" src="https://static.robotwebtools.org/roslibjs/current/roslib.min.js"></script>

<script src="https://cdn.jsdelivr.net/npm/vue">

        </script>
```

The first tag (<link>) adds the Bootstrap framework. Because it's a CSS file, it looks completely different than the <script> tags. It will help us to generate more visually appealing elements on our page not having to spend time styling them.

The second tag is responsible for importing roslib.js.

Finally, the Vue.js framework is included in the third tag. This framework will make our JavaScript code look very different, but it will also be better organized.

We begin by creating a Vue.js object. This object relates to the webpage's element #app. (This is the element referenced by the id="app" attribute.) This means that our JavaScript code can govern everything inside this element.

The following attribute is called data. This attribute is a container for additional attributes. These are custom attributes defined for our application, not pre-defined by the framework.

A boolean linked has been defined. A ros object that manages the connection to the rosbridge server. The server's address, ws address. And the last one logs, which is an array containing event messages.

Then there's the methods attribute. This is pre-defined by the framework and is where we will define functions to aid in the development of our application. We made two: connect and disconnect.

We begin the connect procedure by generating a new log and adding it to the this.logs array. Then we define the connection object and assign it to this.ros. Finally, we define the same callbacks as before, but this time we change the value of the boolean connected and add the logs to the array instead of presenting them in the console.

The disconnect method just terminates the connection.

We must modify the html code by creating main.js to allow main.js to perform its "magic." The first step is to place it at the conclusion of the <body> section.

The elements to be altered must then be adjusted.

The text message that displays the connection's state must be dependent on the linked variable.

The variable ws address must be filled by the input> element, and the variable's value must modify the element.

The buttons must call the provided methods and be shown based on the linked value.

And we want to iterate the logs array to show the messages we have added on the events changing.

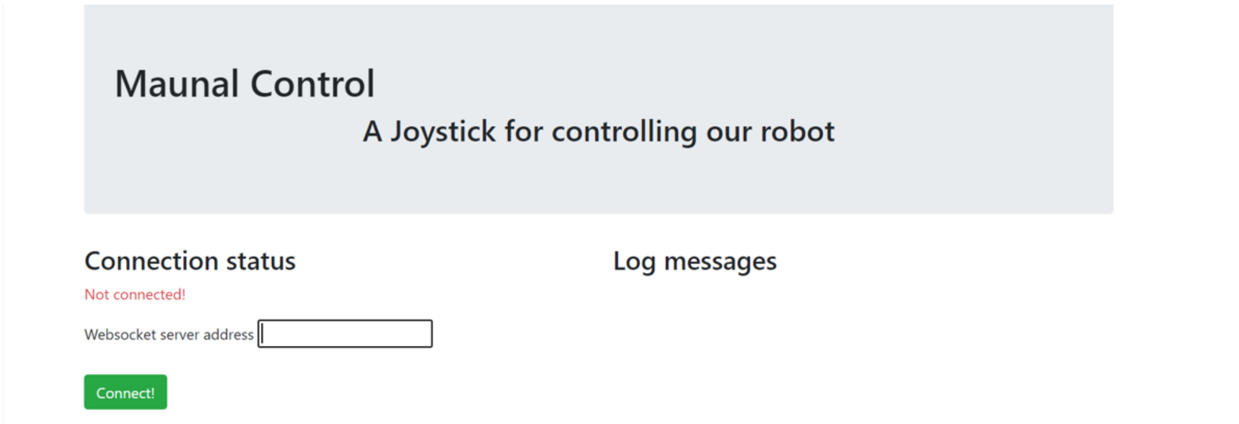

Figure 56: Showing the Connection Status when we are not connected

5.6.3 Building a web joystick to control the lawn mower

First, we'll make the controls that the user will utilize to operate the lawn mower.

Let's add some new techniques to our main.js file to perform the activities we just imagined. We already have two functions in the methods attribute. Let's make the following:

```
setTopic: function() {
            this.topic = new ROSLIB.Topic({
                ros: this.ros,
                name: '/cmd_vel',
                messageType: 'geometry_msgs/Twist'
            })
        },
        forward: function() {
            this.message = new ROSLIB.Message({
```

```
        linear: { x: 1, y: 0, z: 0, },
        angular: { x: 0, y: 0, z: 0, },
    })
    this.setTopic()
    this.topic.publish(this.message)
},
stop: function() {
    this.message = new ROSLIB.Message({
        linear: { x: 0, y: 0, z: 0, },
        angular: { x: 0, y: 0, z: 0, },
    })
    this.setTopic()
    this.topic.publish(this.message)
},
backward: function() {
    this.message = new ROSLIB.Message({
        linear: { x: -1, y: 0, z: 0, },
        angular: { x: 0, y: 0, z: 0, },
    })
    this.setTopic()
    this.topic.publish(this.message)
},
turnLeft: function() {
```

```
        this.message = new ROSLIB.Message({
            linear: { x: 0.5, y: 0, z: 0, },
            angular: { x: 0, y: 0, z: 0.5, },
        })
        this.setTopic()
        this.topic.publish(this.message)
    },
    turnRight: function() {
        this.message = new ROSLIB.Message({
            linear: { x: 0.5, y: 0, z: 0, },
            angular: { x: 0, y: 0, z: -0.5, },
        })
        this.setTopic()
        this.topic.publish(this.message)
    },
```

Let's make the elements on our webpage as well as the methods that execute the actions work together now that we have them.

To accomplish this, we must assign these methods to a "click" events of every button. Therefore, we assign a button for each command. We have also added to each button as: **“**disabled” attribute, which means that the button is disabled if one of the conditions is true. Therefore, at this point, we should have a webpage looking like the following:

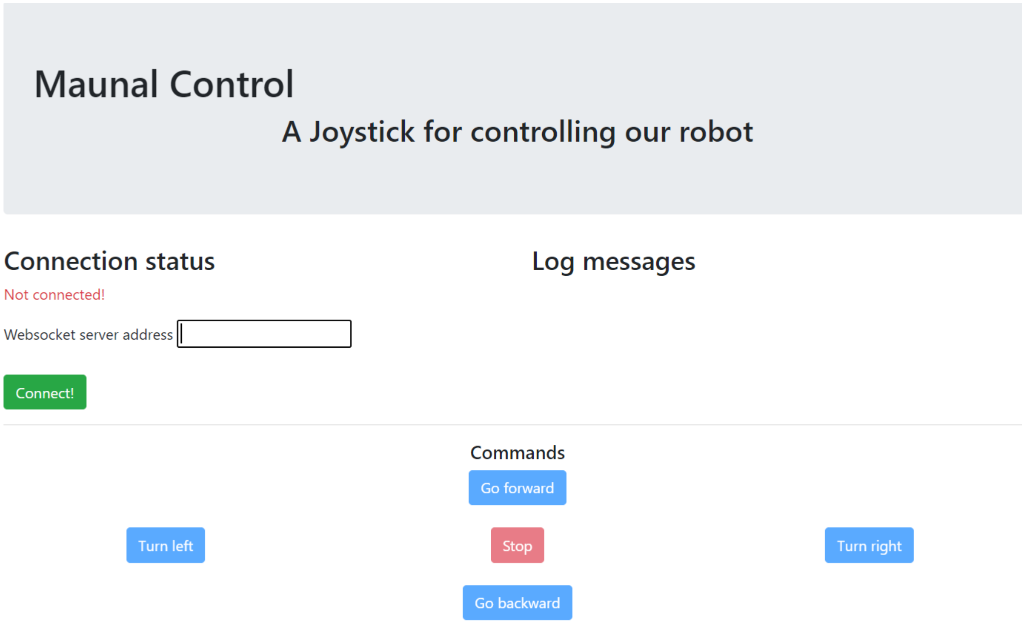

Figure 57: Showing the Commands Responsible for navigation

5.6.4 Streaming the lawn mower's camera on the web page

Before we get to a camera streaming server or even the code to connect to it, we must import the library that makes everything possible. And that's the MJpeg Library. We incorporate it into our head> section as follows:

```
<script src="https://cdn.jsdelivr.net/npm/eventemitter2@5.0.1/lib/eventemitter2.min.js">
    </script>
    <script type="text/javascript" src="https://static.robotwebtools.org/mjpegcanvasjs/current/mjpegcanvas.min.js">
    </script>
```

In the same way that we must start the rosbridge server, we must also launch a special ros process to transmit the images:

```
rosrun web_video_server web_video_server
```

The web video server listens on a local port for inbound HTTP requests. When an HTTP video feed of a ROS image topic is requested, it subscribes to the subject and generates an instance of a video encoder. The client receives raw video packets that have been encoded. Parameters can be added to a query string to be defined.

Let's add the camera connection to our main.js module. It's essentially a method of causing the pre-defined component (in our HTML) to get the images.

```
setCamera: function() {
        console.log('set camera method')
        this.cameraViewer = new MJPEGCANVAS.Viewer({
            divID: 'mjpeg',
            host: IP,
            width: 640,
            height: 480,
            topic: './image_raw',
            port: portnumber,
        })
    },
```

The width and height attributes will be applied to the element's size. Finally, when the rosbridge server has connected, call the method.

```
this.ros.on('connection', () => {
        this.logs.unshift((new Date()).toTimeString() + ' - Connected!')
        this.connected = true
        this.loading = false
        this.setCamera()
    })
```

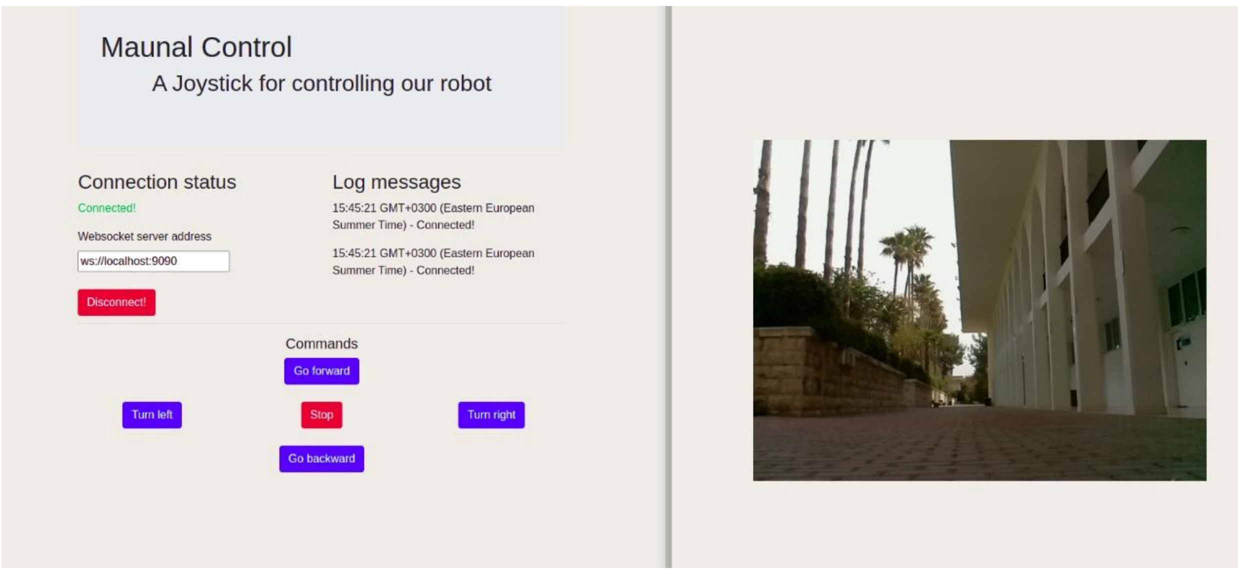

Figure 58: Manual Control User Interface

Appendix A

Codes Used

Code for Arduino:

```
// ** open loop - cmd_vel only


#include "ros.h"

#include <std_msgs/String.h>

#include <geometry_msgs/Twist.h>

#include <ros/time.h>


ros::NodeHandle nh;




float wheel1;

float wheel2;


float wheel1a;

float wheel2a;
```

```
float demandx;
float demandz;

float speed_act_left; // actual left wheel speed in m/s
float speed_act_right; // actual right wheel speed in m/s

unsigned long currentMillis;
unsigned long previousMillis;
int loopTime = 10;



// * ROS callback & subscriber *

void velCallback(  const geometry_msgs::Twist& vel)
{
   demandx = vel.linear.x;
   demandz = vel.angular.z;

   //demandx = constrain(demandx,-1,1);     // try to keep it under control
   //demandz = constrain(demandz,-1,1);

   demandx = demandx * 350;
```

```
    demandz = demandz * 75;
}

ros::Subscriber<geometry_msgs::Twist> sub("cmd_vel" , velCallback);     //create a subscriber for ROS cmd_vel topic

// * Setup *

void setup() {

  nh.initNode();              // init ROS
  nh.subscribe(sub);          // subscribe to cmd_vel
  Serial.begin(115200);
  pinMode(12, OUTPUT);     // motor PWM pins
  pinMode(11, OUTPUT);
  pinMode(10, OUTPUT);
  pinMode(9, OUTPUT);



  //Serial.begin(115200);
}

void loop() {
```

```
   nh.spinOnce();        // make sure we listen for ROS messages and activate the callback if there
is one

   currentMillis = millis();

   if (currentMillis - previousMillis >= loopTime) {  // start timed loop for everything else
      previousMillis = currentMillis;

     // work out the two values for differential drive of each wheel

     wheel1 = demandx - (demandz);
     wheel2 = demandx + (demandz);

     wheel1 = constrain(wheel1,-255,255);
     wheel2 = constrain(wheel2,-255,255);

     // drive motors

     if (wheel1 > 0) {
       wheel1a = abs(wheel1);
```

```
  analogWrite(10, wheel1a);

  analogWrite(9, 0);

}

else if (wheel1 < 0) {

  wheel1a = abs(wheel1);

  analogWrite(9, wheel1a);

  analogWrite(10, 0);

}

else {

  analogWrite(9,0);

  analogWrite(10, 0);

}


// other motor


if (wheel2 < 0) {

  wheel2a = abs(wheel2);

  analogWrite(11, wheel2a);

  analogWrite(12, 0);

}

else if (wheel2 > -0) {

  wheel2a = abs(wheel2);

  analogWrite(12, wheel2a);
```

```
        analogWrite(11, 0);
      }
      else {
        analogWrite(12, 0);
        analogWrite(11, 0);
      }



    } // end of timed loop


} // end of main loop
```

Code for Autonomous Operation:

```
#!/usr/bin/env python
import rospy # Python library for ROS
from sensor_msgs.msg import LaserScan # LaserScan type message is defined in sensor_msgs
from geometry_msgs.msg import Twist #
import time
def callback(dt):
    print '-------------------------------------------'
    print 'Range data at 0 deg:   {}'.format(dt.ranges[0])
```

```
    print 'Range data at 15 deg:  {}'.format(dt.ranges[15])

    print 'Range data at 345 deg: {}'.format(dt.ranges[345])

    print '-------------------------------------------'

    thr1 = 0.8 # Laser scan range threshold

    thr2 = 0.8

    t_timer = time.time()

    while(t_timer<500):

            if dt.ranges[0]>thr1 and dt.ranges[15]>thr2 and dt.ranges[345]>thr2: # Checks if there
are obstacles in front and

                                                                                  # 15 degrees left and right (Try changing
the

                                                                                                  # the angle values as
well as the thresholds)

                move.linear.x = 0.25 # go forward (linear velocity)

                move.angular.z = 0 # do not rotate (angular velocity)

            else:

                move.linear.x = 0.25 # stop

                move.angular.z = 0.93 # rotate counter-clockwise angel 45

                if dt.ranges[0]>thr1 and dt.ranges[15]>thr2 and dt.ranges[345]>thr2:

                  move.linear.x = 0.25

                  move.angular.z = 0.93

            pub.publish(move) # publish the move object
```

```
        move = Twist() # Creates a Twist message type object

        rospy.init_node('obstacle_avoidance_node') # Initializes a node

        pub = rospy.Publisher("/cmd_vel", Twist, queue_size=10)  # Publisher object which will
publish "Twist" type messages

                                                    # on the "/cmd_vel" Topic, "queue_size" is
the size of the

                                              # outgoing message queue used for asynchronous
publishing


        sub = rospy.Subscriber("/scan", LaserScan, callback)  # Subscriber object which will
listen "LaserScan" type messages

                                             # from the "/scan" Topic and call the "callback"
function

                                # each time it reads something from the Topic

    while(500<t_timer<1000):

        if dt.ranges[0]>thr1 and dt.ranges[15]>thr2 and dt.ranges[345]>thr2: # Checks if there
are obstacles in front and

                                                             # 15 degrees left and right (Try
changing the

                                                                           # the angle
values as well as the thresholds)

                    move.linear.x = 0.25 # go forward (linear velocity)

                    move.angular.z = 0.125 # do not rotate (angular velocity)

                else:
```

```
                move.linear.x = 0.25 # stop

                move.angular.z = 0.93 # rotate counter-clockwise angel 45

                if dt.ranges[0]>thr1 and dt.ranges[15]>thr2 and dt.ranges[345]>thr2:

                  move.linear.x = 0.25

                  move.angular.z = 0.93

            pub.publish(move) # publish the move object




        move = Twist() # Creates a Twist message type object

        rospy.init_node('obstacle_avoidance_node') # Initializes a node

        pub = rospy.Publisher("/cmd_vel", Twist, queue_size=10)  # Publisher object
which will publish "Twist" type messages

                                                  # on the "/cmd_vel" Topic,
"queue_size" is the size of the

                                          # outgoing message queue used for
asynchronous publishing


        sub = rospy.Subscriber("/scan", LaserScan, callback)


  while(1000<t_timer<1500):

      if dt.ranges[0]>thr1 and dt.ranges[15]>thr2 and dt.ranges[345]>thr2: # Checks if there
are obstacles in front and

                                                  # 15 degrees left and right (Try
changing the
```

the angle values as well as the thresholds)

```
            move.linear.x = 0.25 # go forward (linear velocity)
            move.angular.z = 0.2 # do not rotate (angular velocity)
        else:
            move.linear.x = 0.25 # stop
            move.angular.z = 0.93 # rotate counter-clockwise angel 45
            if dt.ranges[0]>thr1 and dt.ranges[15]>thr2 and dt.ranges[345]>thr2:
                move.linear.x = 0.25
                move.a…
```

Appendix B

Problems Faced

1. **Camera**

- Difficulties in coding.
- Isn't good under the sun.
- The camera only views one direction which is front, this is not very efficient for our robot.

2. **Coding for S shape**

- The code was only half complete. The robot is only able to rotate in one direction, for the S shape to work we need it to rotate in a different direction every time it reaches the boundary.
- It was impossible to create a variable that saves its values at each turn thus implementing the algorithm was not successful.

3. Initial Wheel Implementation

- There were initial wheels ordered first with different specifications to those implemented on the robot. The initial wheels were supposed to be light weighted as the manufacturer said, but sadly the manufacturer's professionalism wasn't as expected.

4. Raspberry pi

- Unable to setup the ssh between the robot and the computer.
- Low storage in the raspberry pi which made its processing time very high and caused many problems.

5. Height

- It was initially planned that the wheel motors would be from the inside of the robot. However, when the wheels were changed, the motors' initial place was no longer functional since the robot's height would be too low and there wouldn't be space for the blade to operate well.

6. Simulation while Recording

- The computation power of the device we have Linux on (best device between team members) was still relatively low for tracking the simulation of the algorithm and recording it at the same time. Thus, simulation recording required many trials. Tracking the simulation without recording however was always successful. It was only a problem of recording.

7. Battery Monitor Sensor

- Due to time constraint, we didn't implement the battery monitor.
- It's not a necessary feature for the robot, the robot doesn't require the battery monitor to function properly.
- It will be implemented in the future.

8. Boundary wires

- Due to time constraint and not finding the needed sensors, it was opted to use lidar and boundary fences/walls.

Appendix C

1 to 7 Abet KPI's

	How was it addressed in your SLP?	***Where was it addressed in your SLP?***
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics		
1.1 An ability to apply knowledge of mathematics	***Calculation of Torque needed per Motor***	***Page 39***
	Calculations to determine Motor drives	***Page 41***
	Power Consumption Calculation and battery calculations	***Section 2.5 and 2.6***
	Computing Time Needed to Mow Area in S-shaped Algorithm	***Page 50***

1.2 An ability to apply knowledge of science	***Testing Algorithms for Path Covering***	***Section 3.4***
	Forming Multipatterned algorithm	***Section 3.5***
	Programming a webpage to manually control robot	***Chapter 5***
1.3 An ability to apply knowledge of Engineering	***Components Flow Chart***	***Page 38***
	Design and Dimension of robot using Solidworks	***Section 4.1***
	Manufacturing of blade to apply mulching and adjusting cutting height	***Section 4.2***
	Performing Fritzing for the Circuit	***Section 4.4***

	Usage of ROS	***Section 3***
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors		
2.1 Design a system/component of a system or a process to meet specific needs while respecting safety, health, and welfare of the public and adhering to cultural, social, environmental, and economic factors.	***Blade design to mulch grass while respecting safety measures***	***Sec 4.2, 4.5***
	Boundary detection so that robot doesn't leave the targeted area	***Sec 3.3***
2.2 Modify a system/component of a system or a process to meet specific needs while respecting safety, health and welfare of the public and adhering to cultural, social, environmental and economic factors.	***Initial design had wheels that were very heavy which made the robot function less than fair. This problem was solved by going to smaller wheels but adjusting the motor positions***	***Sec 4.3 & page 74***

	under the lower sheet in the robot so that blade height remains effective and safe	
	Initial plan was to have boundary wires but then it was opted to have boundary walls/fences due to time constraints and for ensuring that robot doesn't leave aera	***Page 75***
3. An ability to communicate effectively with a range of audiences		
3.1 Ability to write a well-structured formal report/technical document that addresses an audience with diverse educational-background	***Submitting several technical reports and meetings' minutes to adviser(s) and jury.***	***SLPI report (March 18) + SLPII draft 1 (April 20) + SLPII final report (April 28)***

3.2 Ability to deliver a well-structured formal presentation that addresses an audience with diverse educational-background[1]	***Delivering multiple presentations and demonstrating different phases of the project to adviser(s) and jury members***	***SLPI presentation (March 18 + SLPII Progress presentation (April 20) + SLPII final presentation (April 28)***
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts		
4.1 Identify global, economic, environmental, and societal impact of implementing engineering solutions using applicable engineering code of ethics to differentiate between ethical/unethical behaviors	***State how all ethical/unethical aspects of the project (or alternative designs), as governed by the ASME, ASCE, IEEE, etc… code of ethics, were thoroughly discussed while stating the critical impacts on society,***	***Page xx or sec. xx***

	environment, etc…	
4.2 Identify global, economic, environmental, and societal impact of implementing engineering solutions using applicable engineering standards and codes to differentiate between professional/unprofessional behaviors	***List all professional codes and standards, as governed by ASHRAE, ASME, etc…, were utilized in designing or modeling while stating the critical impacts on society, environment, etc…*** ***Punctuality in attending meetings.*** ***Jury will be assessing this outcome by the level of professionalism in appearance and interactions.***[1]	***Page xx or sec. xx***

5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives		
5.1 Ability to plan and organize team tasks collectively to meet established goals	***All agreed upon actions are properly documented in minutes.***	***Appendix-C (minutes)***
5.2 Ability to carry out tasks assigned by the team to attain set objectives.	***Clear and efficient task assigning process was followed. In addition, team members abided by the agreed upon time plan to ensure efficient accomplishment of all tasks in due time***	***Appendix C (minutes)***
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions		
6.1 An ability to design experiments.	***Different experiments were designed to test the speed, area***	***Sections 3 and 4***

	coverage on different areas, safety functions, and functionality of blade	
6.2 An ability to conduct experiments.	***Different experiments were conducted to test the speed, area coverage on different areas, safety functions, and functionality of blade motors, etc…***	***Sections 3 and 4***
6.3 An ability to draw apt evidence-based conclusions by analyzing and interpreting data	***Table of comparison of competitors***	***Table 1***
	Table of algorithms to choose best algorithm	***Table 5***
	Power consumption Table to	***Table 3***

	choose suitable battery	
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.		
7.1 Identify necessary skills and tools of contemporary engineering practice to solve a problem at hand.	***Gazebo***	***Sec 3***
	Rvis	***Sec 3.4***
	Solidworks	***Sec 4.1.1***
	Arduino IDE	***Appendix-Coding***
	Weight Calculator	***Sec 4.1.2***
	Bending, drilling, and cutting machines	***Sec 4.1.3***
7.2 Apply self-learned skills and tools of contemporary engineering practice to solve a problem at hand.	***Manufacturing Tools for the body such as bending, drilling, and cutting machines***	***Sec 4.1.3***

	Python scripts	***Appendix Codes***
	Open CV	***Appendix, problems faced***
	Forming algorithms	***Sec 3.5***

[1] will be assessed during the presentation.

Appendix D

Survey

A survey was formed to understand the market's needs. This survey included several questions that tackled the size of the area, the shape of the area, the inclinations, problems faced with regular mowers, and interest in owning autonomous lawn mowers. The results of the survey showed the following:

- 50% of mowing areas are under 200 meters squared
- 80%+ have slopes under 20 degrees

- Main problems faced during mowing were:
  - Hard Angles
  - Weight Of the Machine
  - Mowing Time
  - Mower Gets Stuck in grass
- 70%+ were interested in owning an autonomous lawn mower

Appendix E

Meeting Minutes

MINUTES OF MECA/MECH 595A MEETING 4-1-2022

COLLEGE OF ENGINEERING – MME Department

Present: Dr. Hassan Hariri (Advisor), Ahmad Hariri (Student), Adnan Jomaa (Student), Omar Al-Bilani (Student)

Absent: -

The meeting came to order at 10 pm.

1. ***Discussions and Updates***

Discussed some general issues about the project idea.

1. ***Advisor Comments and Recommendations***

Dr. Hassan recommended a table of wight, and block diagram of communication between the robot and the app and determining the level of the grass and read the articles that he provided to us.

1. ***Expected Deliverables for Next Meeting***

Side view sketch, determine the level of grass, table of weight, milestones, and read the article.

1. ***Assessment***

None.

The meeting ended on 12 am.

Minutes taken by: Omar Al-Bilani

MINUTES OF MECA/MECH 595A MEETING 19-1-2022

COLLEGE OF ENGINEERING – MME Department

Present: Dr. Hassan Hariri (Advisor), Dr. Ramzi Halabi (Co-advisor), Mohammad Laza (Student), Ahmad Hariri (Student), Adnan Jomaa (Student), Hussein Harb (Graduate Student)

Absent: Omar Al Bilani (Student)

The meeting came to order at 3 pm.

1. ***Discussions and Updates***

Discussed some general issues about the project idea.

1. ***Advisor Comments and Recommendations***

Several ideas were discussed for the general Lawn Mower. Dr Hassan commented on the milestones on how we will be working. And Dr Ramzi gave some feedback and commented on the block diagram regarding the communication between the robot and the application.

1. ***Expected Deliverables for Next Meeting***

Start with milestone 1 as discussed in the meeting and try simulating on Gazibo instead of using the Turtle bot 3.

1. ***Assessment***

None.

The meeting ended on 5 pm.

Minutes taken by: Mohamad Laza

MINUTES OF MECA/MECH 595A MEETING 27-1-2022

COLLEGE OF ENGINEERING – MME Department – RHU

Present: Dr. Hassan Hariri (Advisor), Mohamad Laza (Student), Ahmad Hariri (Student), Omar Al-Bilani (Student), Chaimaa El Banna (Student)

Absent: Adnan Jomaa (Student), Dr. Ramzi Halabi (Co-advisor)

The meeting came to order at 7:20 pm.

1. ***Discussions and Updates***

We discussed about the IP address of the raspberry pi, and how it is dynamic. It changes every time the machine is turned ON.

1. ***Advisor Comments and Recommendations***

Dr. Hassan recommended on being more efficient, working harder and give each member a specific task. In addition to that, he gave us some task to do.

1. ***Expected Deliverables for Next Meeting***

Few objectives were discussed, such as remotely control mower, report, presentation, assembly, teleop, and mobile app. We have 2 weeks for that, and for next week, we will be showing where we are in process.

1. ***Assessment***

None.

The meeting ended on 8:00 pm.

Minutes taken by: Mohamad Laza

MINUTES OF MECA/MECH 595A MEETING 3-2-2022

COLLEGE OF ENGINEERING – MME Department – RHU

Present: Dr. Hassan Hariri (Advisor), Mohamad Laza (Student), Ahmad Hariri (Student), Adnaan Jomaa (Student)

Absent: Omar Al-Bilani (Student), Dr. Ramzi Halabi (Co-advisor)

The meeting came to order at 7:30 pm.

1. ***Discussions and Updates***

Discussed about the error in code and how the robot moves, in addition to the controller and the camera where the position of the camera should be tilted.

1. ***Advisor Comments and Recommendations***

Dr. Hassan advised us to simulate the robot with a distance between the robot and the line when moving around. In addition to changing the error and the proportional controller. He also recommended to delete the wall on the Gazebo simulation, and to put grass (green color) around the robot and to increase the width of the yellow line.

1. ***Expected Deliverables for Next Meeting***

Dr. Hassan gave us 6 things to do as for assembly, teleop, mobile application, report etc. and that will be worked on continuously.

1. ***Assessment***

None.

The meeting ended on 8:20 pm.

Minutes taken by: Mohamad Laza

MINUTES OF MECA/MECH 595A MEETING 10-2-2022

COLLEGE OF ENGINEERING – MME Department – RHU

Present: Dr. Hassan Hariri (Advisor), Mohamad Laza (Student), Ahmad Hariri (Student), Adnaan Jomaa (Student)

Absent: Omar Al-Bilani (Student), Dr. Ramzi Halabi (Co-advisor)

The meeting came to order at 7:30 pm.

1. ***Discussions and Updates***

Discussed about the error in code and how the robot moves, in addition to the controller and the camera where the position of the camera should be tilted.

1. ***Advisor Comments and Recommendations***

Dr. Hassan advised us to simulate the robot with a distance between the robot and the line when moving around. In addition to changing the error and the proportional controller. He also recommended to delete the wall on the Gazebo simulation, and to put grass (green color) around the robot and to increase the width of the yellow line.

1. ***Expected Deliverables for Next Meeting***

Dr. Hassan gave us 6 things to do as for assembly, teleop, mobile application, report etc. and that will be worked on continuously.

1. ***Assessment***

None.

The meeting ended on 8:20 pm.

Minutes taken by: Mohamad Laza

MINUTES OF MECA/MECH 595A MEETING 17-2-2022
COLLEGE OF ENGINEERING – MME Department – RHU

Present: Dr. Hassan Hariri (Advisor), Mohamad Laza (Student), Ahmad Hariri (Student), Adnaan Jomaa (Student), Omar Al-Bilani (Student), Chaimaa Al Banna (Student)

Absent: Dr. Ramzi Halabi (Co-advisor)

The meeting came to order at 7:00 pm.

1. ***Discussions and Updates***

Discussed about the problem faced with the wheels and the size. After that, discussed the web interface and how it will look. Also discussed the coding part, where we are facing s smalling problem I how to define a variable and make it update this variable after the loops.

1. ***Advisor Comments and Recommendations***

Dr. Hassan advised us to check for the wheels and to send SLP1 report on Friday 18/2/2022 to check it in during the weekend, and to build a real environment for the Turtlebot.

1. ***Expected Deliverables for Next Meeting***

Report SLP1 should be sent to Dr. Hassan on Friday 18/2/2022, and the form of the interface should also be done.

1. ***Assessment***

None.

The meeting ended on 7:45pm.

Minutes taken by: Mohamad Laza

MINUTES OF MECA/MECH 595A MEETING 24-2-2022

COLLEGE OF ENGINEERING – MME Department – RHU

Present: Dr. Hassan Hariri (Advisor), Mohamad Laza (Student), Ahmad Hariri (Student), Adnaan Jomaa (Student)

Absent: Dr. Ramzi Halabi (Co-advisor), Omar Al-Bilani (Student), Chaimaa Al Banna (Student)

The meeting came to order at 7:00 pm.

1. ***Discussions and Updates***

Discussed about the report and showed what was changed after the feedback of Dr. Hasan. After that, discussed about the PowerPoint and what will be done to it. In addition to updating Dr. Hassan of where we have reached in our code and what problems we have faced.

1. ***Advisor Comments and Recommendations***

Dr. Hassan advised us to keep on working on the 'S' shape algorithm and not to jump to the random algorithm due to the changes that we will face. Dr. Hassan also advised us to slightly modify some parts in Chapter 2 in SLP1 report for a better report.

1. ***Expected Deliverables for Next Meeting***

Modifications of SLP1 report should be done for the next meeting. And the PowerPoint should also be done in addition to working on the web interface. Trying to fix the problem facing in the code, and if done, work on environment to the robot.

1. ***Assessment***

None.

The meeting ended on 8 pm.

Minutes taken by: Mohamad Laza

MINUTES OF MECA/MECH 595A MEETING 10-3-2022

COLLEGE OF ENGINEERING – MME Department – RHU

Present: Dr. Hassan Hariri (Advisor), Mohamad Laza (Student), Ahmad Hariri (Student)

Absent: Dr. Ramzi Halabi (Co-advisor), Omar Al-Bilani (Student), Adnan Jomaa (Student)

The meeting came to order at 7:00 pm.

1. ***Discussions and Updates***

Discussed about the algorithm and how the robot is moving in simulation and talked about the angles in the random pathway in specific, and the difference between 2 types of random pathway showed during the meeting. In addition to discussing about the report and showed what was changed after the feedback of Dr. Hasan. After that, discussed about the PowerPoint and what will be done to it.

1. ***Advisor Comments and Recommendations***

Dr. Hassan pointed out that the PowerPoint needs more work and commented on a small part of the report. Dr. Hassan also recommended to do an implementation of environment on the turtlebot.

1. ***Expected Deliverables for Next Meeting***

Modifications of SLP1 report should be done for the next meeting. And the PowerPoint should also be done in addition to show the fully simulated on the RVIZ, and test on turtlebot, and also test the robot moving autonomously in a 5 m straight line.

1. ***Assessment***

None.

The meeting ended on 8:05 pm.

Minutes taken by: Mohamad Laza

MINUTES OF MECA/MECH 595A MEETING 17-3-2022
COLLEGE OF ENGINEERING – MME Department – RHU

Present: Dr. Hassan Hariri (Advisor), Mohamad Laza (Student), Ahmad Hariri (Student), Adnaan Jomaa (Student), Omar Al-Bilani (Student), Dr. Ramzi Halabi (Co-advisor), Hussein Harb (Guest)

Absent: Chaimaa Al Banna (Student)

The meeting came to order at 7:00 pm.

1. ***Discussions and Updates***

Dr. Hassan Hariri discussed about the speed of the machine, and what the differences were between the figures shown during the meeting. Also discussed about the camera and the lidar and the reason why the lidar is going to be used. Dr. Ramzi discussed how to change from manual to autonomous in the web interface. And a decision was reached to use the lidar for detecting the boundaries (4x5 wood fence) and obstacle avoidance, and this is because of the time constrain facing and the problems we faced with the camera algorithm, where the camera only see in one direction in contrary where the lidar is capable of collecting data around the robot for 360 degree.

1. ***Advisor Comments and Recommendations***

Dr. Hassan commented on the PowerPoint and the report stating that the process is on the right track. In addition to commenting on the lidar that when the lidar is used, a new constrain will be obtained which is that the costumer must build a boundary area.

1. ***Expected Deliverables for Next Meeting***

A flow chart for the algorithm shown in the meeting, in addition to comparison between the algorithms time and area. Other than that, some benefits of the used algorithm. And also repeat the line following with the actual speed in different places at the RHU campus.

1. ***Assessment***

None.

The meeting ended on 7:55pm.

Minutes taken by: Mohamad Laza

MINUTES OF MECA/MECH 595A MEETING 24-3-2022

COLLEGE OF ENGINEERING – MME Department – RHU

Present: Dr. Hassan Hariri (Advisor), Ahmad Hariri (Student), Adnaan Jomaa (Student), Chaimaa Al Banna (Student)

Absent: Mohamad Laza (student), Omar Bilani (Student)

The meeting came to order at 7:00 pm.

1. ***Discussions and Updates***

In our meeting we have discussed the linear and the angular speed (values) concerning the simulation. We also discussed the structure of the flowchart and talked about the advantages and disadvantages of the patterns and mentioned the advantages of our own algorithm. Moreover, we went through the comparison table and talked about the time values.

1. ***Advisor Comments and Recommendations***

Dr. Hassan commented on the flowchart that it should be clearer for the reader, and also had mentioned that the boundary fences should not be stated as a disadvantage since it is a constrain by the usage of the lidar. In addition, he has mentioned few comments concerning the comparison table and suggested to include the area to he table.

1. ***Expected Deliverables for Next Meeting***

Updating the flow chart and making some modification to it. Simulating the robot in the 4x5 area in different positions (middle, top right, top left). In addition, we need to test our algorithm on the real robot. And mention our constrains and putting the reasons for the constrain mentioned.

1. ***Assessment***

None.

The meeting ended on 8:30 pm.

Minutes taken by: Ahmad Hariri

MINUTES OF MECA/MECH 595A MEETING 7-4-2022

COLLEGE OF ENGINEERING – MME Department – RHU

Present: Dr. Hassan Hariri (Advisor), Mohamad Laza (Student), Ahmad Hariri (Student), Adnaan Jomaa (Student), Omar Al-Bilani (Student), Chaimaa Al Banna (Student)

Absent: Dr. Ramzi Halabi (Co-advisor)

The meeting came to order at 8:30 pm.

1. ***Discussions and Updates***

Dr. Hassan Hariri discussed about the linear velocity in the flowchart, and also about the symbols of it and how to use them in our own flowchart. In addition to discussing Chaimaa's work, and the problem faced and how Omar's part is related to Chaimaa's wireless STOP button.

1. ***Advisor Comments and Recommendations***

Dr. Hassan commented on the algorithm and the speeded-up video of the algorithm and talked a bit about the "Spiral Algorithm". Dr. Hassan also recommended to watch the "Probably Approximately Correct Coverage for Robots with Uncertainty" video for algorithms (systematic and random). Furthermore, Dr. Hassan also commented on the height of the robot why the height was not predesigned during the assembly.

1. ***Expected Deliverables for Next Meeting***

Retake videos of simulation and show simulations on different surface shapes using same speed and algorithm. In addition to test algorithm in an indoor place and outdoor place. Draw a schematic for the push button circuit integrated in the main circuit. And add the ADXL in the robot.

1. ***Assessment***

None.

The meeting ended on 9:40 pm.

Minutes taken by: Mohamad Laza

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