MECA-Y403

Mechantronics 1: Intelligent Kitchen Table Cleaning Robot

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Contents

1 Project motivation

In our research, we found out that many people struggle with cleaning their tables. It's not just about taking up a lot of time and energy; for some, like those with disabilities or the elderly, it can be really tough. We want to make things easier for everyone, so cleaning the table doesn't have to be such a hard task.

2 Project working modes, functionality and requirements

#	Description	k	Criterion	Level	Flexibility	F
1	to clean	1	Selected cleaning mechanisms	/	/	F3
2	Can be handled easily	1	Mass	3 Kg	±1Kg	F0
3	to have suitable dimensions	1	height	10cm	±2cm	F2
			length	25cm	±1cm	F1
			width	20cm	±1cm	F1
4	to be easy to use	1	/	/	/	F0
5	to be silent	1	it should not produce annoying sound while cleaning	/	/	F2
6	to avoid falling from edges	1	it should have the necessary sensors to avoid falling from edges for both robot and user safety	/	/	F0
7	to finish the cleaning in a reasonable time	1	time	5min	±2min	F1

Table 1: Functional Analysis (Modified)

#	**Priority**	**Category**	**Feature**	**Value**
1	High	Safety	to not have sharp edges	
2	High	Safety	to have edge detection to avoid falling	
3	High	safety	to be able to detect heat and avoid heated plates	
4	High	Safety	to have an obstacle detection to avoid collisions with objects on the table	
5	High	Geometry	to have a geometry which ensures that the robot can be handled and stored easily	
6	High	Dimensions	it should have the appropriate dimensions to clean and move on tables from different sizes	25cmx20cmx10cm
7	High	Capacity	it should be able to hold the objects on its top	<5kg
8	High	Price	the price should be reasonable and affordable for people	around 500$
9	Medium	Ergonomics	the parts should be easily removed/replaced when needed	
10	Medium	Durability	Should work perfectly and safely during its life span	around 5years
11	Medium	Environmental impact	It should use materials and processes that have low environmental impact	
12	Medium	Ergonomics	it should have a touch screen to assure easy interaction between the robot and the user	
13	Medium	Maintenance	per year	once
14	Low	Aesthetics	it should look well	
15	Low	Materials	it should be made from recyclable material	

Table 2: Table of Requirements

3 Conceptual Design

3.1 Challenges

The main issue to surpass in our project is for the robot to detect and avoid falling edges.

There were three types of components that we needed to compare:

- Motors
- Sensors
- Wheels

In regards of our motor choice we had three different options

Motor Type	**Voltage**	**Torque**	**Size**	**Weight**
3.7V Micro DC Motor	3.7V	Low to Medium	Small	Light
12V Geared DC Motor	12V	Medium to High	Medium	Moderate
24V High Torque DC Motor	24V	High	Large	Heavy

Table 3: Comparison of DC Motors

We went with the 3.7V motor mainly due to low power requirement and light weight.

In terms of sensors we had between 3 different options to choose from

Sensor Type	**Falling Edge Detection**	**Application**
Ultrasonic Sensor	Detects falling edges in distance measurements.	Distance measurement, object detection.
Infrared (IR) Sensor	Detects changes in IR reflection for edges.	Proximity sensing, object detection.
Laser Sensor	Detects interruptions for edge detection.	Distance measurement, precise object detection.

Table 4: Sensor Comparison

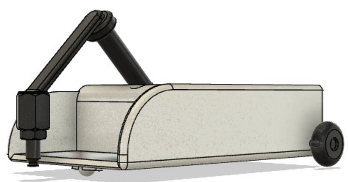
We decided to go with the ultrasonics as they were easier to use. And lastly for the wheels we had 3 options to choose from:

Wheel Type	**Weight**	**Control & Programming**	**Application-Specific Needs**
Meccanum Wheels	Light	Complex	Omnidirectional maneuvering
Rubber Wheels	Moderate	Simple	Versatile, indoor/outdoor
Caterpillar Tracks	Heavy	Moderate	Rough terrain, heavy payloads

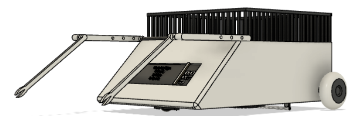
Table 5: Comparison of Small Robot Wheels (Weight, Control/Programming, Application Needs)

Rubber wheels were the better option as it full filled our project needs and was easier to obtain and had simple control in programming

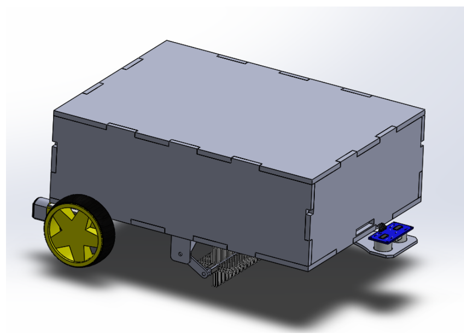
Regarding the final design we went with we had four different designs mainly having different concept for a gripper but ultimately we decided to scrap the gripper and go with a design that had a small weight and a brush in the middle(concept3)



(a) Rubber Wheel



(b) DC Motor



(c) Motor Mount

	Criteria	Concept 1	Concept 2	Concept 3	Importance
1	carry heavy load	1	1	3	4
2	store objects safely	0	1	3	4
3	lift easily the loads	1	0	3	3
4	Good shape	3	1	2	1
5	Simplicity	0	2	1	3
6	Safety	1	1	3	4
7	Comfort of use	2	2	3	3
8	to be easily cleaned	3	3	3	1
9	Easy to maintain	1	3	3	2
10	Price	3	1	2	2
	Total points	31	35	72	

Table 6: Comparision of different concepts

4 Embodiment design

Our project consist of simple parts divided in cleaning unit, dirivng unit and sensors shown in the figure below

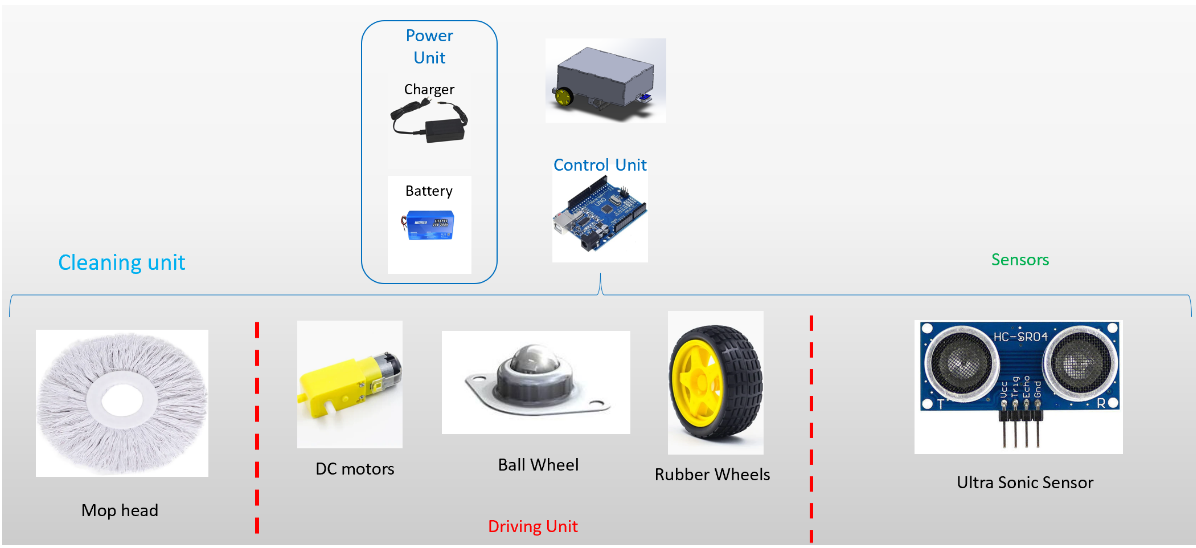


Figure 2: Overview Diagram

The goal of the prototype is to move automonosly while cleaning the table on it's patch with a roller brush, The bahavior of the prototype can be described in the logic diagram below:

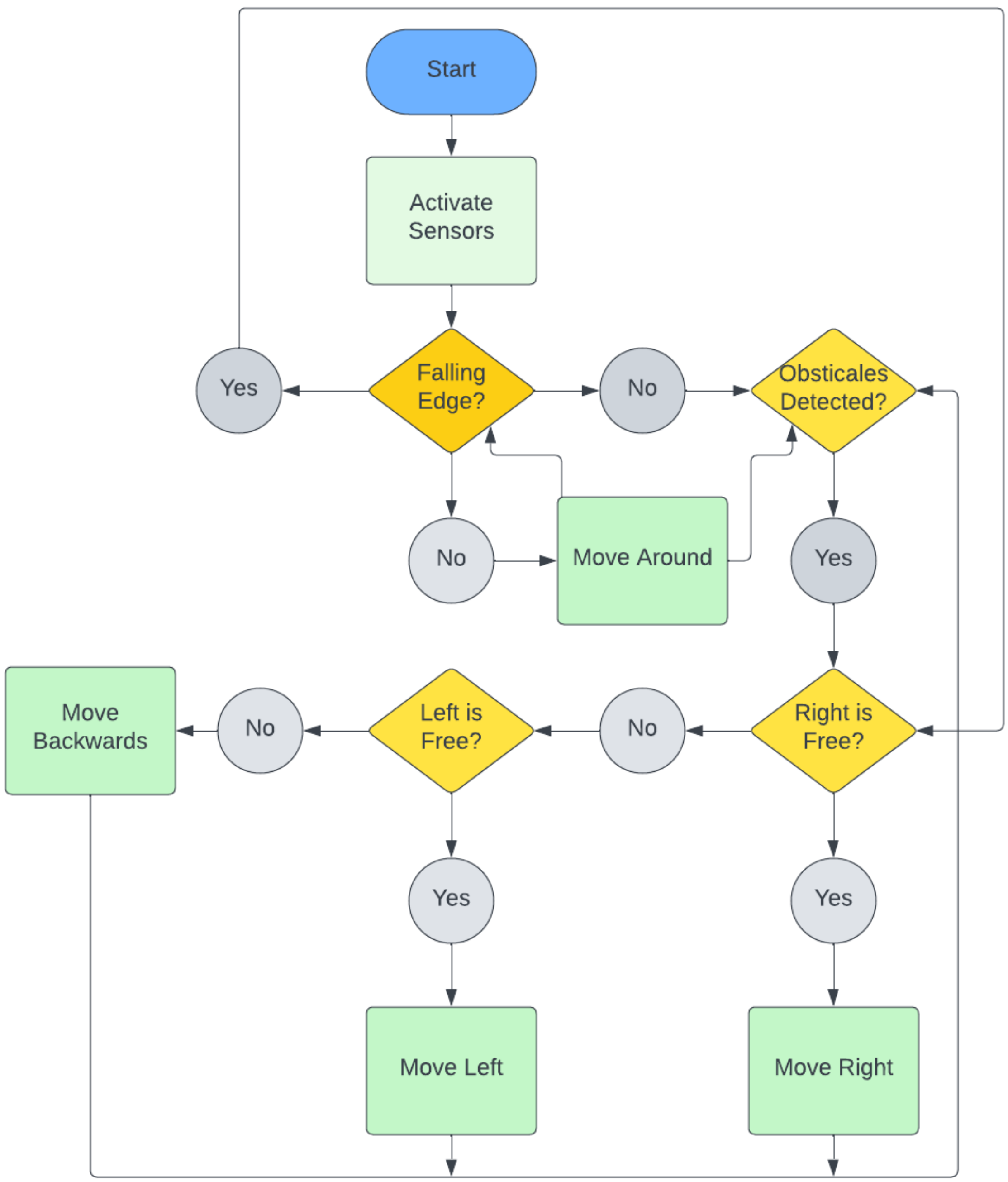


Figure 3: Overview Diagram

5 Design of Sub-Systems

In this section we focus more in depth on different systems for the prototype

5.1 Mechanical Systems

When designing the prototype the main requirement that surfaced was to design the prototype as compact and light weight as possible.

With the limited time, Budget and equipment we realized that achieving the full goal of the project would not be possible so we decided to go layer by layer achieving bare minimum in our project to make an affordable and easy to reproduce robot that can clean the table without falling off the table.

For the chassis of the robot we used 5mm MDF planks which are sturdy and a good alternative for prototyping.

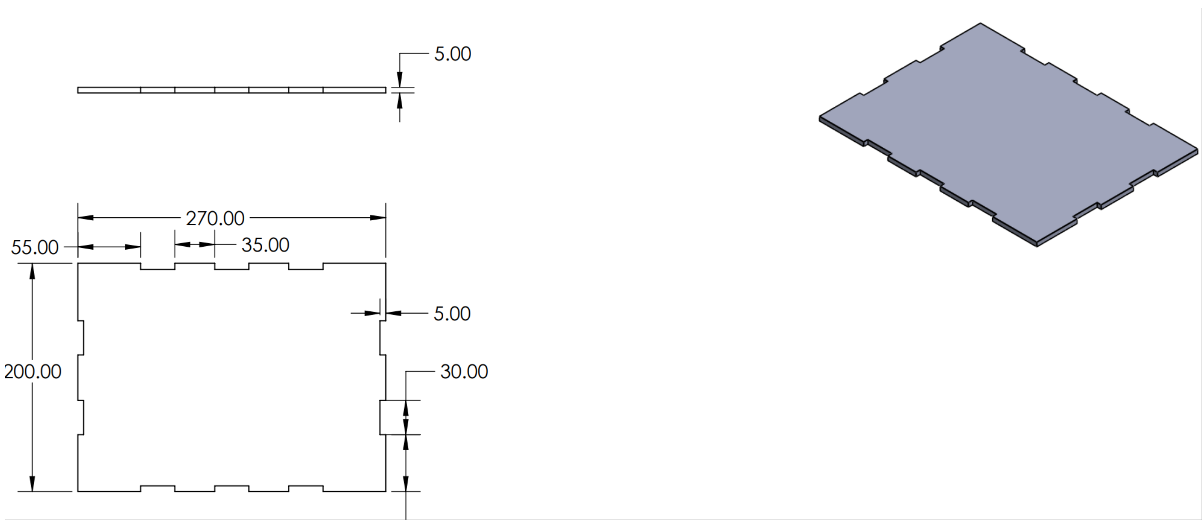


Figure 4: Base Plate

After designing the chassis and using the laser cutter to get our desired robot body model and some trial and errors we managed to obtain the body model we required for our robot. using 3D printed nudges we managed to secure the walls of the robot together.

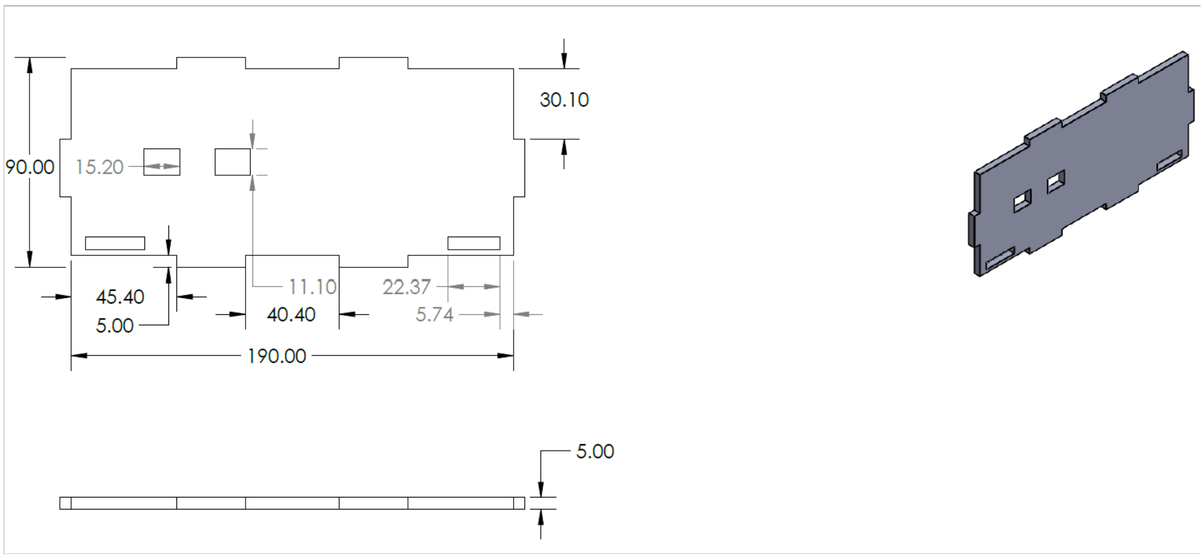


Figure 5: Support walls

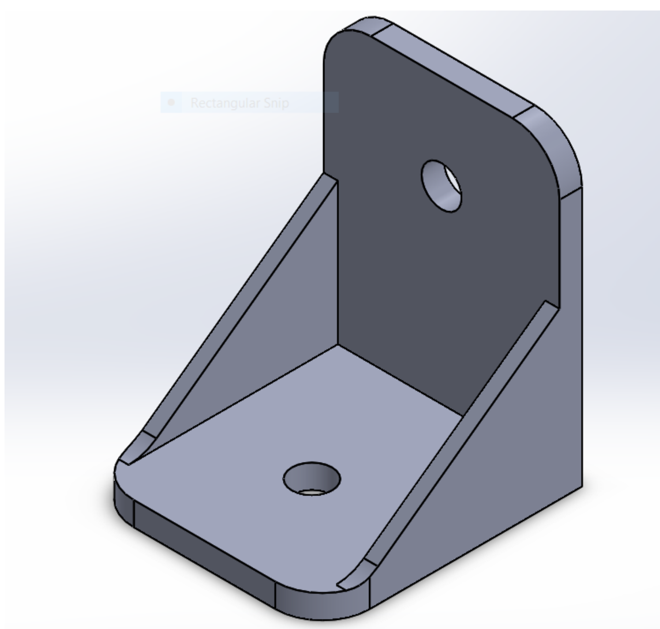
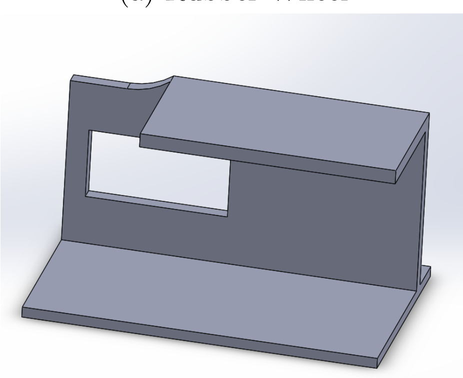


Figure 6: Support walls

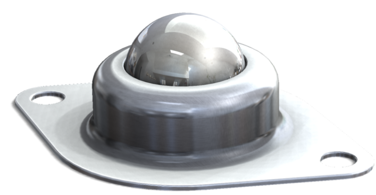
We used two rubber wheels with two 3.7v Dc motors along with a caster ball wheel in front of the robot for better turning which are held to the body of the robot using 3D printed mounts and long screws securely along with a roller brush to clean as the robot moves autonomously.

(a) Rubber Wheel

(b) DC Motor



(c) Motor Mount



(d) Ball Wheel

Figure 7: Drive Unit

After having our frame of the robot we shifted our focus on wiring and programming of the robots behavior.

5.2 Circuitry and Sensors

For our robot to avoid ledges we used an ultra sonic sensor to detect falling edges of tables, another Ultrasonic sensors would help the robot to avoid obstacles on the table however due to our limited time constraint it was not installed however the process of it would be the same but given different parameters within arduino IDE.

The DC motors were connected to the arduino board using an L298n H-bridge in order to control the wheels individually as well as use them together as well as allowing us to control the speed of each wheel individually.

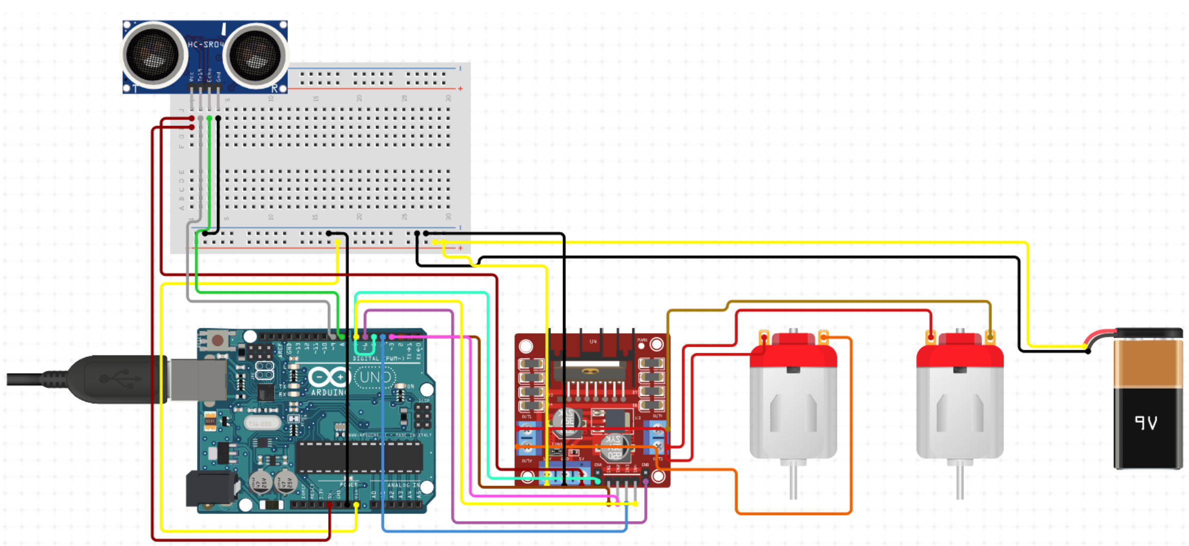


Figure 8: Base Plate

In order to have the right amount of torque a simple calculation was done to ensure the motors would be able to drive our robot.

$$T_w = \frac{r \times M \times \mu_s \times g}{4} \tag{1}$$

- T_w being torque [N/m]
- r being radius [m]
- M being total mass [Kg]
- mu_s being friction coefficient
- g being gravitational constant [N/Kg]

With our components in place it was time to program and test our robot in order to finalize our project.

5.3 Software

one of the main requirements of our robot is fast reaction after detection of falling edges of tables and obstacles. with arduino Uno's limited computational abilities the complexity of our program and data processing needed to be low for our program to work.

Again in order to achieve our goal we went about programming the robot layer by layer, First testing out each part individually to make sure there were no malfunctioning parts, After detecting faulty parts and replacing them we focused on having the robot move forward, detect a falling edge and then going backwards in order to get a good understanding of how much time was needed for our robot to react as fast as it could.

After Which through some trial and error we programmed the robot to turn and find a new path after detecting a ledge and moving backwards.

Here's our Final code:

```
// Motor pins
int motor1_ena = 3;
int motor1_in1 = 4;
int motor1_in2 = 5;

int motor2_enb = 9;
int motor2_in3 = 10;
int motor2_in4 = 11;

// Ultrasonic sensor pins
const int trigPin = 6;
const int echoPin = 7;

// Motor speed
const int motorSpeed = 125;

```

```
// Movement control variables
bool obstacleDetected = false;
bool isMovingBackward = false;
unsigned long obstacleStartTime = 0;
const long obstacleDuration = 1000; // 1 second for backward movement
const long turnDuration = 1000; // 1 second for turning

void setup() {
  pinMode(motor1_ena, OUTPUT);
  pinMode(motor1_in1, OUTPUT);
  pinMode(motor1_in2, OUTPUT);

  pinMode(motor2_enb, OUTPUT);
  pinMode(motor2_in3, OUTPUT);
  pinMode(motor2_in4, OUTPUT);

  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);

  Serial.begin(9600);
}

void loop() {
  unsigned long currentMillis = millis();

  // Ultrasonic sensor logic
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  long duration = pulseIn(echoPin, HIGH);
  int distance = duration * 0.034 / 2;

  Serial.println(distance);

  // Obstacle detection and movement logic
  if (distance > 9) {
    obstacleDetected = true;
    obstacleStartTime = currentMillis;
    moveForward();
  }

  if (obstacleDetected) {
    if (currentMillis - obstacleStartTime >= obstacleDuration) {
      obstacleDetected = false;
      isMovingBackward = false;
      turnLeftOrRight();
    } else {
```

```
      isMovingBackward = true;
    }
  } else {
    if (!isMovingBackward) {
      moveBackward();
    }
  }
}

// Function to move motors forward
void moveForward() {
  Serial.println("Moving Forward");
  analogWrite(motor1_ena, motorSpeed);
  analogWrite(motor2_enb, motorSpeed);

  digitalWrite(motor1_in1, LOW);
  digitalWrite(motor1_in2, HIGH);

  digitalWrite(motor2_in3, LOW);
  digitalWrite(motor2_in4, HIGH);
}

// Function to move motors backward
void moveBackward() {
  Serial.println("Moving Backward");
  analogWrite(motor1_ena, motorSpeed);
  analogWrite(motor2_enb, motorSpeed);

  digitalWrite(motor1_in1, HIGH);
  digitalWrite(motor1_in2, LOW);

  digitalWrite(motor2_in3, HIGH);
  digitalWrite(motor2_in4, LOW);
}

// Function to turn left or right after obstacle
void turnLeftOrRight() {
  // For example, turning left
  analogWrite(motor1_ena, motorSpeed);
  analogWrite(motor2_enb, motorSpeed);

  digitalWrite(motor1_in1, LOW);
  digitalWrite(motor1_in2, HIGH);

  digitalWrite(motor2_in3, HIGH);
  digitalWrite(motor2_in4, LOW);

  delay(turnDuration);

  // Stop after turning
```

```
  analogWrite(motor1_ena, 0);
  analogWrite(motor2_enb, 0);
}
```

Listing 1: The Code

6 Integration guide

As mentioned before our prototype is composed of:

- Driving Unit
- controller Unit
- Cleaner
- Sensor

The Motors are connected to the bottom of the frame using 3D printed mounts held by screws and bolts as well as the ball wheel in bottom front of the frame along with the cleaning brush which is connected in the bottom middle of the frame with 3D printed mounts and small MDF wood.

The Controller unit(Arduino board) and the L298n H-Bridge were attached inside the robot along with 5 9V batteries, 4 to power the motors and 1 to power the controller unit, an ultra sonic sensor is installed in front of the robot facing downwards to detect falling edges should the detection distance rise.

7 Demo Project Showcase and Quick Start Guide

7.1 Demo

a Demo can be found in the google drive link provided in this report

7.2 Quick Start

Some steps were already explained, Here is an explicit instruction

- Cut and print all the necessary parts which are provided in the google drive link
- Attach the motors and ball wheel to the base plate of the frame
- Attach all the electronic parts to the base frame
- Solder and attach wires from motors to the L298n H-bridge
- Wire all the outputs to their designated pins provided in the code section
- Solder and attach a 9v battery to the arduino along with a micro switch
- solder and attach four 9V batteries to the H-Bridge along with a micro switch to turn on the motors
- attach the supporting walls to the base frame and finally attach the ceiling part to the supporting walls of the frame

8 Project Review

Given the limited time, resources, availability of the equipment's and printers in the lab and changes to our group members half way through the project we must first acknowledge the fact that our robot runs.

One of the main issues that we all learned from was that in the beginning of the project we were so focused on parts and features of the robot that were meant to be implemented way later in the project that we lost track of achieving bare minimum, after realizing this we decided to progress through the project layer by layer giving us a clear path ahead.

However even with that in mind we could not install and implement all the features we had in mind due to time constraints and lack of equipment/Staff.

Another issue that even with prior knowledge and anticipation we ran into was the added extra weight keeping the motors from driving properly which costed us a great deal of time however by the end this issue was realized and resolved.

The design of our robot was changed many times, going from a bigger chassis to a smaller one and changing wheels from maccunam to rubber wheels as we were not satisfied with the mounts we could connect the maccanum wheels to our robot, costing us even more precious time.

9 Sustainability Considerations

We tried our best to mostly use MDF wood for sustainability as 3D printing was very limited. we recycled all we could to both save time resources and energy as much as we could during the project period. The robot is easy to assemble and re-assemble again and almost all of the parts can be salvaged and used for future projects possibly by next year students on their robots.

10 Bill of materials

our final bill for everything we used in our project came down to 50.65 euros which is a quarter of our allowed project allowance.

Item	Price (in Euros)
Arduino Uno Board	8.49
L298N H-Bridge	5.29
5mm MDF Wood	13.51
DC Motors	3.67
Rubber Wheels	2.34
Ultrasonic Sensors	2.99
Jumper Wires	2.39
9V Batteries	9.99
Ball Wheel	1.99
Total	**50.65**

Table 7: Bill of Contents with Prices

11 Team

11.1 Aryan Torabi

BCs in mechanical and construction, Current BRUFACE Master, I was engaged mostly in selecting and building the electronic circuit, Sensors, motors and programing the board with a small help in designing and modeling the frame.

11.2 Hamza Yousaf

My Bachelor in Mechanical Engineering and already has some experiences with robotics in bachelor. I was engaged mostly in CAD , Laser cutting Regarding our project,I learned a lot about electronics, Arduino, and project management.

11.3 Sandra Salloum

Bachelor's degree in mechanical engineering, in this project I was engaged in selecting the appropriate design for our robot, Laser cutting/ 3D printing, and joining the different parts of our robot. I learned a lot about electronics, sensors and Arduino. Also, I have developed problem-solving and teamwork skills.

11.4 Mansoor Ali Sabir

I hold a Bachelor's degree in Mechanical Engineering and am presently an Erasmus student at VUB. During this project, my role encompassed contributing to the design, as well as working on Arduino programming and electronic circuits. The project was instrumental in enhancing my design abilities, and I gained practical experience in laser cutting and 3D printing of components. Additionally, it provided an opportunity for me to engage in brainstorming sessions to generate innovative design ideas.

11.5 Mohamad ELMASRI

I'm Mohamad ELMASRI, a double-degree student in the BRUFACE program's Master of Electromechanical Engineering. This year, I made the decision to continue my education in Brussels after completing my bachelor's degree at "Lebanese University."For this project, the mechanical component takes up the majority of the time. Drawing and sketch realisation, CAD design, production, and assembly have been my primary areas of concentration. Due to my strong interest in the field of design, I have found that this project has been most enjoyable in its design aspect. Working with new teammates and picking up new skills from them has also been an experience for me. In addition to laser cutting, I also have some experience with 3D printing.

12 Project Rep

Here is the google drive link to all the files of this project.

https://drive.google.com/drive/folders/1TmWVr48p7PvrTOPtXUQwH7Rnh
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13 References

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