Autonomous Multipurpose Floor Cleaner

SUPERIOR UNIVERSITY

B.Sc. ELECTRICAL ENGINEERING

Noman Rashid
(Beem-F19-016)

M Qumail Asad
(Beem-F19-013)
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Thesis Supervisor: **Dr Manzoor Ellahi**

DEPARTMENT OF ELECTRICAL ENGINEERING

SUPERIOR UNIVERSITY LAHORE, PAKISTAN

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Autonomous Multipurpose Floor Cleaner

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Electrical Engineering

Noman Rashid **(**BEEM-F19-016)

M Qumail Asad **(**BEEM-F19-013)

Supervisor:

DR. MANZOOR ELLAHI

DECLARATION

This thesis is a presentation of my original research work. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions. I also declare that this work is the result of my own investigations, except were identified by references and free from plagiarism of the work of others.

Signature: …….

Noman Rashid

M Qumail Asad

Date: …….

The undersigned hereby certify that they have read and recommend the thesis entitled **"Autonomous Multipurpose Floor Cleaner"** has been investigated and carried out by Noman Rashid And M Qumail Asad for the degree of Bachelors of Science in Electrical Engineering.

_____

Supervisor Name

Dr Manzoor Ellahi

_____

Thesis Committee Member1 Name

Dr M Rehan Usman

_____

Thesis Committee Member2 Name

Dr Saif Ur Rehman

_____

Thesis Committee Member3 Name

Dr Mustafa Shakir

_____

Name

External Examiner

_____

Dr. Mustafa Shakir

Chairman, Electrical Engineering Department

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In the name of God, who is most beneficial and most merciful!

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Thank you,

Noman Rashid

M Qumail Asad

DEDICATION

I would like to dedicate this thesis to our Prophet Hazrat Muhammad (S.A.W) and to my beloved family, teachers and friends.

Table of Contents

List of Tables

LIST OF FIGURES

ABSTRACT

In recent years, people are becoming more career oriented and due to their irregular working schedules, it becomes challenging to maintain both home and office together, especially for women. Most of the cases, they hire cleaners to clean their homes, offices, etc. but have no trust in cleaners. To overcome the problem, Traditional Vacuum Cleaner has come up with more advancements in technology and is designed to automate the cleaning process. The application is used to initiate the robot. The navigation of the robot is according to the S-curveplanning and with the help of sensors, it detects and avoids obstacles. To save people's time, the smart vacuum cleaner helps clean the floor's surface without any human intervention. Cleaning houses and the surrounding environment is more arduous in the hectic schedule. At present, there are vacuum cleaners that require humans to handle them. Thus, there is a dire need to implement a vacuum cleaner that works without human intervention. An efficient method to clean the desired area has been implemented through this project. By using this vacuum cleaner hazardous place can be cleaned which thereby reduces risks to mankind. Thisis achieved by implementing an autonomous system.

Today, the research is concentrated on designing and developing robots to address the challenges of human life in their everyday activities. The cleaning robots are the class of service robots whose demands are increasing exponentially. Nevertheless, the application of cleaning robots is confined to smaller areas such as homes. Not much autonomous cleaning products are commercialized for big areas such as schools, hospitals,malls, etc.

Development methods which included the following phases: analysis, design, implementation and testing. The robot, developed using an Omni wheel and is equipped with a vacuum cleaner and floor polishing motor. The control system used is based on the Arduino microcontroller, the robot is also equipped with a Bluetooth communication system so that it can be controlled via an Android smartphone. The developed robot is able to move according to navigation controls via an android smartphone. Besides this robot is also able to move to avoid obstacles if the distance between the robot and the barrier will be 5 inches. Floor cleaning performance on various types of dirt is quite good with only leaving dirt on the floor less than 20%.

CHAPTER 1
INTRODUCTION

This chapter presents the background of the Autonomous cleaning robots states in terms of scientific research. Moreover, we discuss the objectives of this thesis and our main contribution, structure and the environment used for this work.

1.1. Background

In this thesis, the proof of concept is designed for the autonomous floor-cleaning robot. A thorough background study is conducted on domestic service robots to understand the technologies involved in these robots. The components of the vacuum cleaner are assembled on a commercial robotic platform. The principles of vacuum cleaning technology and airflow equations are employed for the component selection of the vacuum cleaner. This system uses a belt drive mechanism to maneuver. The use of belt drive increases the area of magnetic attraction while the robot is in motion. A semi-systematic approach using patterned path planning techniques for the complete coverage of the working environment is discussed in this thesis.

Cleaning the environment around us is one of the important duties of each and every individual. Bigger the area to be cleaned, greater number of people will be needed. Some places will be so dirty that cleaning such areas causes huge impact on health. Due to dust present in the surroundings, people are prone to allergies, watery eyes, cold, cough, rashes etc. [1]. Vacuum cleaner can be used for domestic purposes such as to clean the floor, car, carpets etc. It can be used efficiently in colleges as the space is also large. In the current COVID situation since social distancing has to be maintained, a greater number of people cannot clean together. In this era where digital technology is rising rapidly, mankind is becoming more and more dependent on the same. Since majority belongs to the working population, there is always a shortage of time.

The Internet of things (IoT) is a network of physical devices that are embedded with electronics, sensors, software, and network connectivity to share data. The IoT gives access to sensitive and controls the objects remotely in a network which gives direct integration of the physical world into computer-based systems.[2] Robotics details with design, operations, construction, and application of robots. It also details a computer system for control, information processing, and sensory feedback. The Internet of things and Robotics have been hand-holding each other contributing to individual growth and development.

1.2. Selection of Method

The first step of this project was to investigate the requirements for a Multipurpose robot cleaner. This step provided information about specifications that customers expect from the product. The result was an important input to the design work. The necessary parts included and dimensions could be determined. A preliminary design was

developed, and a first prototype manufactured. Depending on the function of the prototype the design process continued and improved the product. Finally, through numerous iterations, a functional prototype was developed.

1.3. Problem Statement

Since there are lots of problems happened during floor cleaning process, like human as well as systematic error may be happened during cleaning of floor. Due to the increasing of human work load they are unable to clean. As we know that technology comes up from time to time and need to upgrade for making more easy human tasks. To bring innovation and advancement in Vacuum technology. So, to clean every Corner of Floor we are designing the robot who can do work regarded cleaning manually as well automatically.

1.4. Methodology

The Figure 1.1 describes block diagram which includes components like ultrasonic sensors, motor drivers, Wi-Fi module and vacuum cleaner which are connected to microcontroller and the power supply of 12V is given. The dotted lines represent that microcontroller controls the Ultrasonic sensors and motors for obstacle detection and to move in a particular direction. Wi-Fi Module is used to control the robot through dashboards for ON/OFF by connecting to cloud

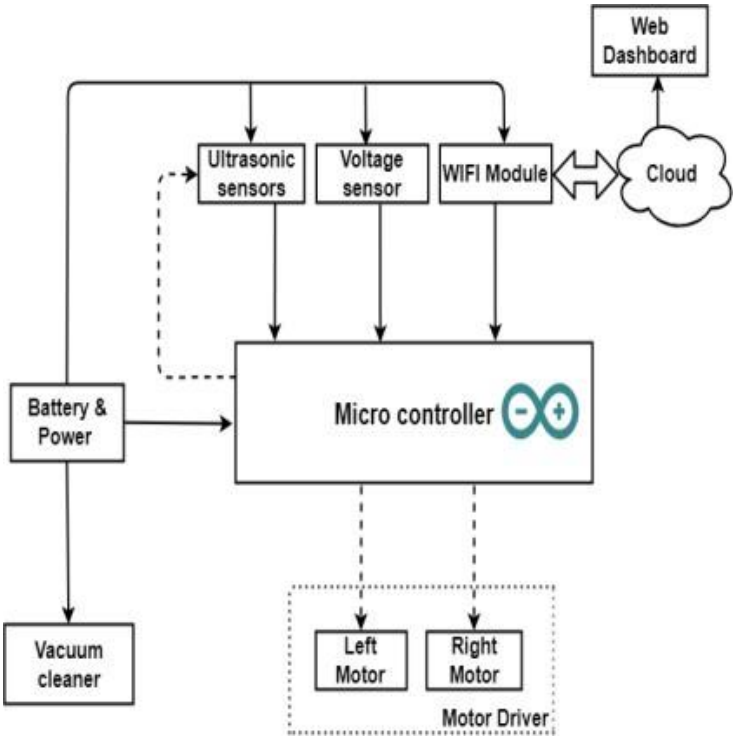

Figure.1.4-1: Functional Block Diagram

The Figure 1.2 describes the flow of information between the components. When the application is started, the user must authenticate then s/he can control the robot through

dashboards. When the robot is turned on the ultrasonic sensors check for the obstacles on its path. If obstacle is detected, the robot stops for few seconds and changes its direction according to the program. Every time the robot moves it checks for the obstacles and continue its cleaning process.

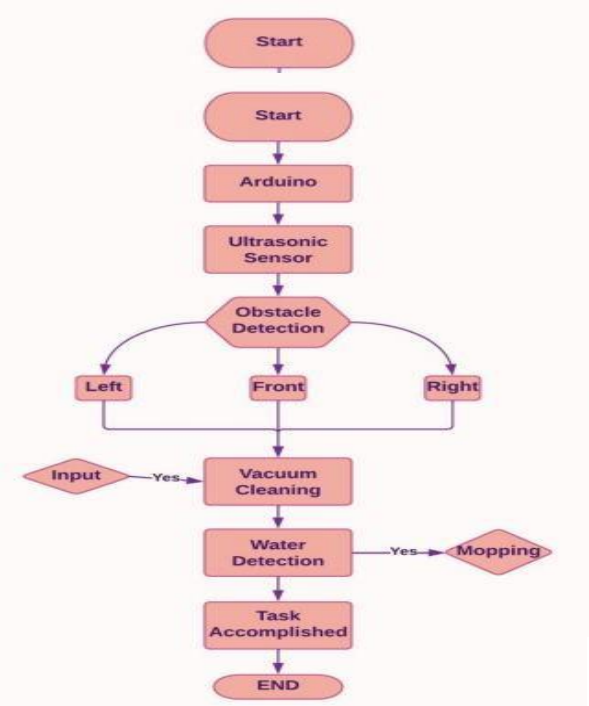

Figure 1.4-2: Movement Flowchart

1.5. Objectives

This thesis has the following objectives:

1. To make an autonomous vacuum for cleaning
2. Bringing innovation and moving towards AI.
3. Also, can be controlled by mob App and web
4. By using Arduino Controller and by programming it according to requirement
5. Using Multiples sensors for making it safe and efficient.
6. for its movement use a DC motor and battery of 12v for their supply.

The first step for the initiation of any project or research is defining its objective. The topic "autonomous multipurpose cleaning robot" in- volves a vast set of concepts, tools, theories, methods, and problems. It can be narrowed down only based on the project requirements. The idea of a robotic vacuum cleaner is good, but it is already existing at private homes. This motivated to design a proof of concept to a large area like schools. Nevertheless, the concept of automated board cleaner is still in the research stage. Hence, the idea of collaborative implementation of automated vacuum cleaner robot along with board cleaning robot was generated.

1.6. Main Contributions

The modern robotics is a science of intelligent control and connection between perceptionand action. The action of the robot is fulfilled by locomotion for moving in and around the environment while the operation of objects present in the environment is through manipulation. Wheels, propellers, thrusters, crawlers and limbs form the basic locomotion components for a robot while the manipulation is achieved with end effectors, grippers, artificial arms, and hands. Sensors are used to obtain information about the state of the robot such as speed, position, range, vision, forces acting, etc. The micro-controller or robot computer is used to perform programming, planning and control [3].

Our main contribution is to make a multipurpose cleaner in one thing. Already there are many products available in the market but they are much expensive and some have complications to use they are not very much user friendly so, we are making that will be less expensive and will be very simple to operate and user friendly.

Currently, the research is concentrated on designing and developing robots to address the challenges of human life in their everyday activities. The work is focused on developing a new generation of robots that can live together with humans by providing assistance and services to humans at their home, workspace, and public spaces.

1.7. Structure of the Dissertation

Chapter 1 Introduction and Background of the Project or cleaning robots Chapter 2 describes the literature review and previous work done. Chapter 3 Simulation of the project. chapter 4 presents the hardware implementations and its working. Chapter 5 will be presenting the conclusions and final results.

1.8. Used Environment

Following tools and environment were used for data processing and visualization.

1.8.1. Arduino IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.[4].

Figure 1.8-1: Arduino IDE Software

1.8.2. Proteus

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing printed circuit boards[5].

1.8.3. Hardware

Hardware of the project will be done using multiple tools and electrical components for its implementation. Components that will be used are DC Motors and different multiple sensors and battery.

1.9. Work Division

Table 1.9.1:Working Division

Sr No	Name	Allocated Task
1	Noman Rashid	Software based simulation, mechanical structure and Documentation.
2	M Qumail Asad	Software logic development and Hardware integrated design.

1.10. Conclusion

This Chapter describes IOT based Autonomous Multipurpose Floor Cleaner. In recent years we are facing problems of cleaning due to lack of time. As it will be remotely controlled so it will save time for busy people. It is capable of performing dusting, Moping etc. Furthermore, The front panel with the sharp distance sensors is able to identify the obstacles which then allow an robot to move in an obstacle free path

CHAPTER 2
LITERATURE REVIEW

2.1. Literature Study

The reference [6], They have designed a robot and the robot is controlled using Bluetooth which is present at both the transmitter and receiver ends. In this paper, for controlling the robot they are using Bluetooth and it is at the transmitter side and receiver side. By passing the commands, from mobile phone and maintain minimum prescribed distance by the Bluetooth committee for transfer of information. Based on the instructions robot will starts the working.

In [7] the S-curve planning is used for efficient working along with sensors to avoid obstacles.

The Authors in [8] is In this paper, an automatic car is built using the concept of neural networks. This detects the obstacles present using sensors. Arduino and Raspberry Pi are used in this model.

In [9] They have developed a smart floor-cleaning Robot that can clean the place by navigating, sucking the dust, and polishing the floor. The robot consists of an Omni wheel which is equipped with a vacuum cleaner and floor polishing motor. It is coded in Arduino IDE by using an Arduino microcontroller and it is equipped with Bluetooth so that it can work from a smartphone connected via Bluetooth.

The Authors [10] is "Deep Reinforcement Learning-based ROS-Controlled RC Car for Autonomous Path Exploration in the Unknown Environment". The software used here is ROS and Arduino.

In [11] Here, sensors are used to detect any obstacle and Arduino is used to control the robot. Mapping is applied so that the robot can clean without any human intervention once it is switched on.

The Reference [12] Here, different modes of cleaning available such as mopping, sweeping, or both mopping and sweeping are discussed. For controlling the robot, a Bluetooth module is used and other functions are coded in Arduino. This can even clean corners of the floor.

The Authors in [13] this paper, a robot has been designed that stores the plan of the room and makes the work feasible. This can be used for various environments as well. It is a cost-effective system.

The reference [14] is Here, an economic prototype is designed using Arduino Mega and Raspberry Pi. A GPS module is also present which helps the bot to move in the right direction.

In [15] Here, a bot is designed which can be controlled through Android. By using the

application, the bot can be turned in the desired direction.

The Authors in [16] is In this paper, the vacuum cleaner is implemented which operates automatically or through an android application. If the battery percentage is less, a message is sent to the registered mobile number regarding the same.

In [17] In this paper, a bot is designed to clean the solar panels using DC Motor which powers the wiper. Water is not used to clean the panels. This system's efficiency is about 87 to 96 percent.

The reference [18] design and development of floor cleaner robot which works on both automatic and manual mode. This robot is controlled by AT89S52 microcontroller. This robot detects the obstacles in its path by the IR sensor. It uses dual relay circuitry, one for pumping the water and the another for driving the motors. This robot is designed like if it detects an obstacle in its cleaning path, it changes it lane and move back, in its automatic mode. Obstacle detection and hurdle detection in the path of the robot are displayed on LCD.

In reference [19] The Social Impact of a Systematic Floor Cleaner, the robot named Mint was developed to clean and mop the hard surfaces of the floor using clothes was designed. It reveals the works of the robot which works automatically and helps the human being in their daily lifestyles. Mint was designed for the systematic cleaning and it automatically change itself with respect to the surface in which it works.

In [20] presents the look, developed and fabricated model of programmed cleaner robot. this type of robot performs automated function with extra features like choose and place mechanism and dirt container with air vacuum mechanism. this type of labor is straightforward and helpful in betterment of life variety of a mankind.

The reference [21] provided a comprehensive overview of the technological advantages helped within the real world for the convenience of just about all of the people that are extremely busy. Consequently, this has led to arriving up with a goal of constructing an automatic home appliance. The review includes computerized cleaner having components to DC motor operated wheels, the dustbin, cleansing brush, mop cleansing and obstruction avoiding sensor. A 12V battery is employed for supplying power. Special technique of ULTRAVIOLET germicidal cleaning technology. The study has been done keeping in mind economical expense of product.

The Authors in [22] discussed the event of Automatic Floor Cleaner. The project is often used for domestic and professional purpose to scrub the surface automatically and manually. When it's turned ON, it gulps within the dust particles by moving everywhere the surface (floor or the other area) because it moves over it. the driving force control mechanism are often wont to drive the motors where robot having the ability to maneuver and also the also few sensors are accustomed detect and avoid the obstacles. this can be often useful in making the approach to life better for humankind.

The reference [23] reviewed the requirement of a residence Cleaning Automatic robot. For

keeping time there's a requirement of programmed system that cleans alone without person interventions. Also, they considered how precisely to help those that have physical disabilities. Because that they had to induce this done, they needed a cleaning system that may add accordance from what we are saying, thus supporting a physically someone.
In [24] presents that floor cleaning is worn out a neater way and efficiently by robot utilizing wireless system. This proposed robot saves the time and economy of labor. within the previous research papers like robot household appliance and automatic floor cleaner robot had some drawbacks like colliding with objects before of it and this vacuum couldn't reach to small areas and left those areas unclean and therefore the automatic floor cleaner robot collects the dirt but the downside up here is that it doesn't clean the wet floor. Few of the drawbacks during this project paper are overcome.

The Authors in [25] the target of this project is to form a totally automated hybrid home cleaning robot. Which is fully automated and may perform tasks like mopping and cleaning of floor. After the testing we discover that it can perform all tasks fine with none hurdle. We tested our robot on various parameters like path following, obstacle avoidance, navigation, mopping and vacuum mechanism.

2.1. Comparison Table

This table represented the previous work done in relevant to our project and their deficiencies in the previous work.

Table 2.1.1: References Comparison Table

Ref no	Year	Contribution	Limitation	Recommendation
[6]	2019	Design a cleaning robot that is operated Through Bluetooth and controlled by the user	This can only be controlled by Bluetooth and required human interference.	It should perform some tasks on its own without human interference.
[7]	2021	Design a smart vacuum that works according to S-curve planning.	It only operates on S-curve planning there is no otherway to operate it.	There should be multiple ways to operate for ease.
[8]	2020	Design a Driverless RC car that detects obstacles by sensors and does this by using Arduino and raspberry pie	It detects obstacles on its own but needs a human or person for its operation.	It also should able to perform cleaning automatically.
[9]	2019	Design a smart floor cleaning robot that is also operated by a Mobile phone through	It also uses Bluetooth and isnot fully automatic and needs human	Robot mustdetects own its on and start cleaning

		Bluetooth and clean the place by navigate the area.	interference	
[10]	2020	Develop a ROS-controlled RC that explores its path in an unknown environment on its own	It can explore paths autonomously but does nothave sensors for obstacle detection or other purposes safe sensors.	It must have sensors so it can also detect obstacles.
[11]	2020	Develop low coast cleaning robot which uses mapping algorithms for its operation and detects obstacles.	It only works with specificmapping algorithms.	It must have multiple mapping for more effectiveness.
[12]	2019	Develop a multifunctional floor cleaner that uses a Bluetooth module to control or operate it.	It also operates by Bluetooth and control by a human. It's not fully autonomous.	By having microcontroller, it will become almost fully automatic.
[13]	2019	Develop an intelligent cleaning robot for the uneven environment and it is cost-effective also.	This robot is also controlledby a human.	It must be fully automatic.
[14]	2020	An autonomous vacuum cleaner consists of a GPS module for its movement in the right direction.	This robot is expensive andless affordable.	They also have tomake less expensive.
[15]	2019	Android-based smart floor cleaner which can be controlled through the application.	To control it users, have to use its application and fromthere it can be operated by the person.	They should make it application free and fully automatic
[16]	2021	Develop a smart vacuum with two modes of control,by remote or automatically.	It is expensive and doesn't serve multi-purposesof cleaning.	It should be able to perform multiple
[17]	2021	Develop an auto solar panel cleaner using Arduino and DCmotors for wipers.	It can only be used for solarpanel cleaning and there is no other place where it can be used.	There should another source of power along with solar panels.

2.2. Conclusion

There are many existing paper and models that represent the additional features for cleaning robot. Few of the models may have drawback that can be overcome by applying the intelligently programmed with advance techniques

Chapter 3
Simulation and Results

3.1. Introduction

The project is based on the design of an Autonomous multipurpose floor cleaner robot. The cleaning robot is a combination of many mechanical and electrical equipment such as Arduino, ultrasonic sensors, vacuum cleaners, a mopping motor, and a two-way battery source. The simulation of the project is designed in Proteus. At first, electrical connections are established in Proteus for testing purposes. In this proposed model designed in Proteus three ultrasonic sensors are used for the detection of obstacles in the path of the robot. A vacuum cleaner is turned on through a switch and it starts cleaning the floor, for water detection controller senses the presence of water through the sensor and turns on the mopping to clean water. Robots work according to the scenario. In scenario 1, the robot moves in the forward direction if there is no obstacle it keeps moving straight on the path. In scenario 2, if the robot detects an obstacle in front, the robot turns toward the right side and starts moving. In scenario 3, if an obstacle is detected by the robot at the front and right side it will turn to the left side and start moving. In scenario 4, if an obstacle is detected by the robot at the front, right and left sides it will turn backward.

3.2. Mechanism and working of the robot

The floor needs to be cleaned, the robot starts cleaning via Bluetooth control and manual control. The robot starts mopping if the sensor detects water and sends input to the controller. In general, the robot's functioning includes four steps.

1. When the robot is turned on, the vacuum pump starts to clean the dust.
2. During cleaning, if the robot detects water on the floor, it starts mopping and turns off the vacuum
3. Avoiding the obstacle by sensing the vibrant scenarios.
4. Fully automatic, Semi-automatic, and Manual control system

In the simulation, all the results are displayed on the virtual monitor. LEDs are connected to the controller for indicating the movement of the robot. The primary purpose of the autonomous

A robot is to clean the floor effectively, it can clean the dirt and mope water from the floor. The robot can detect obstacles and can avoid those to clean the area.

3.3. Algorithm Flowchart

The algorithm flowchart described below used in our Proteus simulation is shown in Figure 3.3.1. This flowchart algorithm shows the step-by-step process.

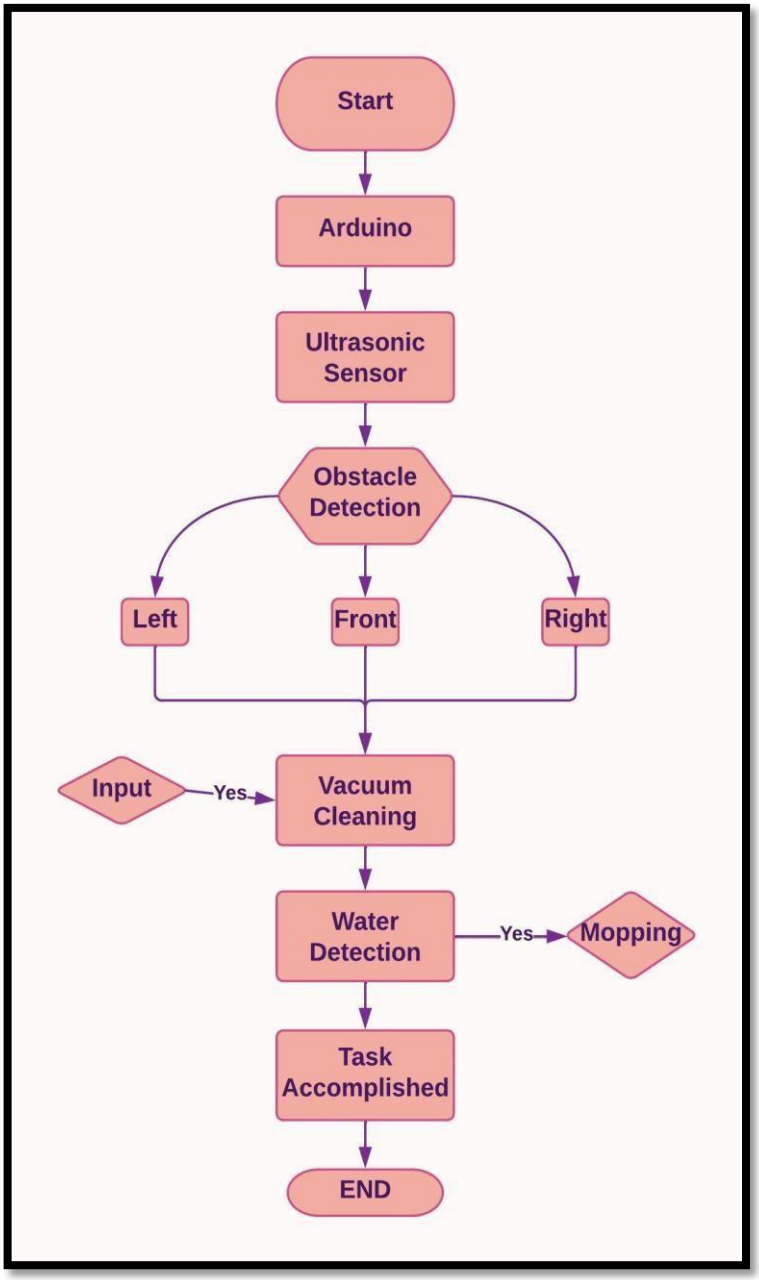

Figure 3.3-1: Flowchart of Robot working

3.4. Components

The components used for the simulation of the project are:

- ARDUINO
- Ultrasonic Sensor
- Vacuum cleaner
- Mopping Brush
- Moisture Sensor
- Motors
- Virtual Monitor

3.5. Methodology

ARDUINO controller is used along with the sensors to provide an efficient solution. The following steps are followed for the simulation

- Sensors to sense the water on the ground and obstacles
- Selection of path according to the scenario
- Motors to control the vacuum and mopping brush
- ARDUINO to fetch the parameters from sensors
- Pseudo code in ARDUINO IDE (Integrated Development Environment)
- Proteus for connecting the electrical sensors
- Virtual Monitor to observe the Results

Parameters for path selection and motor controlling mentioned below in Table 3.1

Table 3.5.1: Simulation Parameters

Sr. no	Distance	Move Forward	Turn Right	Turn Left	Turn Back
1.	5 inches	> 5 in	< 5 in	< 5 in	< 5 in
2.			> 5 in	< 5 in	< 5 in
3.				>5 in	< 5 in
4.					> 5 in

The controller has to first check the distance from the front side, if it is greater than the threshold value then moves forward without checking the distance on the right, left, and back sides.

3.6. Mathematical Calculations

An ultrasonic Sensor is used to calculate the distance between the sensor and an object by emitting high-frequency sound waves and measuring the time it takes for the waves to bounce back. Distance is determined by utilizing the accompanying equation**:**

$$\boldsymbol{Distance = \left(\frac{time}{2}\right) \times speedof\ sound} \quad \textbf{(3.1)}$$

$$\boldsymbol{Speed\ of\ Sound = \left(\frac{344m}{s}\right)} \quad \textbf{(3.2)}$$

$$\boldsymbol{Distance = \left(\frac{time}{2}\right) \times \frac{344m}{s}} \quad \textbf{(3.3)}$$

The distance is equal to half of its time because the time taken by the sound waves to travel to the object and back to the sensor is double. Hence divided by 2 to acquire the distance from the object to the robot where the speed of sound is the velocity of sound waves through the medium the waves are traveling in (usually air), and the time is the time it takes for the sound waves to travel to the object and back.

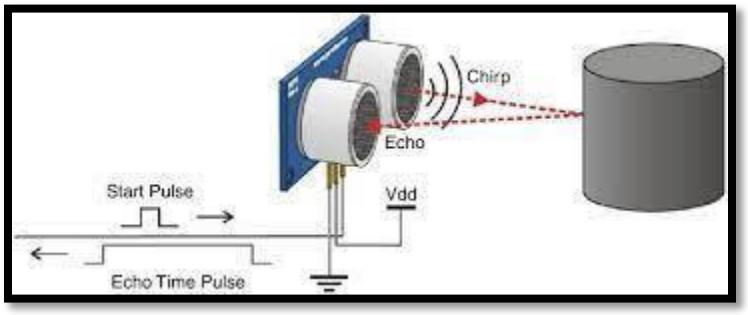

Figure 3.6-1: Ultrasonic Sensor Working [26].

Let us have time of 1.5 ms
By putting the values to equation 3.1
we have,

$$\boldsymbol{= 34\ Cm\ \times 1.5\ ms\ /2} \quad \textbf{(3.4)}$$

=25.5 cm

3.7. Simulation Results

The simulation of an Autonomous multipurpose floor cleaner robot is presented on Proteus. ARDUINO controller is used here as a platform to sense the obstacles, detection of water, and

for path selection through sensors and control the vibrant scenarios.

Four cases are presented i.e., obstacles, path selection, water detection and mopping, and vacuum cleaner. Hence the lights are controlled based on the path followed by the robot. If there is no obstacle detected in the path front light will be high and the robot will keep moving onto the forward path. ARDUINO observes all the paths through the given data of the sensor of all routes individually by a sequence. If the obstacle is detected on any route then the robot selects the path to act accordingly to control the lights. The electrical connections are presented in Figures 3.7.1 and 3.7.2.

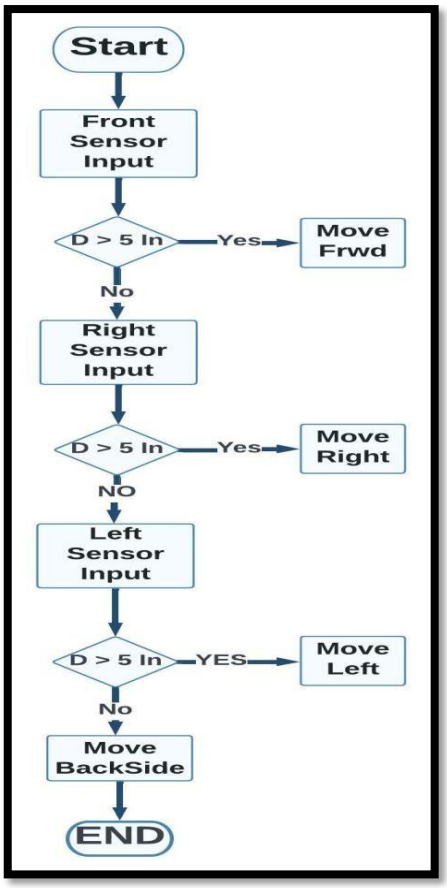

Figure 3.7-1: Robot Path Selection

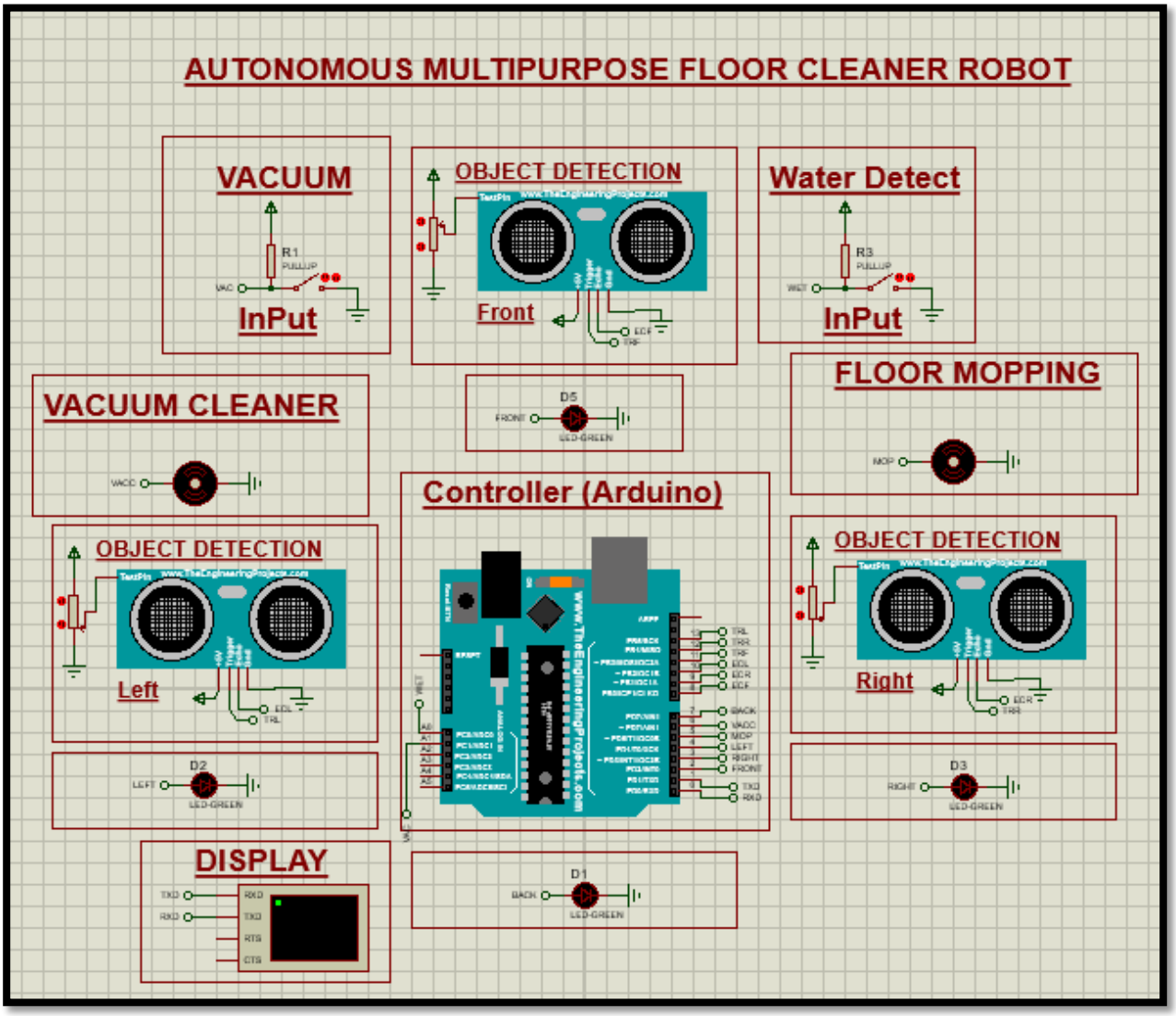

Figure 3.7-2: Proteus Circuit Diagram

Four cases are presented i.e., normal routine, avoiding obstacles, vacuum cleaner, and mopping of the floor. Hence the robot lights are controlled based on their vibrant scenarios. Overall, there are four routes to be followed by the robot. If there is no obstacle at the front route the front light will be turned ON. If there is an obstacle in front, the robot will change its path.

Case 1

In the first case, the robot uses the designed algorithm to find the optimal path. The path planning algorithm will observe the sequence of data collected through the ultrasonic sensor. In this case, there is no obstacle detected in front of the robot. Hence front led is turned to indicate the path followed by the robot. Robot Virtual Monitor will display the results as shown in figure 3.7.2

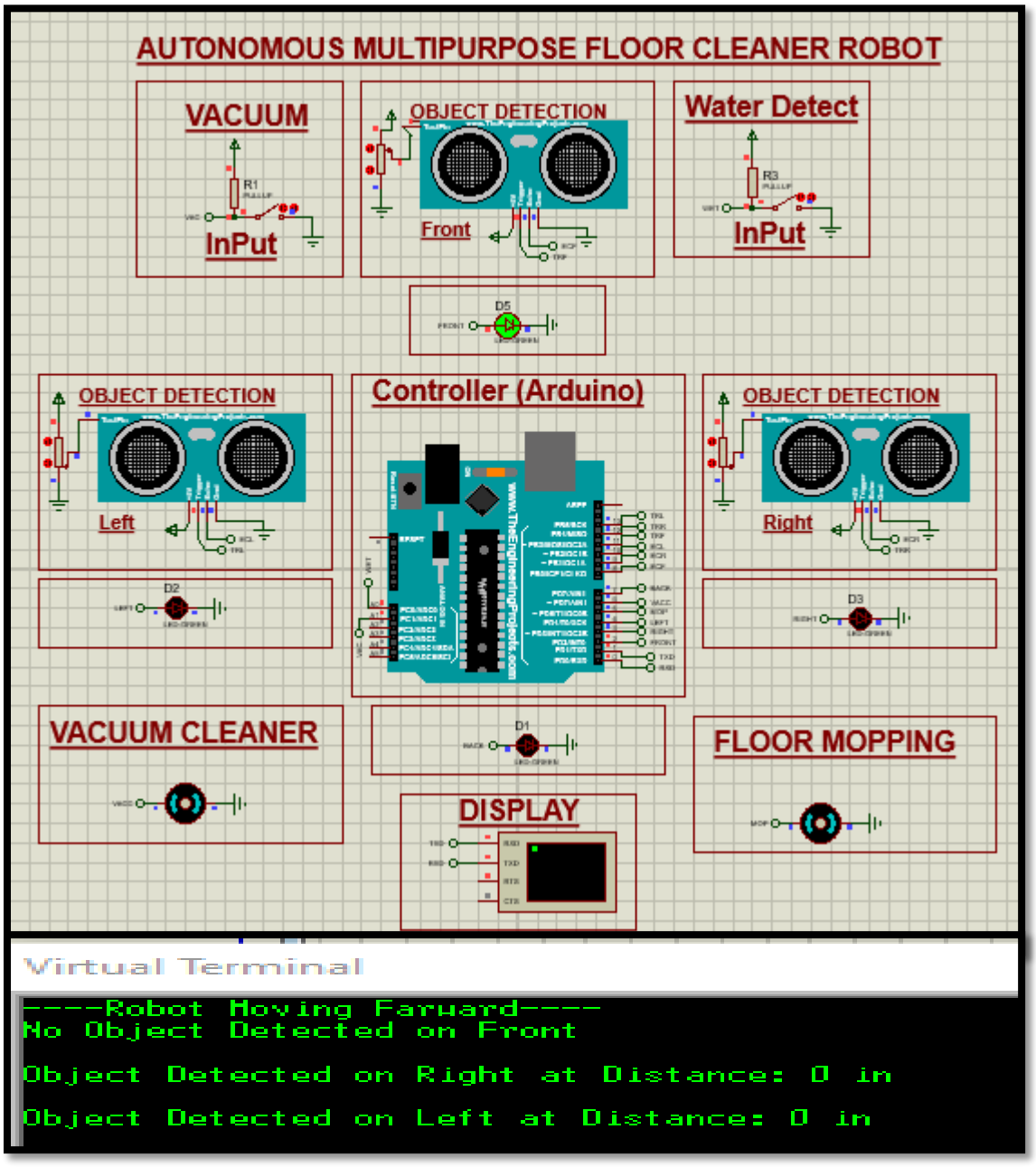

Figure 3.7-3: Moving on Front Route

Case 2

In the Second case, the robot used its sensors and path-planning algorithm to control its movement. The robot has detected an obstacle in route. Hence robot turned left and the light on the left side is turned ON. The robot's control system would execute a set to change the path and avoid obstacles as shown in Figure 3.7.3.

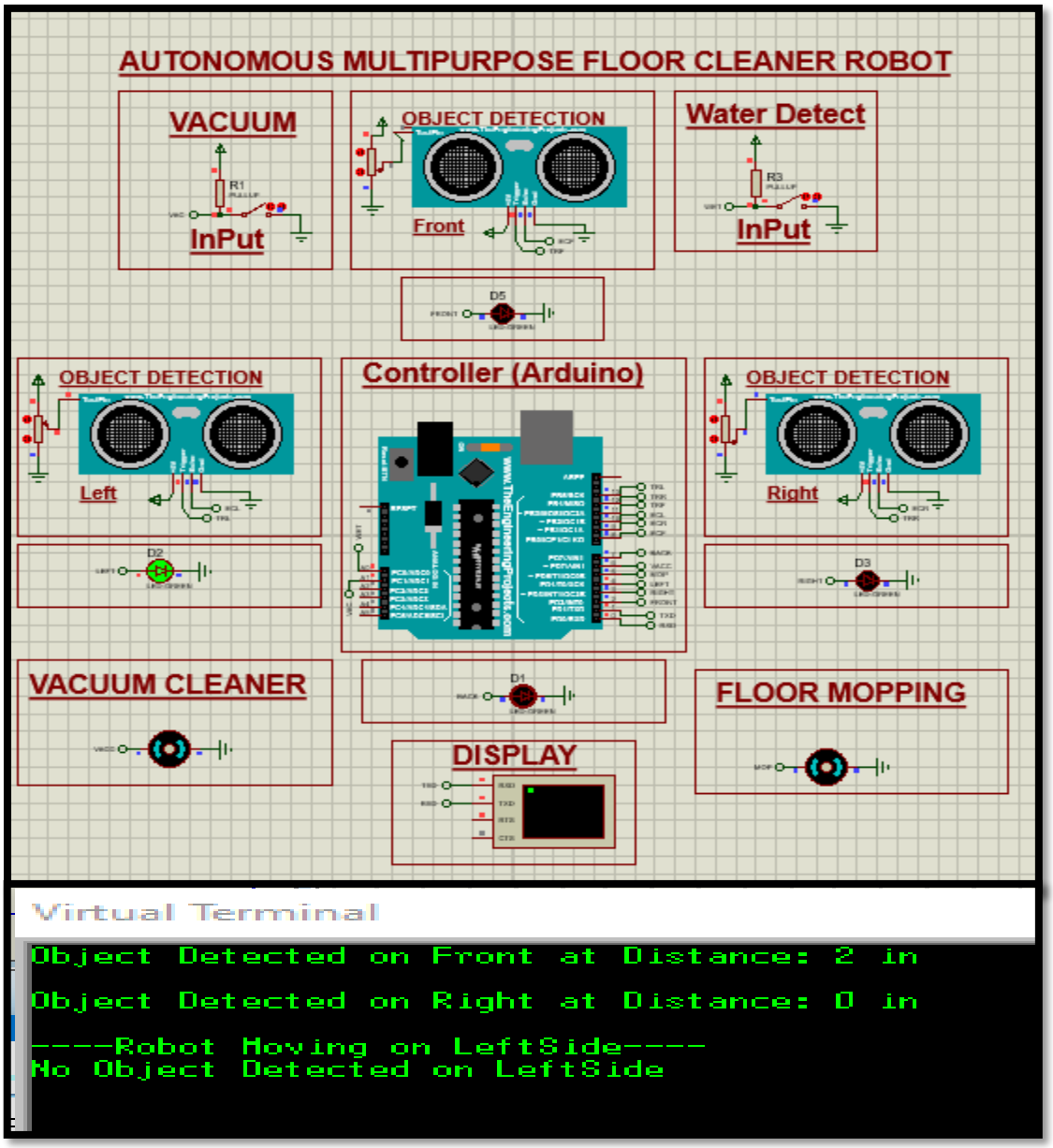

Figure 3.7-4: Moving on Left Route

Case 3

In the third case, the robot has used a motion planning algorithm to determine the specific movements required to move in the desired direction along the path. When the robot detects an obstacle on both the front and left side it will change the direction to the right side and the light on the right side will be turned ON to indicate the path. This would involve path determining and controlling the motor to control the robot's wheels. Results are shown in Figure 3.7.4.

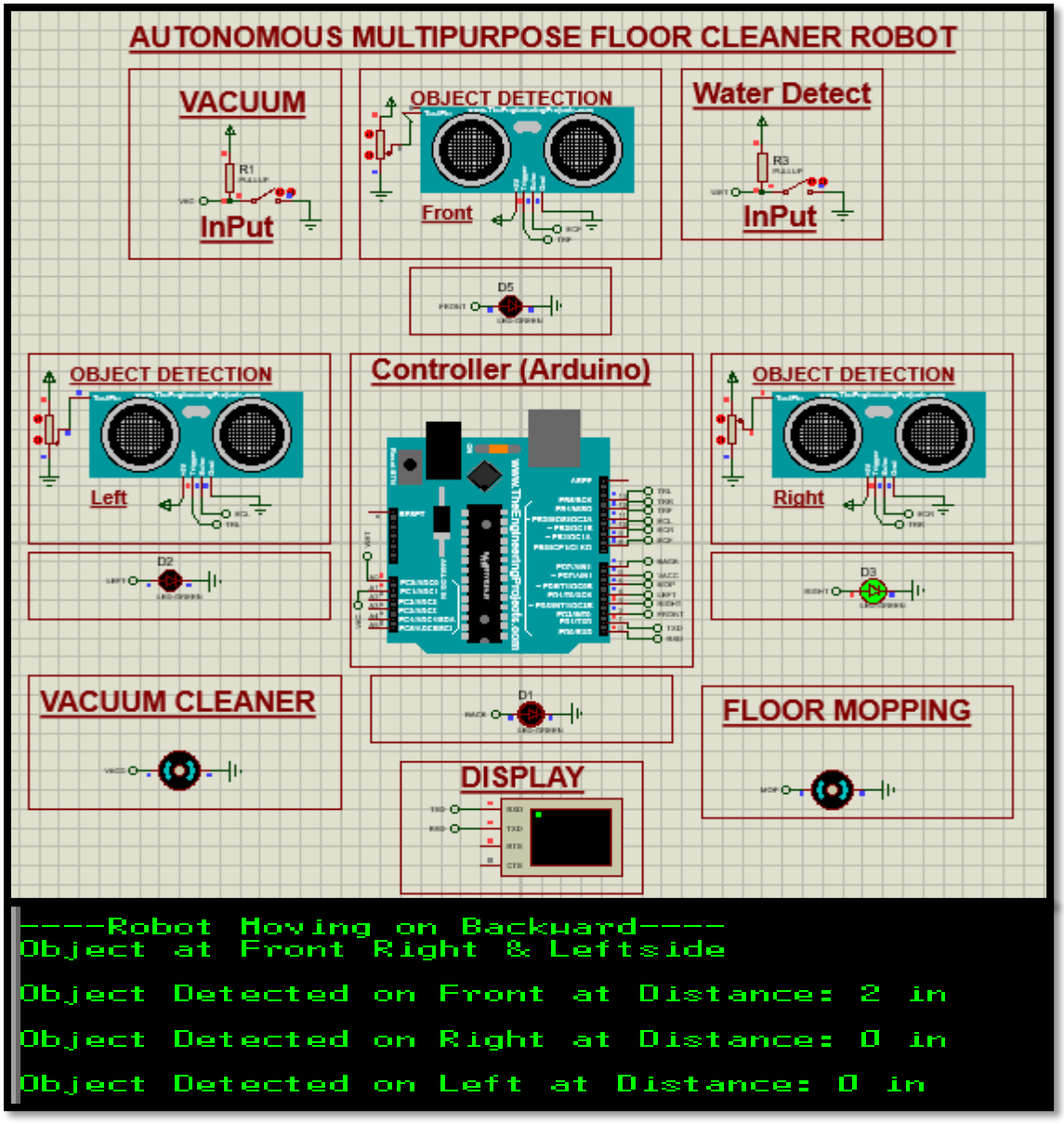

Figure 3.7-5: Moving on Right Route

Case 4

In the third case, the robot again checks all the routes individually. The robot detected the obstacles on all the routes and used a motion planning algorithm to change its direction. The backlight gets turned ON. The robot will continuously repeat this cycle of detection, planning, and executing movements until it reaches its objective. Results are shown in Figure 3.7.2.

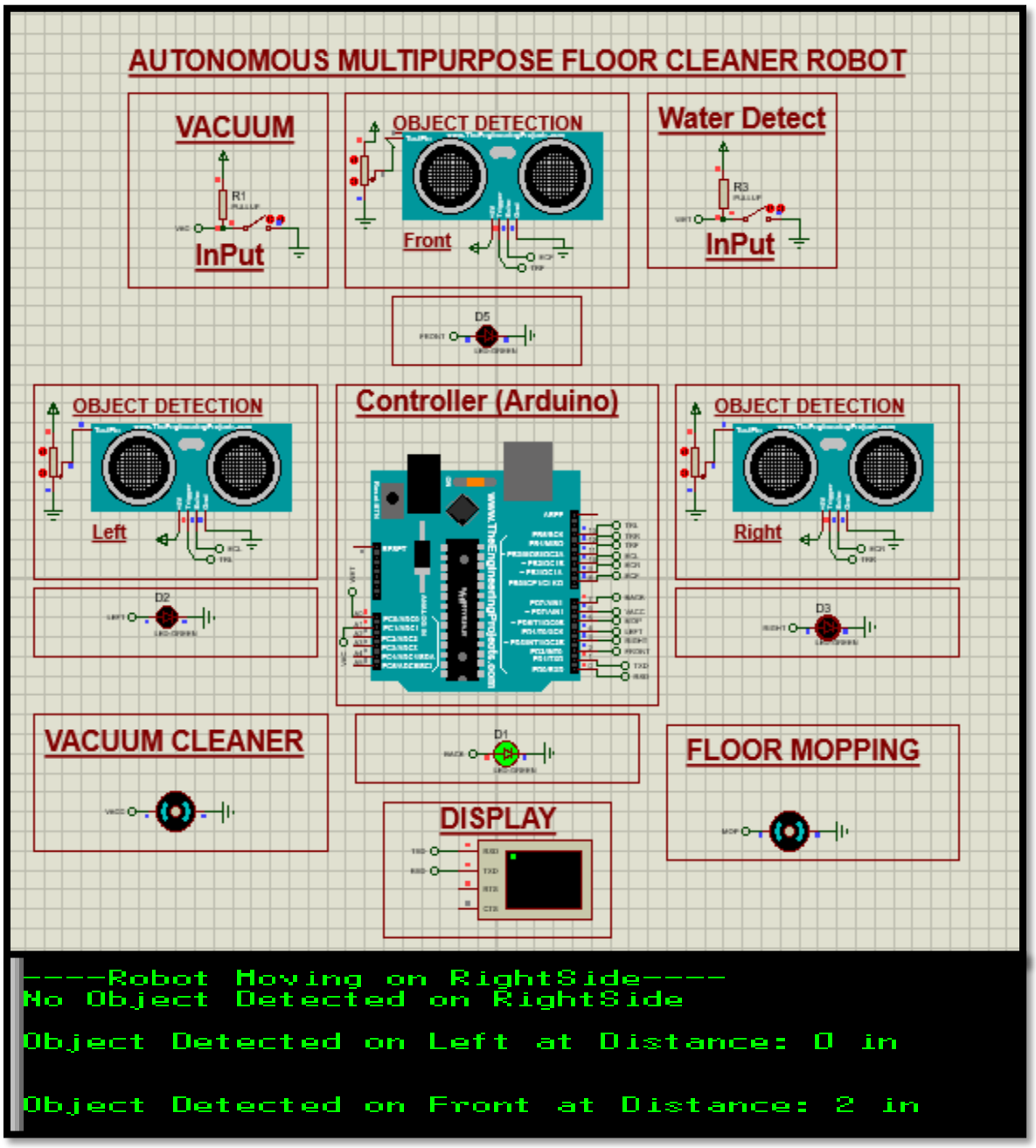

Figure 3.7-6: Moving on Backside Route

3.8. Conclusion

This chapter presents the Proteus simulation of an autonomous multi-purpose floor-cleaning robot. Due to its advanced features, it is a very compatible solution for households, industries, hospitals, etc. It is a semi-automatic and fully automatic controlled robot for the cleaning and dusting of the floor. Moreover, the system is designed to avoid obstacles. Meanwhile, the simulation is designed according to the environmental parameters.

Chapter 4
Hardware Implementation

4.1. Introduction

To real time develop this project. The proposed block diagram is shown in figure 4.2.1.

4.2. Block diagram:

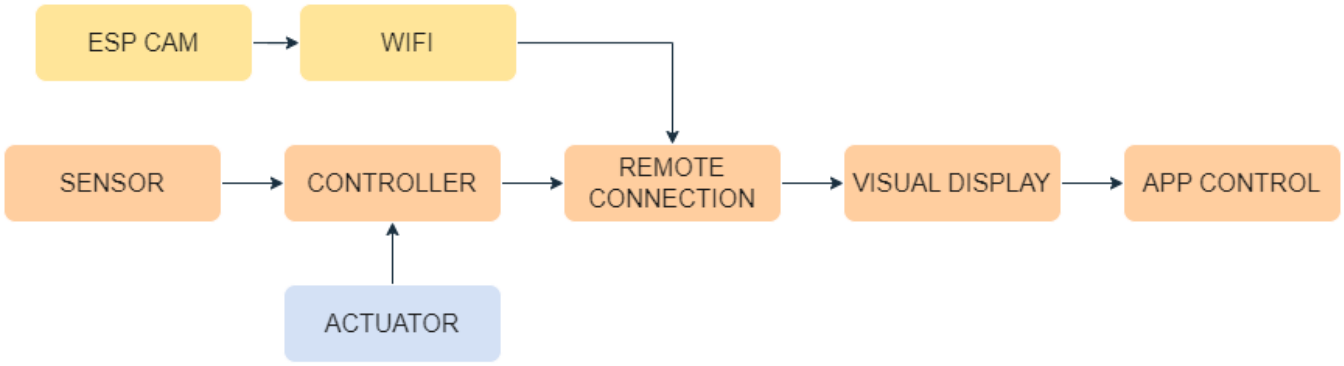

Figure 4.2-1: Block Diagram

4.3. List of Components

The list of equipment is shown below in Table 4.3.1 as follows:

Table 4.3.1: List of equipment

Sr no	Name	Amount
1	Arduino	**1**
2	Dc Motor	**2**
3	Brushless DC motor	**2**
4	Two-way supply	**1**
5	Solar and battery	**1**
6	Ultrasonic sensors	**3**
7	Camera	**1**
8	Vacuum	**1**
9	Mopping wiper	**1**

4.3.1 Arduino

Arduino is a free and open-source electronics platform that includes a microcontroller and a development environment. It enables the creation of interactive projects and prototypes in a straightforward and adaptable manner. Arduino boards are available in a variety of variants, including the Arduino Uno, Arduino Mega, and Arduino Nano, each with its own set of features and capabilities. The digital and analogue input/output pins on Arduino boards can be used to communicate with various sensors, actuators, and other electrical components. The Arduino IDE (Integrated Development Environment), which is based on the C and C++ programming languages, can be used to program the boards.

Figure 4.3-1:Arduino

The specification of Arduino is presented in Table 4.3.2

Table 4.3.2: Specification of Arduino

Sr No.	Specification	Detail
1	Operating Voltage	5V
2	Input Voltage (recommended)	7-12V
3	Input Voltage (limit)	6-20V
4	Digital I/O Pins	14 (of which 6 provide PWM output)
5	PWM Digital I/O Pins	6
6	Analog Input Pins	6
7	DC Current per I/O Pin	20 mA
8	DC current for 3.3V Pin	50 A

4.3.2 Dc Motor

A direct current (DC) motor is a type of electrical device that transfers electrical energy into mechanical rotation. It works on the principles of electromagnetism. DC motors are made up of a stator, which is the stationary component, and a rotor, which is the revolving component. Permanent magnets or electromagnets are used in the stator, whereas wire coils are used in the rotor. When

current travels through the coils, it produces a magnetic field that interacts with the magnetic field of the stator, causing rotational motion. DC motors are extensively used in robotics, automation, and other applications where motor speed and torque must be precisely controlled.
A brushless direct current (BLDC) motor, also known as an electronically commutated motor (ECM) or synchronous direct current (DC) motor, is a type of motor that operates on a different principle than standard brushed direct current (DC) motors. BLDC motors, as opposed to brushed DC motors, use electronic commutation to control the flow of electrical current.

Figure 4.3-2:DC Motor

A direct current (DC) motor drive, also known as a motor controller or motor driver, is an electrical device or circuit that regulates the functioning of a direct current (DC) motor. It offers the control signals, power, and protection features required to properly drive and manage the motor's speed, direction, and torque.

The fundamental function of a DC motor drive is to transform the input electrical signals into the power and control signals required by the DC motor. It often communicates with a microcontroller or a control system to receive commands or feedback signals and modifies the motor's functioning as needed.

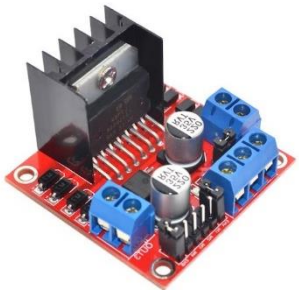

Figure 4.3-3:DC Motor Drive

4.3.3 Two-way supply (Solar & Batter)

The ability to power a system using either a solar panel or a battery is referred to as two-way supply. This configuration enables the system to use solar energy as the primary power source while switching to the battery when solar energy is unavailable or insufficient. Solar panels use the photovoltaic effect to turn sunlight into electrical energy. Solar energy can be used directly or stored in a battery for later use. When solar power is unavailable, the battery acts as a backup power source, allowing for uninterrupted functioning. The two-way supply ensures that the system receives consistent and uninterrupted power.

- **Solar Power:** Solar power is the use of solar panels or photovoltaic cells to harvest energy from the sun. Solar panels use the photovoltaic effect to turn sunlight into electrical energy. When solar panels are exposed to sunlight, they produce electricity, which can be used to power equipment directly or stored in a battery for later use. Because solar power is renewable and environmentally beneficial, it is an appealing alternative for off-grid or sustainable energy solutions.

Figure 4.3-4:Solar Panel

- **Battery Power:** Batteries store electrical energy and serve as a portable, self-contained power source. They are normally rechargeable and can be charged using a variety of techniques, such as solar panels or standard electrical outlets. Batteries provide a dependable power source, particularly when solar energy is unavailable or during periods of low sunlight. They provide as a backup or alternate power supply, ensuring that the gadget or system continues to operate.

Figure 4.3-5: Battery

A two-way supply system allows for greater flexibility and dependability when powering devices, especially in distant places or areas with intermittent or unreliable power sources. It enables the use of solar energy when it is available while maintaining uninterrupted functioning via battery power when solar energy is limited.

4.3.4 Ultrasonic sensors

Ultrasonic sensors detect the presence, distance, and position of objects by using sound waves with frequencies exceeding the range of human hearing. They operate on the echolocation concept, which is similar to how bats navigate. Ultrasonic sensors are typically made up of a transmitter that sends out ultrasonic waves and a receiver that detects the returned waves. The sensor can measure the distance to an item by measuring the time it takes for sound waves to bounce back. Ultrasonic

sensors are frequently utilized in robots, security systems, parking assistance, and other applications where proximity sensing or object detection are required.

Figure 4.3-6:Ultrasonic Sensor

4.3.5 Camera

A camera is a device that captures and records photos or videos. A camera can be used for visual monitoring, image processing, or computer vision applications in the context of your setup. Image resolution, frame rate, and interface options (e.g., USB, I2C, or wireless) may differ depending on the exact camera module or device utilized. Cameras can record still images or video streams that can be processed, analyzed, and communicated for a variety of purposes such as surveillance, object recognition, and live broadcasting.

The ESP32 is a popular microcontroller development board with a variety of features and capabilities, including the ability to communicate with a camera module. The ESP32 can be outfitted with a camera module to record photos or stream video, making it ideal for use in surveillance systems, IoT devices, and image recognition projects.

Figure 4.3-7:ESP32 Camera

An OV2640 or OV7670 image sensor takes images and delivers them to the ESP32 for processing or transmission. The serial camera control bus (SCCB) or parallel camera interface (GPIOs) connects the camera module to the ESP32 board.

4.3.6 Vacuum

A vacuum system, often known as a vacuum cleaner or vacuum pump, is a device that removes air or other gases from an enclosed space to generate a partial vacuum. Vacuum cleaners are generally used for cleaning, whereas vacuum pumps are utilized in a wide range of applications, including industrial processes, laboratory research, and medical equipment. Suction is used in hoover systems to draw air or fluids into a chamber in order to remove pollutants or meet certain operational criteria.

Figure 4.3-8:Vacuum

4.3.7 Mopping wiper

A mopping wiper is a cleaning and wiping component that is commonly used on floors. It is intended to effectively remove dirt, dust, and stains from a variety of flooring materials, including hardwood, tile, laminate, and vinyl.

Mopping wipers are extensively used in janitorial, commercial, and residential cleaning applications. They are a quick and easy solution to keep floors clean and free of dust, debris, and spills. The kind of flooring, cleaning preferences, and desired level of convenience and efficacy all influence the selection of a mopping wiper.

Figure 4.3-9:Mopping Wiper

Here are some important factors and considerations for a mopping wiper:

- **Design:** A mopping wiper is typically made out of a mop head or cleaning pad connected to a handle or a mop mechanism. The mop head is comprised of absorbent materials that trap and absorb dirt particles, such as microfiber fabric, cotton, or sponge.
- **Cleaning Pad options:** Different types of cleaning pads, including reusable and disposable ones, may be available with mopping wipers. Reusable pads can be washed and reused several times, making them both cost-effective and environmentally beneficial. Disposable pads are intended for single use and can be readily replaced after each cleaning session.
- **Absorbency and Cleaning Efficiency:** The absorbent characteristics of the mop head are critical for good cleaning. It should be able to absorb liquids and debris from the floor while leaving no streaks or residue behind. Microfiber pads are well-known for their great absorbency and ability to effectively catch and retain dirt.
- **Maintenance and cleaning:** Depending on the type of mop head, it may need to be cleaned or replaced on a regular basis. Reusable pads are often washable in a washing machine, however disposable pads can be readily discarded after use.

4.3.8 Module Operation

For device setup, set maximum and replicate minimum. Set the "Trigger" high-level pulse to a minimum of 10us. At that instant, to begin timing, port the wi-fi controller timer. Wait for the ECHO port to catch the upstream edge output to avoid the counter. Currently notice the duration of the clock, which is the ultrasonic transmission period throughout the atmosphere. As the formula: Distance = (Pulse top level sensors Speed Period X top level Pulse (velocity of Sound in air 340m/s) / 2, by this you get to know the range of the object.

Module Timing

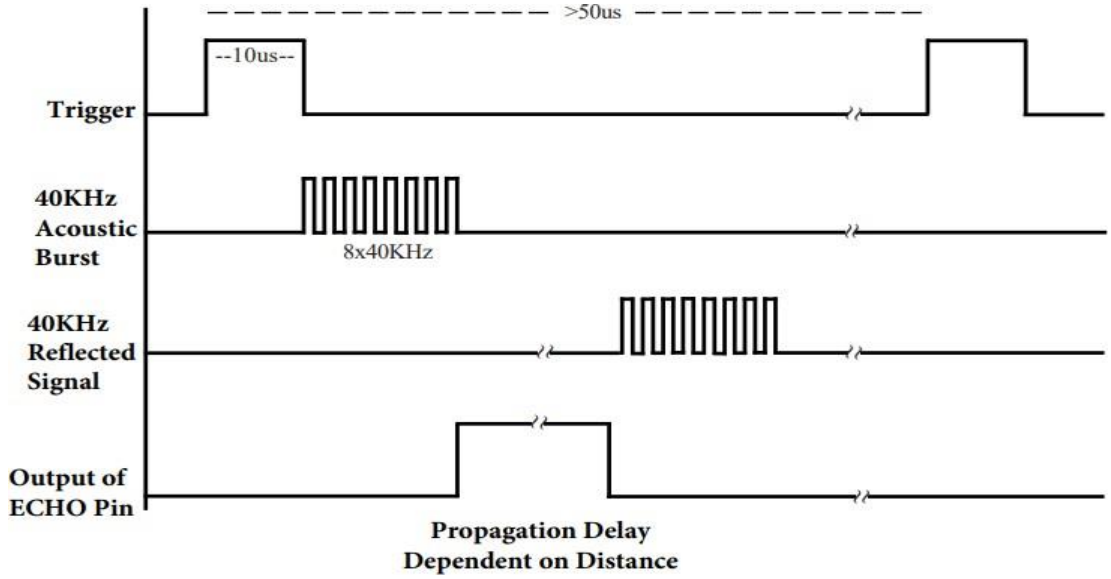

Figure 4.3-10:HC-SR-04 ultrasonic module

- **Trigger**

11us minimum required to start the calculation. Maximum Frequency is 51us.

- **ECHO**

The transmitted signal from the output to the microcontroller is the duration 40 KHz bursts to the echoed pulse is registered. Width in cm = width of replicated signal in µs/59 range in inch = width of Doppler signal in µs /147.

Distance calculation:

Sound = 340 m/s

Time =distance / speed

Time = 10/0.034 us = 294 us

Distance = (speed x time) / 2

Distance = (0.034 x 294) / 2

4.4. PROBLEM STATEMENT:

Basically, connectivity between the edge devices and the mobile app is provided by the Wi-Fi and Bluetooth. It reflects the ultrasonic sensor signals and relays of its driven network. The role of Wi-Fi controller here is to receive data from the sensors and send that data to mobile app. In this project Arduino controller has been used. ESP32 cam used for live streaming onto mobile application. Arduino is used to receive data from sensors and to control the actuators connected to robot.

ARDUINO controller is used here as a platform to sense the obstacles, detection of water, and for path selection through sensors and control the vibrant scenarios. Four cases are presented i.e., obstacles, path selection, water detection and mopping, and vacuum cleaner. Hence the lights are controlled based on the path followed by the robot. If there is no obstacle detected in the path front light will be high and the robot will keep moving onto the forward path. ARDUINO observes all the paths through the given data of the sensor of all routes individually by a sequence. If the obstacle is detected on any route then the robot selects the path to act accordingly to control the lights.

Figure 4.4-1: Hardware of Autonomous Robot

4.5. MOBILE APPLICATION:

Bluetooth module is connected with the Arduino controller to communication between mobile application and robot. To control the movement of robot user can use voice as command and also button is available to move the robot in any direction. The mobile application interface is shown below

Figure 4.5-1: Controlling through Mobile Application

Chapter 5
Business Description

In the modern Era Robots are playing an important role in our lives through their advanced capabilities that can make human lives easier and more comfortable. The cleaning robots are effective in assisting humans in maintaining cleanliness at homes, hotels, restaurants, offices, hospitals, workshops, warehouses, and universities, etc. So, they have taken more recognition on robotics research.

4.6. PROBLEM STATEMENT:

Due to the increasing of human work load they are unable to clean. As we know that technology comes up from time to time and need to upgrade for making more easy human tasks. To bring innovation and advancement in Vacuum technology.

4.7. PROJECT DESCRIPTION:

As we know that it's very important to live in a clean environment but due to an increase in the workload of humans, they are unable to focus on cleanliness. We are going to develop an Autonomous Multipurpose floor cleaner which will help people to clean their places. As already existing vacuum cleaners have only limited application and floor cleaning robots are not affordable for majority. We aim to make a multipurpose floor cleaner in lesser cost having features like, dusting, mopping and garbage removal. The device can be operated manually and/ or remotely through a mobile application. It will have the capability to perform cleaning operation even in the narrow spaces and vents like, under the sofa, beds, etc. The area can be preinstalled in the cleaner, and it will move and clean the specified area according to a given pattern. Thus, saving valuable time and energy of people while providing necessary cleanliness and peace of mind.

4.8. METHADOLOGY:

Components like ultrasonic sensors, motors drivers, Wi-Fi module and vacuum cleaner which are connected to microcontroller which is energized through a power supply of 12V. We are using Proteus design suite which is a proprietary software tool used primarily for electronic design automation. Arduino IDE it contains a text editor for writing code, a message area, a text console. It connects to Arduino hardware to upload programs and communicate. Arduino operates the ultrasonic sensors and motors for obstacle detection, dusting and mopping while moving in a particular pattern. If obstacle is detected, the robot stops attempts to remove it, otherwise changes its direction, and continue the cleaning process according to the installed program.

4.9. PROJECT OBJECTIVES:

- To make an autonomous vacuum for cleaning (dusting, mopping and garbage removal).
- Making the system remotely accessible and controllable so that precious time of the users can be saved.
- To make affordable innovation and improve local production capability for providing necessary cleanliness and peace of mind for the users.

4.10. Vision:

- Our vision is to provide the market with such an advanced cleaning machine which is cost effective and time efficient.
- Providing people with such type of product that will be able to stand on their hopes and will be able to provide clean surrounding.
- To meet the demand of households, due to the trend of working women, along with other sectors.

4.11. Growth of consumer robotics:

- The consumer robotic industry is moving at very high pace, creating tough competition.

- Consumer tasks robots are still dominated by the familiar robotic vacuum cleaner today, but still these are not much used because of high price, beyond the reach of common man.

4.12. Market size:

- Robotic cleaning is in great shape across the world.

- slowly it is making its impact on people, due to increase in trend of working women and adat\ptation to luxurious lifestyle by the people.

- our main focus will be the household sectors and service sectors and after that we will be in coparate and other sectors.

- starting from household and service sector will give a good boost to our product.

4.13. Target costumers:

- our main target will be different service providing sectors, where cleanliness and clean surrounding is must, such as hospitals, banks.

- certain industrial sectors and house hold sectors where clean and hygiene environment is always required.

- with the smart city concept now in progress, so the people those who will be the residents, for them cleanliness will be a top priority. So, they must be our target costumer.

4.14. Market Competition:

- Our product will face competition from companies like LG, Philips and SAMSUNG, as they are in this line of making consumer robotics since past few years.

- But due to their high pricing concept, the costumer turns over or the consumers for robotics product is less.

- So, because of competitive pricing, without compromising in quality, our product will excel in future.

4.15. SWOT Analysis:

Strength:

- A new innovative product
- Specialist marketing expert
- Quality processes and procedures
- Affordable Pricing

Weakness:

- Non tech Savvy, establishing a reputation on the internet is tough Job
- New: Don't have reputation or money alike of big brands
- Lack of funding

Opportunities:

- New generation Techniques and high Trend technology
- Growing markets: High demand of product due to lack of time by households
- Similar products in the market are not so reliable or are more expensive.

Threats:

- Competitor market
- New distribution channels

4.16. Marketing:

- Futurists have long predicted that a world in which robots perform dull and dirty tasks so human can focus their energies elsewhere.
- Home care has become the first breakout market for a growing new device category.

- The future is here thanks to robotic appliances that help home owners take care of boring chores like vacuuming, moping and even cleaning.

- Our launch plan is to introduce our cleaner robot, by following door to door marketing and also by giving demo to show the efficiency of our machine.

4.17. Product promotion or Marketing:

- ✓ Local Area marketing
- ✓ Social media Advertising
- ✓ Online Selling of our product
- ✓ Home demo about product working
- ✓ Recruiting, training, motivating individuals and team

4.18. Financial Plan

Resources required:

Following resources are required:

- All the basic Resources are required to start a business (i.e Machinery, Electronic equipment's and proper place etc)
- Accessories
- Human Resources
- Electricity (etc)

Table 4.18.1: Financial Plan

SR.No	Capital Nature Expenses	Amount (PKR)
1	Laptop (80,000 × 1)	80,000/-
2	Equipment (30,000 × 1)	30,000/-
	Revenue Nature Expenses	
3	Internet (4000 × 12)	48,000/-
4	Misc Expenses(3000 × 12)	36,000/-
5	Electricity(15000 × 12)	180,000/-
6	Purchase of Raw material(12000 × 12)	144,000/-
	Total: Initial Expenses	518,000/-

Chapter 6
Conclusion & Future Work

Conclusion

In this thesis, we are representing cleaning robot that integrates mechanical and electrical components to clean and mop floors efficiently. The robot uses ultrasonic sensors to detect obstacles, vacuum cleaners to remove dust and a mopping motor to mop water from the floor.

The goal of the project is to design and construct an autonomous multipurpose floor cleaning robot. The robot is supposed to be a hoover cleaner and a mopper, capable of efficiently cleaning floors without the need for human intervention. The project's purpose is to combine mechanical and electrical components including Arduino, ultrasonic sensors, vacuum cleaners, a mopping motor, and a two-way power supply. Proteus simulation is used to test and confirm the electrical connections and performance of the robot.

The robot functions based on several scenarios, altering its movement according to the barriers observed. It can go forward, turn right or left, or even reverse to effectively avoid obstructions. For added operational flexibility, the robot includes Bluetooth and manual control.

The robot includes a live streaming module that allows consumers to watch a live video feed of the cleaning process on their mobile devices or laptop computers. The ultrasonic sensors on the robot detect obstructions along its path. If an obstruction on the right side is detected, the robot will turn left, and vice versa. This obstacle avoidance technology allows the robot to go around things without colliding with them.

The robot has three separate modes of operation.

i. **Manual Mode:** Users have complete control over the robot's movement and cleaning capabilities when in manual mode.
ii. **Semi-Automatic Mode:** The robot acts autonomously in semi-automatic mode, but with user-defined settings or instructions.
iii. **Fully Automatic Mode:** In fully automatic mode, the robot operates autonomously, utilising its AI skills to navigate, clean, and avoid obstacles without the need for human involvement.

The major purpose of the robot is to effectively clean floors by vacuuming dust and mopping water. It can sense the presence of water and engage the mopping motor on its own. LED indicators are used during simulation to show the robot's movement on a virtual monitor.

Having a cleaning robot that can hoover and mop the floor provides various advantages and developments in domestic cleaning. Consider the following crucial points:

i. Cleaning duties become more effective and time-saving as the cleaning robot eliminates the need for manual labor. It can roam the space automatically, sweeping and mopping as it goes, without continual supervision.
ii. Individuals can enjoy a clean and tidy floor with a cleaning robot without having to personally engage in the cleaning process. It can be set to function at predetermined periods or activated on demand, providing convenience and flexibility.
iii. The robot's capacity to hoover and mop guarantees that the floor surfaces are thoroughly cleaned. It can effectively remove dust, filth, pet hair, and other debris from the floor, resulting in better living environment cleanliness and hygiene.
iv. The robot frees up time for folks to focus on other activities or spend quality time with family and friends by taking care of floor cleaning. It cuts down on overall cleaning time and allows for a more balanced lifestyle.

Overall, the autonomous floor cleaning robot provides a convenient and efficient alternative for cleaning jobs on the floor. It can explore the area, detect impediments, and change its path to clean the floor effectively. It can greatly ease housekeeping duties while also providing a more pleasant and sanitary living environment. The combination of mechanical and electrical components, as well as the simulation in Proteus, all contribute to the project's success.

Future Work

Using AI in a cleaning robot includes using object recognition to classify and prioritize cleaning chores based on different types of trash. Cleaning patterns that are adaptive can be created, allowing the robot to analyze the floor layout and optimize its cleaning processes for increased efficiency and coverage. Adding AI capabilities for context awareness, learning and development, and integration with smart home devices can also increase the robot's usefulness, user experience, and environmental awareness. These developments would make the cleaning robot a more sophisticated and effective tool for keeping the living environment clean and healthy.

References

[1] Huang, Jie, Qing Xi Hu, Yuan Yuan Liu, Hai Guang Zhang, and Zhao Fu Chi. "The Realization of New Automatic Vacuum Casting System." In 2010 International Conference on Machine Vision and Human-machine Interface, pp. 646-649. IEEE, 2010.

[2] Gudi, SLK Chand. "Fog robotics: An introduction." In IEEE/RSJ International Conference on Intelligent Robots and Systems. 2017.

[3] Khatib, Oussama, and Bruno Siciliano, eds. Springer handbook of robotics. Springer International Publishing, 2016.

[4] Fezari, Mohamed, and Ali Al Dahoud. "Integrated development environment “IDE” for Arduino." WSN applications (2018): 1-12.

[5] Su, Bo, and Li Wang. "Application of Proteus virtual system modelling (VSM) in teaching of microcontroller." In 2010 International Conference on E-Health Networking Digital Ecosystems and Technologies (EDT), vol. 2, pp. 375-378. IEEE, 2010.

[6] Khan, Mohd Shahbaz, and M. Gurunadha Babu. "Bluetooth Control Cleaning Robot using Arduino [J]." International Journal of Innovative Technology and Exploring Engineering (IJITEE) 8, no. 11s2 (2019).

[7] Manasa, M., T. S. Vidyashree, V. Bindushree, Sanjana Rao, and P. S. Gowra. "Smart vacuum cleaner." Global Transitions Proceedings 2, no. 2 (2021): 553-558.

[8] Do, Truong-Dong, Minh-Thien Duong, Quoc-Vu Dang, and My-Ha Le. "Real-time self-driving car navigation using deep neural network." In 2018 4th International Conference on Green Technology and Sustainable Development (GTSD), pp. 7-12. IEEE, 2018.

[9] Yatmono, S., M. Khairudin, H. S. Pramono, and A. Asmara. "Development of intelligent floor cleaning robot." In Journal of Physics: Conference Series, vol. 1413, no. 1, p. 012014. IOP Publishing, 2019.

[10] Hossain, Sabir, Oualid Doukhi, Yeonho Jo, and Deok-Jin Lee. "Deep reinforcement learning-based ros-controlled rc car for autonomous path exploration in the unknown environment." In 2020 20th International Conference on Control, Automation and Systems (ICCAS), pp. 1231-1236. IEEE, 2020.

[11] Ong, R. J., and KNF Ku Azir. "Low cost autonomous robot cleaner using mapping algorithm based on internet of things (IoT)." In IOP conference series: materials science and engineering, vol. 767, no. 1, p. 012071. IOP Publishing, 2020

[12] Anbumani, V., V. Geetha, V. Renugha, and V. Praveenkumar. "Development of Ingenious Floor Cleaner using ARDUINO." International journal of recent technology and Engineering (IJRTE) 8, no. 41 (2019): 5848-5853.

[13] Saleem, Adeel, Atif Iqbal, and Adnan Sabir. "Design and implementation of an intelligent dust cleaner robot for uneven and nonstructural environment." In 2019 2nd International Conference on Computing, Mathematics and Engineering Technologies (iCoMET), pp. 1-6. IEEE, 2019.

[14] Prayash, HA Shakhawat Hossen, Md Ragib Shaharear, Md Farhanul Islam, Saiful Islam, Noushad Hossain, and Shamik Datta. "Designing and optimization of an autonomous

vacuum floor cleaning robot." In 2019 IEEE International Conference on Robotics, Automation, Artificial-intelligence and Internet-of-Things (RAAICON), pp. 25-30. IEEE, 2019.

[15] Murdan, Anshu Prakash, and Pawan Kumar Ramkissoon. "A smart autonomous floor cleaner with an Android-based controller." In 2020 3rd International Conference on Emerging Trends in Electrical, Electronic and Communications Engineering (ELECOM), pp. 235-239. IEEE, 2020.

[16] Sarmast, A. T. S., T. Pourseif, R. E. Nezhad, M. Mohajeri, S. Mohammadi, and A. Vaezi. "Designing a Smart Vacuum Cleaner in Two Modes of Remote and Automatic." International Research Journal of Engineering and Technology 7, no. 07 (2020): 5291-5298.

[17] Habib, Md Rawshan, Md Shahnewaz Tanvir, Ahmed Yousuf Suhan, Abhishek Vadher, Sanim Alam, Tahsina Tashrif Shawmee, Koushik Ahmed, and Abdelrhman Alrashed. "Automatic solar panel cleaning system based on Arduino for dust removal." In 2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS), pp. 1555-1558. IEEE, 2021.

[18] Vijayalakshmi, M., Bhargavi Baljoshi, G. Lavanya, Gouri Master, and Gurav Sushil. "Smart vacuum robot." In ICT for Competitive Strategies, pp. 81-90. CRC Press, 2020.

[19] Gutmann, Jens-Steffen, Kristen Culp, Mario E. Munich, and Paolo Pirjanian. "The social impact of a systematic floor cleaner." In 2012 IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO), pp. 50-53. IEEE, 2012.

[20] GSSSIETW, Mysuru, R. Rakshitha, N. Sandhyashree, and Arpitha Shankar. "Design and Development of an Automated Floor Cleaning Robot for Domestic Application."

[21] Hussain, Rasheed, and Sherali Zeadally. "Autonomous cars: Research results, issues, and future challenges." IEEE Communications Surveys & Tutorials 21, no. 2 (2018): 1275-1313.

[22] Kubba, Sam. "Indoor environmental quality." LEED Practices, Certification, and Accreditation Handbook (2010): 211.

[23] Monika, S., K. Aruna Manjusha, S. V. S. Prasad, and B. Naresh. "Design and implementation of smart floor cleaning robot using Android app." International Journal of Innovative Technology and Exploring Engineering (IJITEE) 8, no. 4S2 (2019).

[24] Hess, Jürgen, Maximilian Beinhofer, Daniel Kuhner, Philipp Ruchti, and Wolfram Burgard. "Poisson-driven dirt maps for efficient robot cleaning." In 2013 IEEE International Conference on Robotics and Automation, pp. 2245-2250. IEEE, 2013.

[25] Vijayalakshmi, M., Bhargavi Baljoshi, G. Lavanya, Gouri Master, and Gurav Sushil. "Smart vacuum robot." In ICT for Competitive Strategies, pp. 81-90. CRC Press, 2020.

[26] Working principle of ultra sonic sensor.” ResearchGate https ://www .researchgate. net/figure/Working-principle-of-ultrasonic-sensor_fig1_310022308 (accessed Mar. 11, 2023)