IOT Based Intelligent Clothes Dryer Rack – Automated Motorized Clothes Dryer System

by

HM-Adnan Zami

1131121034

Session 2016/2017

The project report is prepared for
Faculty of Engineering
Multimedia University
in partial fulfilment for
Bachelor of Engineering (Hons) Electronics
majoring in Computer

FACULTY OF ENGINEERING
MULTIMEDIA UNIVERSITY
September 2017

DECLARATION

I hereby declare that this work has been done by myself and no portion of the work contained in this report has been submitted in support of any application for any other degree or qualification of this or any other university or institute of learning.

I also declare that pursuant to the provisions of the Copyright Act 1987, I have not engaged in any unauthorized act of copying or reproducing or attempt to copy / reproduce or cause to copy / reproduce or permit the copying / reproducing or the sharing and / or downloading of any copyrighted material or an attempt to do so whether by use of the University's facilities or outside networks / facilities whether in hard copy or soft copy format, of any material protected under the provisions of sections 3 and 7 of the Act whether for payment or otherwise save as specifically provided for therein. This shall include but not be limited to any lecture notes, course packs, thesis, text books, exam questions, any works of authorship fixed in any tangible medium of expression whether provided by the University or otherwise.

I hereby further declare that in the event of any infringement of the provisions of the Act whether knowingly or unknowingly the University shall not be liable for the same in any manner whatsoever and undertakes to indemnify and keep indemnified the University against all such claims and actions.

Signature: ________________________

Name: HM-Adnan Zami

Student ID: 1131121034

Date:

ACKNOWLEDGEMENT

In recognition of the contributions made by my supervisor, moderator, colleagues and friends, I would like to firstly thank my supervisor Dr. Vishnu Monn Baskaran for his trust in me, patience and guidance throughout the span of this project. This project wouldn't have come to life if it wasn't for the resources and technical guidance provided by my moderator Mr. Lo Yew Chiong. His generous act of providing a workspace in the Robocon Lab has equipped me with the necessary tools to carry out this project.

My gratitude further extends to my partner Mazen Mohamad Elorbany whose relentless efforts in assisting me in every way possible has kept my progress on track. Alongside him, I would like to thank Almokri for providing specific tools and resources which assisted in creating an improved design. Finally, without the love and support of my parents, none of this would come to be.

ABSTRACT

This thesis aims to dissect and discuss a modern, partially autonomous IOT based smart clothes drying rack. The purpose of this product is to assist users to naturally dry their clothes while remotely monitoring and controlling the system. The focus for this paper will be on the structural design, sensory modules and mechanical and pseudo psychomotor functionalities of the design.

To fulfil the need of an automated clothes drying system, a custom made wooden wardrobe has been designed which has been equipped with necessary sensors and motors to perform its actions autonomously. The core of the system is using an Arduino Mega 2560 R3.

The system developed functions autonomously to detect sunlight using light dependent resistors and positions itself accordingly within the given perimeter. Once positioned for optimal sunlight, the user will receive continuous updates on the placement and status of clothes via sensors through a cloud. If the system detects rain using the rain meter sensor, it will cover the sides of the wardrobe using waterproof curtains and retract back into the residence. The user will also be able to perform this action remotely and manually through the cloud.

The overall system provides a smart and autonomous method of naturally drying the user’s clothes. Trendy design of the wardrobe allows the user to use it indoors as well.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

IOT	Internet of Things
KB	Kilobytes
MHz	Mega Hertz
I/O	Input/Output
SRAM	Static Random Access Memory
EEPROM	Electrically Erasable Programmable Read-Only Memory
Li-Po	Lithium Polymer
FWD	Front Wheel Drive
EMF	Electromagnetic
LDR	Light Dependent Resistor
DC	Direct Current

CODE LISTINGS

CHAPTER 1 INTRODUCTION

1.1 Overview

Climate change is becoming ever so prominent in the modern world today. With the increase in global temperature, instability of the weather has made it difficult for individuals to get through the day without performing frequent weather checks. This issue is significantly noticeable in tropical regions which accommodates 40% of the world's population. Due to having 2 general seasons, wet season and dry season, in most areas, chances of precipitation on any given day throughout the year is imminent. Thus, an individual must be prepared to resolve any concern which may result from a sudden change in weather.

One issue that arises from this is the method of drying clothes. Conventionally, clothes are either dried using a dryer at a local laundry or hung on a rack preferably near sunlight. Although these methods might produce positive results, physical presence of an entity is necessary to monitor the clothes. In the case of using a dryer, a person has to travel to their local laundry and wait for the dryer to complete its timer. Afterwards the person has to travel back to their residence with a bulk of dried clothes. The second method of drying clothes using a rack is slightly more troublesome. Although it doesn't require an entity to travel to a destination, it does require their supervision of monitoring the clothes in case of rain.

When compared to other issues of greater magnitude, this may seem small and insignificant. However, in today's time, most households have both parents working during the day resulting in a lack of entity for managing household chores. Due to the fluctuation of the weather, following the second method of drying clothes in the sunlight becomes difficult. Furthermore, using a laundry within the vicinity of the residence is troublesome as it requires travelling and waiting. Integrating an IOT based autonomous clothes drying rack can be an inexpensive and healthy solution.

1.2 Problem Statements

The practice of drying clothes has been the same throughout for centuries. The two methods mentioned previously causes extra hassle as well as pose health risks. Drying clothes indoor can create a moist environment which may result in the growth of certain fungi on the clothes especially in the absence of sunlight. Spores from these fungi can easily enter the respiratory system while wearing these clothes and can cause allergic reactions. Using a dryer, on the other hand, is troublesome as it requires commute and waiting time. Local laundry dryers deteriorate fabric easily and also causes shrinkage. Sweat shirts and jerseys which has printed designs are greatly affected by the heat which can melt the design as well. This requires a person to organize clothing before putting them in the dryer which is another unnecessary annoyance. The usage of these dryers in public areas arises hygiene concern as well since several people use it on a daily basis and constant maintenance is needed to keep the machines clean. Furthermore, dryers have become the 2nd largest home appliance consuming energy which is around 43 million MWh per year in the United States alone. [6]

Technological advancement in the past few years has enabled us to simplify our daily activities. Currently, the application of IOT devices is on the rise. Hence, an IOT based system can be created which makes drying clothes effortless. A wardrobe equipped with IOT devices to monitor, track and protect the clothing while being guided towards optimal sunlight can be created to reduce the efforts required in drying clothes in a healthy manner.

1.3 Project Scope

To create a complete system, a wardrobe has been designed to carry the clothes which will require drying. The system will detect the sunlight and position the wardrobe in a manner that allows maximum sunlight to fall on the clothes. To monitor, track and control this system, wheels and sensors will be connected for it to perform autonomously. A notification system was built to allow the user to have constant access on monitoring the device's performance from remote places via the internet. The focus of this report will be on the hardware design and the integration of the sensory modules. Figure 1.1 shows the block diagram of the system proposed in this report.

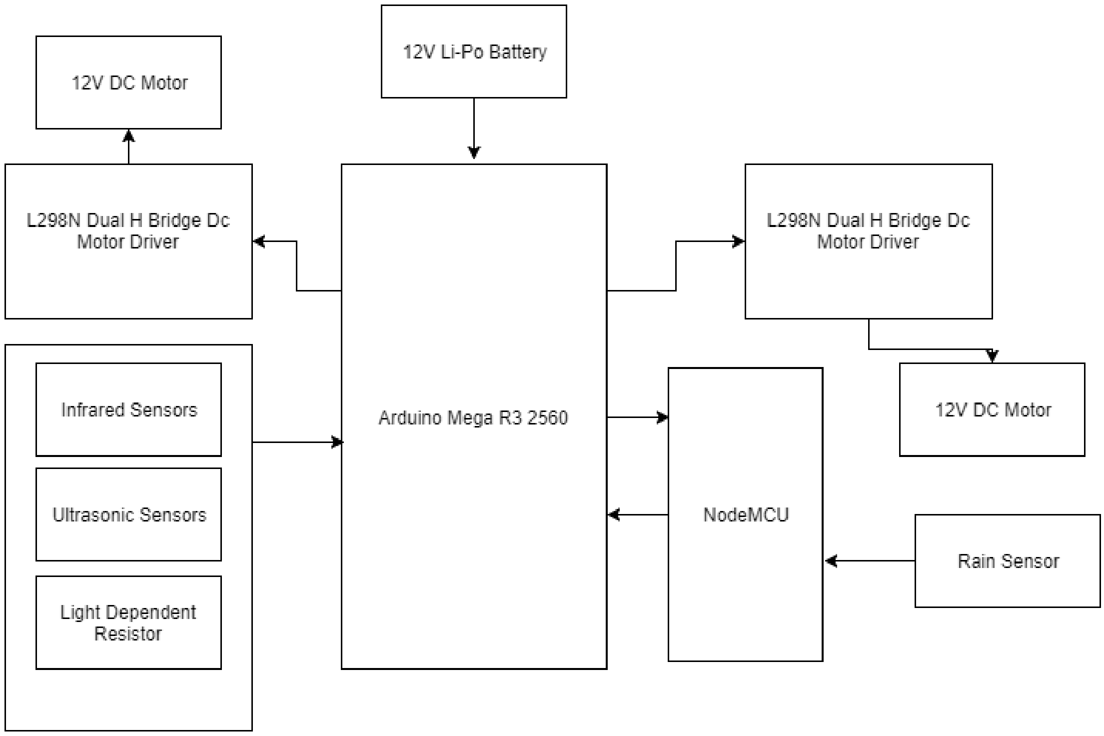


Figure 1.1: Block Diagram of the System

1.4 Project Objectives

a. To design and develop a motorized cloth dryer rack system for residential usage.

b. To design and develop a weather based sensor module, integrated with the motorized system.

c. To design and develop a user notification system.

1.5 Report Outline

This report consists of 5 Chapters. The following chapters will be presented in the manner listed below.

- **Chapter 2** will analyse and dissect existing methods and techniques from research papers relative to the project which will be used to create the system.
- **Chapter 3** presents the details of the design of the system and a breakdown of the equipment and algorithms used to fulfil the objectives of the system.
- **Chapter 4** will report the discussion on the results and performance of the overall system.
- **Chapter 5** concludes the report with recommendations on further development of the system.

CHAPTER 2 LITERATURE REVIEW

This chapter will focus on analyzing papers relative to the system being developed and discuss the feasibility of the applying those methodologies to this project. Furthermore it will substantiate the selection of the components for this project through background research.

2.1 Introduction to IOT

The current trend of technological development consists of a major field of interest known as IOT which stands for Internet of Things. In the world of IOT, all devices, whether electronic or not, are intertwined into a network system that is accessible through the internet. The purpose of this system is to provide information on a given entity through remote access. This allows users to monitor and control anything of interest in real time via the internet. Some popular sectors of IOT implementations are home automation, health monitoring systems, security systems and many more. The applications of IOT is endless as it can turn any “thing” into a data hub.

Due to its flexibility in application, it is widely used today with a smartphone being at its core in most cases. Since the growth of the smartphone market, smart phones are accessible by mass users today making it the ideal controller. Since phones are available now a days for any person of interest, it is the principle device to build a system upon.

Providing a system that can overcome the problems associated with the conventional method of drying clothes consists of other challenges as well. The system will not only need to provide the user with frequent updates on the actions but also perform tasks autonomously. To overcome these challenges, the following papers relative to conventional and modern clothes drying techniques were studied.

2.2 Relative Work

2.2.1 Review Paper on Design and Fabrication of Cloths Drying Machine [2]

This paper reports the history of clothes drying machine. The earliest dryer dates back to the 18th and 19th century in England and France. These dryers were made of large metal drums with ventilation holes and power by hand cranks. A fire was lit underneath these dryers which carried the out the drying process. This system failed to suffice because the clothes always smelled like smoke and sometimes even caught fire. Figure 2.1 shows the design of this dryer.

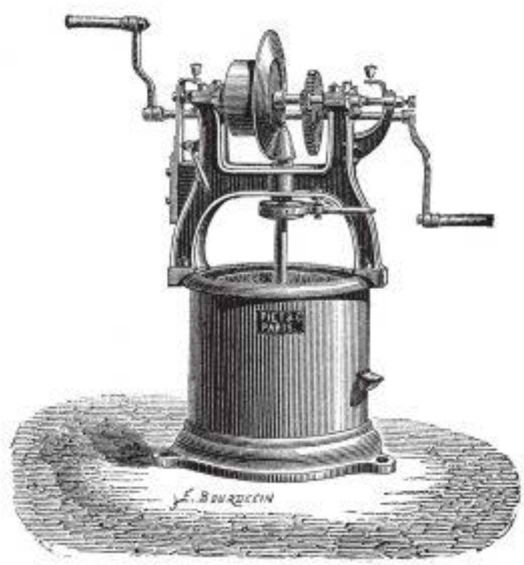


Figure 2.1: Early Manual Clothes Dryers

The first electric dryer emerged in the 20th century which was designed by inventor J. Ross Moore in North Dakota. [2]. Moore made a shed where clothes would hand on a line underneath a fire. This was the beginning of the development of electric dryer. After several years of development, the modern day dryer was introduced in the 1990s. These dryers went through developments that made them eco-friendly and also equipped with filters to reduce airborne diseases.

Although these dryers are available at many residential apartments, it's not personal and it still requires great amounts of power to be used. A standard electronic clothes dryer can have a power rating of a minimum 1000W to a maximum of 4000W. [2] This limitation encourages us to find a more energy friendly solution.

Sunlight has been the conventional method of drying clothes and also the least energy consuming method as it is all natural. Using the sun's energy can allow us to create a system that is much more efficient than modern dryers today. For this reason, the source of energy for drying clothes using this system will be sunlight.

2.2.2 A Low-Cost Collision Detection System for Compact Vehicles [3]

To create a system which uses sunlight, the hardware will need to move about which brings in the question of collision detection. This paper performs and experiment by building a low-cost collision detection system for compact vehicles.

Figures 2.2 and 2.3 shows the design of the system and the position of the sensors. It uses an array of 8 HC-SR04 Ultrasonic sensors connected to an Arduino UNO at its core. The system was used in autonomous driving and parking system. The sonar methodology used in this system is shown in Figure 2.4. It works by sending out a pulse at 40KHz using the trigger unit which bounces off an object and received by the corresponding echo unit. This sensors works in the range of 2cm to 3 meters.

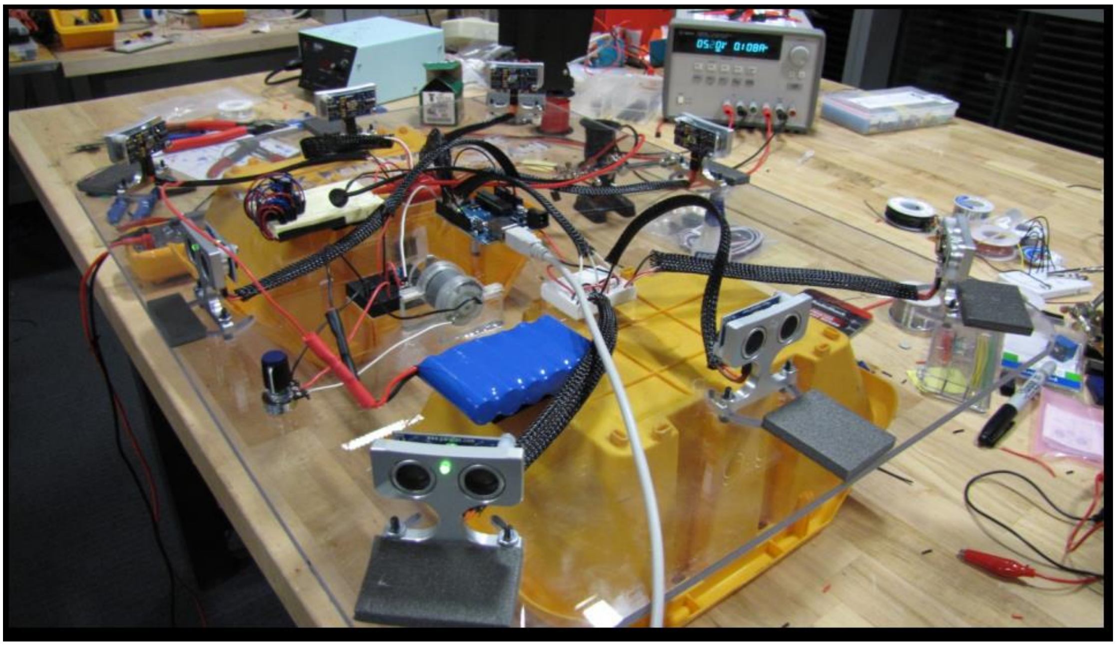


Figure 2.2: Low-Cost Collision Detection System

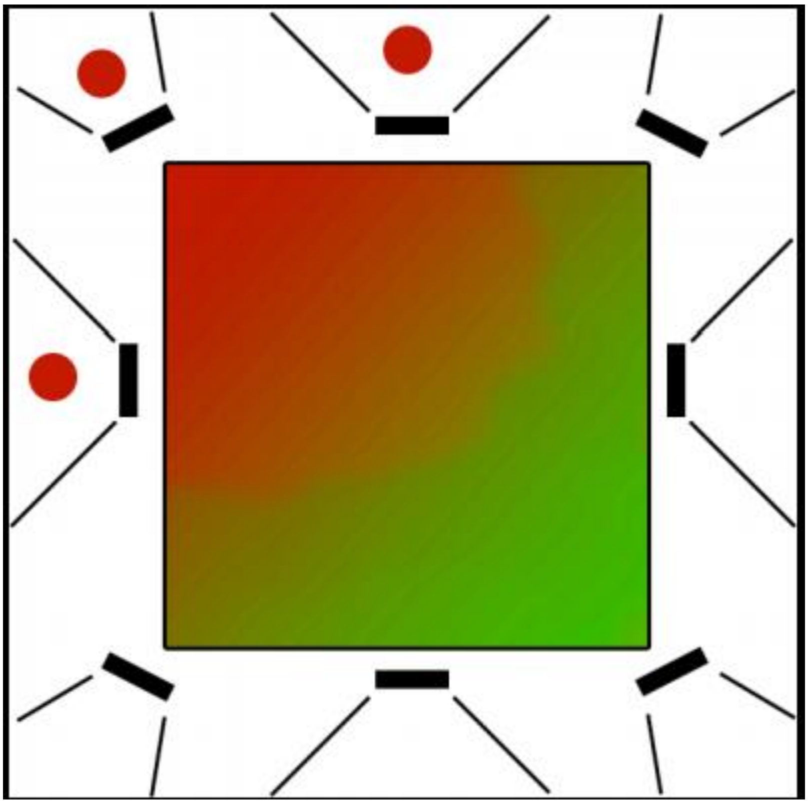


Figure 2.3: Position of the HC-SR04 Ultrasonic Sensors

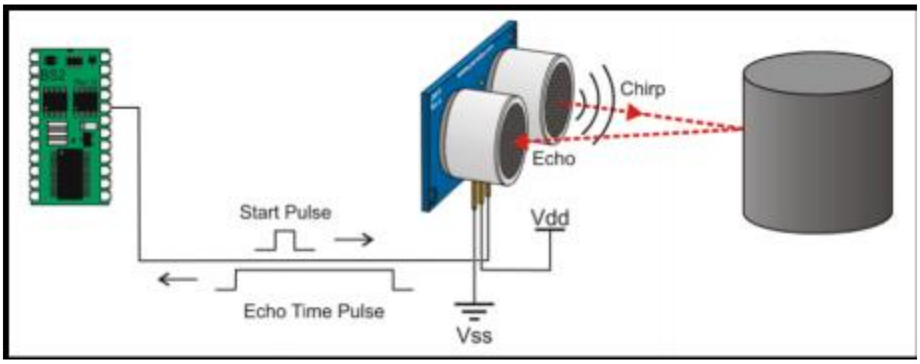


Figure 2.4: Working Principals of the Ultrasonic Sensor

In conclusion of this experiment carried out by Nicholas and Praveen of MIT, the system was successful at detecting collision of autonomous vehicle and assist in parking. Due to the success of this experiment, this system will be implemented into the clothes drying rack which will allow it to autonomously move about as well as retract into the house in the case of rain without colliding into any objects.

2.2.3 MOTION CONTROL ANALYSIS OF A MOBILE ROBOT [7]

This article examines the motion of a mobile nursing robot. The main focus of the article is on reducing position errors and avoid slippage. To achieve this, the system applies a coupling control algorithm that guarantees zero steady state error. The experiment results stated that in order to minimize slip, the contact surface between the wheel and the floor must have a high friction coefficient. It also proved that uneven load can compress rubber wheels for which a rigid design is preferable. Misalignment of the driver wheels can produce unwanted drag. This can be fixed by a correction factor which is multiplied to the pulse from the misaligned wheel.

2.2.4 Dual Axis Solar Tracker [5]

This research focus on searching solar energy and aligning a solar array with the sun. The system uses 5 Light Dependent Sensors (LDR) which allow the user to detect higher density of sunlight. Figure 2.5 shows the sample panel made by the author for his experiment.

Figure 2.5: LDR Panel

The experiment was successful at distinguishing sunlight of higher density using the circuitry shown above. The reason for this is that LDR sensors have higher sensitivity to sunlight's wavelength. Figure 2.6 shows the wavelength of color spectrum in general whereas Figure 2.7 shows the sensitivity of LDR sensors to different wavelengths. For this reason, LDR sensors were chosen to be used in the clothes drying system as its sensitivity to sunlight is optimal.

Figure 2.6: Color Spectrum Wavelength

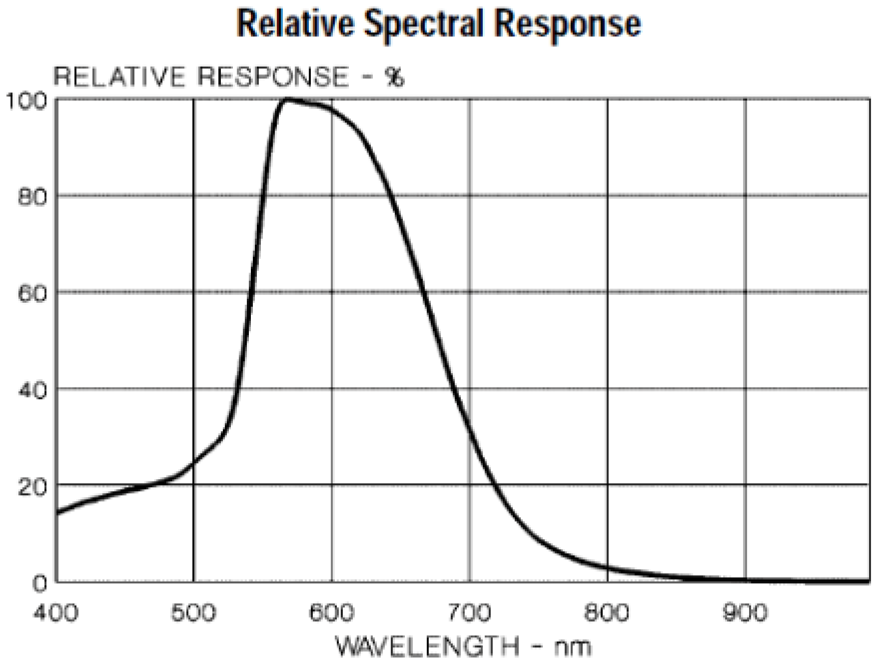


Figure 2.7: LDR Sensitivity to Color Wavelengths

2.2.5 Rain Alarm Project [4]

The Rain Alarm Project is a simple project that tests out the performance of a rain meter sensors. As the name suggests, this sensor is made of a copper plate that changes it's resistance based on the availability of water, in this case rain hence detecting the presence of rain. Figure 2.8 shows the circuitry and the sensor plate. Due to the success of this project in detecting rain, this sensor will be used in the system to detect rain.

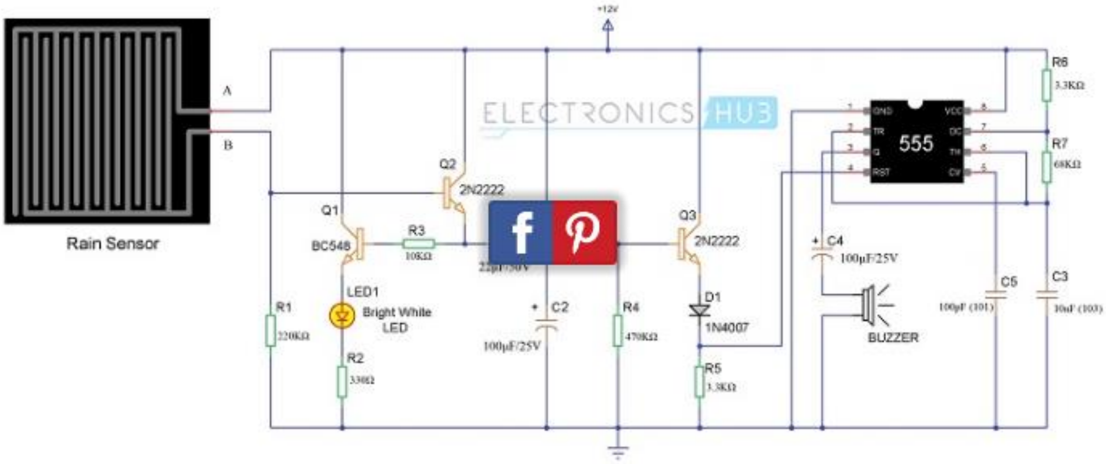


Figure 2.8: Rain Meter Sensor Circuit

CHAPTER 3 DETAILS OF THE DESIGN

The following chapter discuss the structural design of the system as well as the sensory components implemented in the system. Integration of the sensory modules with the hardware will also be discussed from a technical perspective.

3.1 Structural Design

To create a motorized clothes drying rack the first thing needed to be done was to design the structure of the rack. Figure 3.1 shows the design of a wardrobe which was built using an aluminium frame and plywood body. The dimensions and weight of the wardrobe are shown in Table 3.1. The goal was to create a lightweight but firm wardrobe as its aesthetic qualities can allow the user to use it indoor as a wardrobe as well as outdoor as a dryer. Although the prototype is made of plywood, the idea was to create a transparent body which will allow sunlight to go through and fall on the clothes allowing for a more effective drying system. The shutters used on the sides to protect the clothes immediately from the rain are made from shower curtains which are made of plastic.

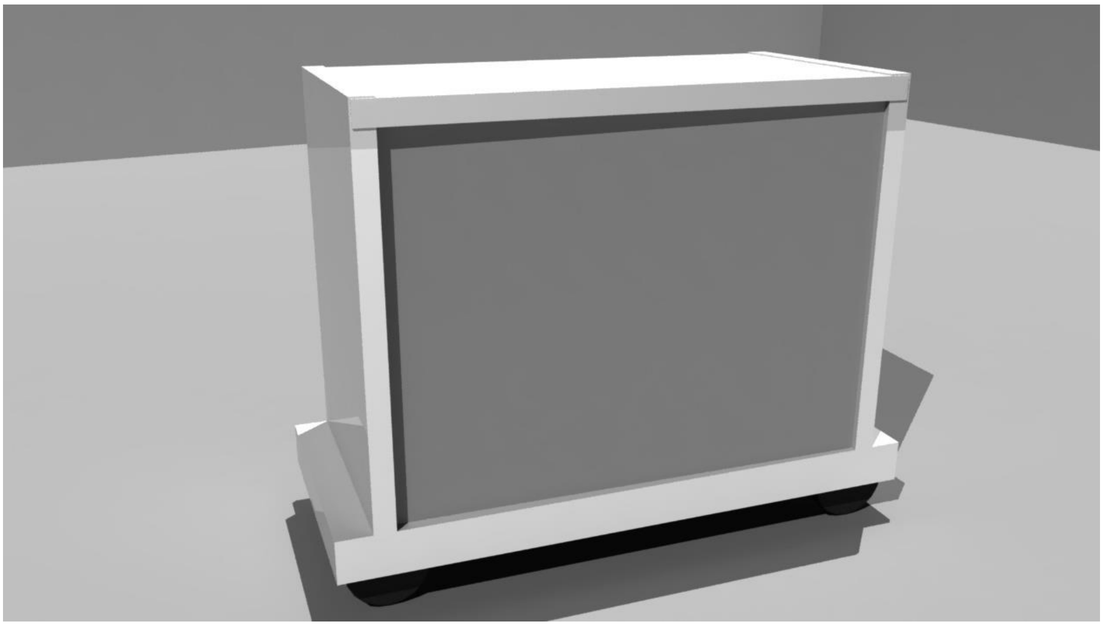


Figure 3.1: Structural Design of the Wardrobe

Table 3.1: Drying Rack Measurements

Dimensions & Measurements	
Height	110 cm
Width	88.5 cm
Length	51 cm
Weight	13 kg

3.2 Arduino MEGA R3 2560

The functionality of the system is built with an Arduino MEGA R3 2560 at its core. Arduino MEGA consists of an ATmega1280 microcontroller with a 16MHz crystal oscillator. It also includes 128KB flash memory, 8KB SRAM and 4KB of EEPROM. The primary reason for choosing an Arduino MEGA is the quantity of the I/O pins. The full specification of the Arduino MEGA R3 2560 is listed in Table 3.1

Figure 3.2: Arduino MEGA R3 2560

Table 3.2: Arduino MEGA R3 2560 Specifications

Specifications	Arduino mega2560
Processor	ATmega 2560
Flash Memory	256 KB
Data Memory	8 KB
EEPROM	4 KB
Digital I/O Pins	54
PWM outputs	15
Analog outputs	16
Clock Speed	16 MHz
Serial Ports	4

3.3 Mobility

One of the objectives of the dryer is to find optimal sunlight and position itself. To achieve this goal, the dryer will need to move around. Due to residential usage, the dryer's movement is limited to flat, hard surface as the wheels and motors used as well as the structural design will not make it suitable for tougher terrains. For performing movement, two 12V DC motors will be used powered by a 12V Li-Po battery and a driver circuit. The dryer will have 2 wheels attached to the motor and 2 wheels mounted on a rotating axis making it a 2 wheel drive dryer.

3.3.1 DC Motors and Wheels

The DC motors responsible for moving the 13kg wardrobe were chosen based on high torque. Figure 3.3 shows the motors and their structural design where the measurement is in millimetres. Table 3.3 shows the specifications of the motors. The motors were mounted onto the front end of the dryer making it a front wheel drive (FWD) dryer. The reason for making this a front wheel drive is to reduce the alignment error while turning which is caused by the 360 rotating wheels attached to the other end of the dryer. The wheels used for the motors are 5inches in diameter and shown in Figure 3.4.

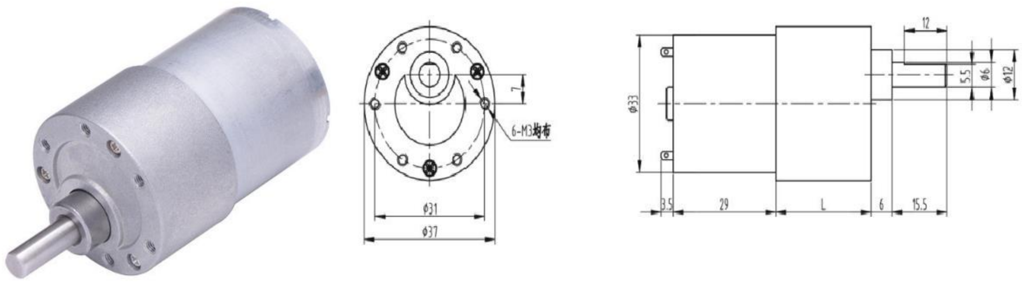


Figure 3.3: DC Motors Dimensions

Table 3.3: 12V DC Motor Specifications

Specifications	
Motor Model	JGB37-3530
Rated Speed	20 RPM
Rated Torque	19kg.cm
Rated Voltage	12v DC
No load current	0.5a
Stalling current	1.4a

Figure 3.4: Wheels Connected to the Motors

3.3.2 L298N Dual H Bridge DC Motor Driver Module

A motor driver module acts as an amplifier that converts lower current signals into higher current signals to provide a stable, appropriate current input for the motors. In this system, an L298N microcontroller, shown in Figure 3.5, has been used to design a driver module. The driver module is shown in Figure 3.6 and the schematics is shown in Figure 3.7. This module is capable of providing power for 2 motors at a time. It has been integrated with the Arduino MEGA to provide the motors with ample power. Not only does a driver motor provide stable power supply to motors, it protects the motors from creating backwards EMF which can hurt the Arduino as it is directly connected to the inputs of motors.

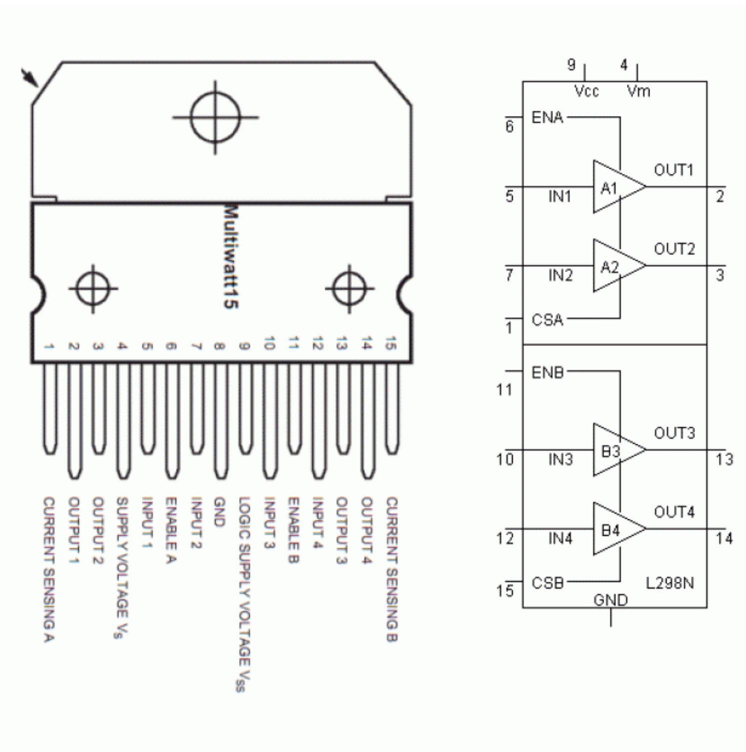


Figure 3.5: L298N Microcontroller chip and schematic

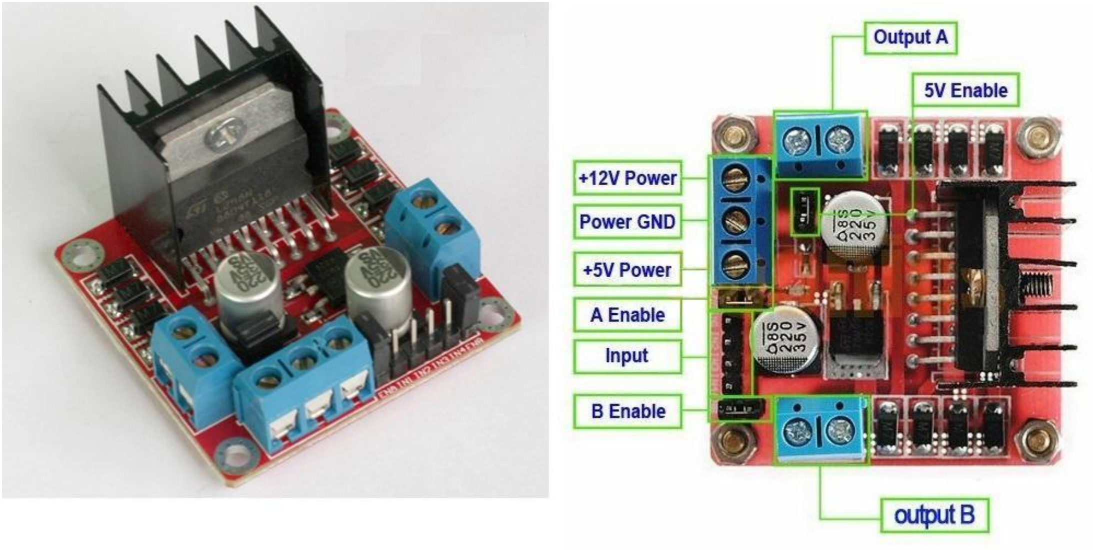


Figure 3.6: Motor Driver

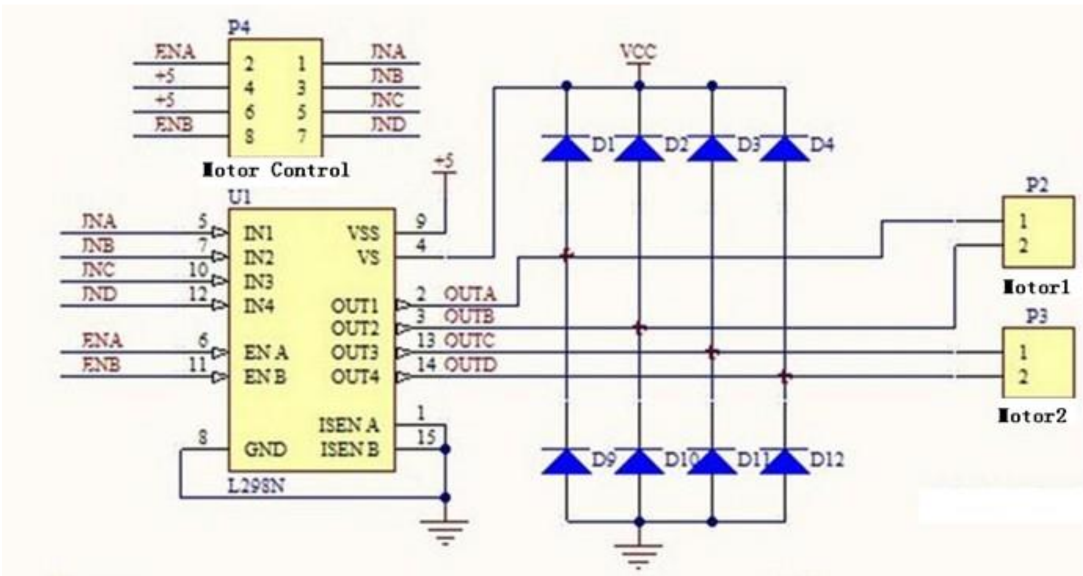


Figure 3.7: Schematic of a Driver Module using L298N Microcontroller

3.4 Boundaries for Mobility

Due to the limitations of the design and sensory modules, a system had to be designed to allow the dryer to move about freely yet remain in its designated area.

For this system, IR sensors were equipped to the bottom of the dryer which will detect a given boundary. The boundary for the system has been drawn using black tape. The clothes dryer will remain in this boundary and search for sunlight within the vicinity. Based on the user’s preference, they can make it any size as long as it has 4 edges connected end to end. Figure 3.8 shows a sample of the boundary as well as the dryer inside.

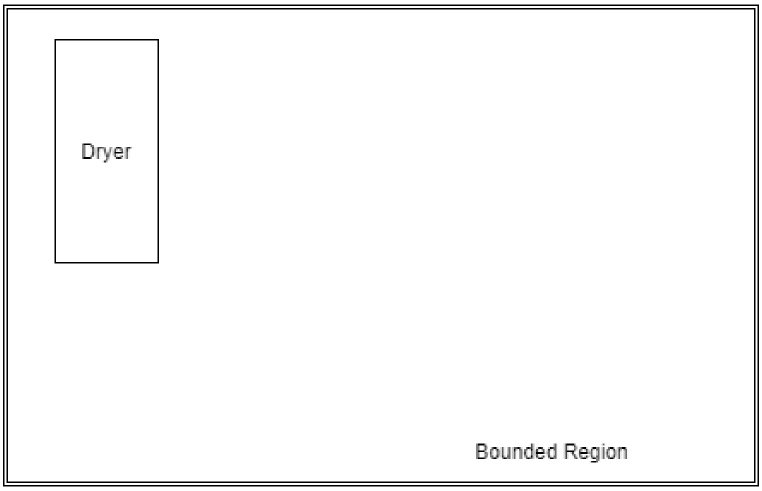


Figure 3.8: Boundary

3.4.1 Infrared Sensors

Infrared sensors detects infrared light which has been reflected from objects within its specified range. For this experiment, TCRT5000 sensors has been used to detect the black line. This sensors contains an IR Emitter and an IR Phototransistor packed together which is shown in Figure 3.9. The emitter emits an infrared wave which bounces off an object and then captured by the IR Phototransistor. This allows the user to get a distance to an object. Along with distance, it can also differentiate between white and black based on the contrast of the object. Table 3.4 shows the specifications of the TCRT500.

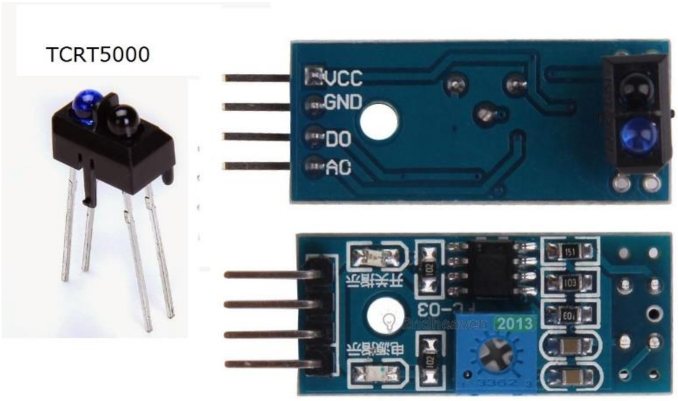


Figure 3.9: IR Sensor Module

Table 3.4: IR Sensor Specifications

IR Sensor Specifications	
Working voltage:	3.3-5VDC
Output signal:	Digital (0 and 1)
Operating current:	around 15mA
IC used:	LM393
Size:	31mm*10mm

To implement this, a simple circuit was designed using an LM393 comparator. The circuit has an analog and a digital output. Figure 3.9 shows the schematics for the TCRT5000 sensor circuit. The circuit for the sensory module contains a potentiometer which provide both digital and analog outputs. For this experiment, the analog output has been used as it allows for greater precision and evaluation of raw data.

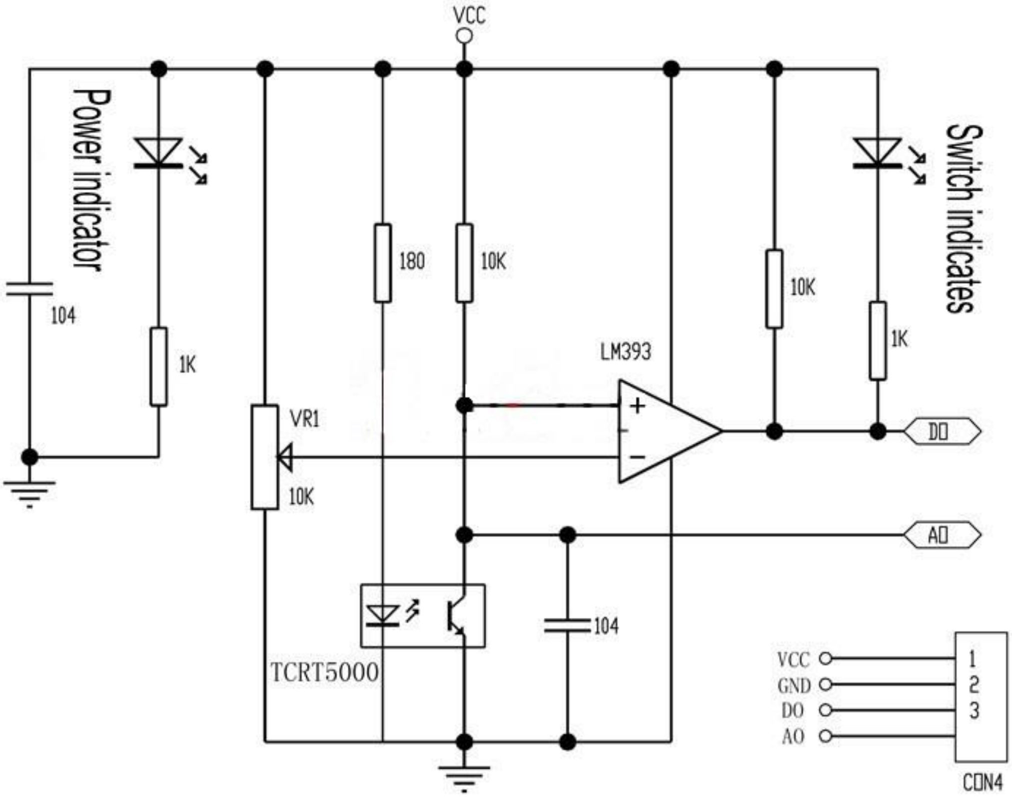


Figure 3.10: IR Sensor Module Schematic

3.5 Collision Detection

Collision detection is crucial for any mobile system as it provides a form of protection. The system is required to perform outdoors which provides as well as retract inside the house. Collision detection is important for both situation. Considering the size and speed, ultrasonic sensors were chosen to be implemented into the system. Four ultrasonic sensors are to be put on each end of the dryer for it to detect any collision and thus avoiding it through Arduino commands.

3.5.1 HC-SR04 Ultrasonic Sensors

The HC-SR04 is an ultrasonic sensors which uses sound energy to calculate the distance to an object. It sends out an ultrasonic wave at 40KHz which bounces back and is captured by the sensor. The distance is calculated by using the speed of sound and the time taken for the wave to return. The formulas used for this is shown below.

$$distance = \frac{speed\ of\ sound\ \times time\ taken}{2}$$

Because of its dependency on sound waves to bounce back, this sensor is limited to materials with hard surfaces that allow sound to bounce back. Since this experiment is taking place outdoors, most objects that come in contact will have a surface off of which sound can bounce back which makes it a suitable choice for use. Figure 3.11 shows the sensor and Table 3.5 shows the specifications of this sensor.

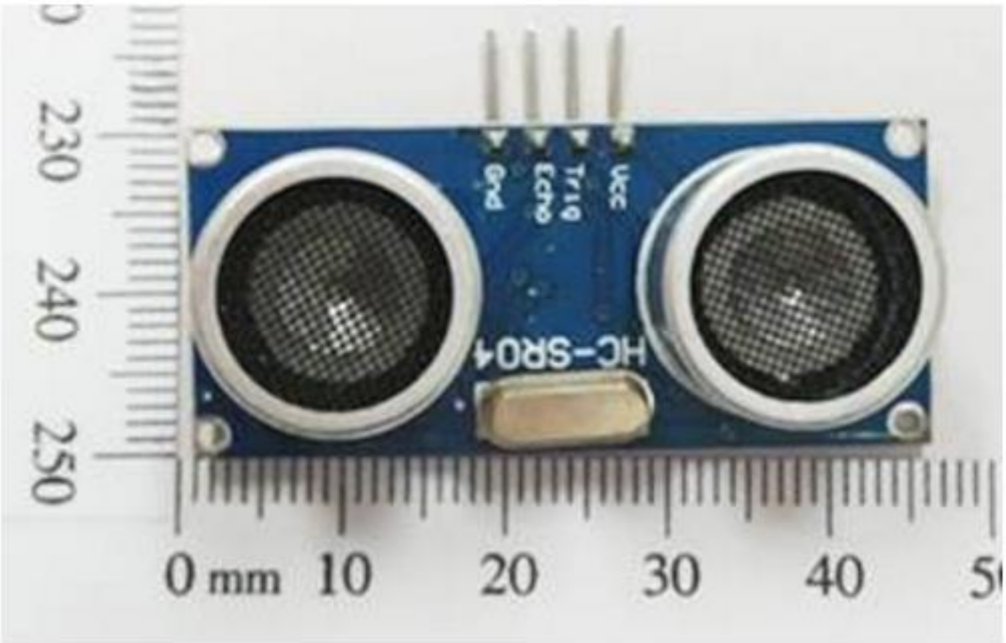


Figure 3.11: HC-SR04 Ultrasonic Sensor Specifications

Table 3.5: HC-SR04 Ultrasonic Sensor Specifications

HC-SR04 Ultrasonic Sensor	
Power Supply	+5V DC
Quiescent Current :	<2mA
Working Current:	15mA
Effectual Angle:	<15°
Ranging Distance	: 2cm – 400 cm/1″ – 13ft
Resolution :	0.3 cm
Measuring Angle:	30 degree
Trigger Input Pulse width:	10uS
Dimension:	45mm x 20mm x 15mm

3.6 Locating Optimal Sunlight

This system heavily relies on sunlight as the proposed solution requires it to locate sunlight and position itself accordingly. For this reason, light dependent resistors (LDR) were embedded onto the dryer's top. Four of the sensors were positioned on the top of the dryer nearer to the center to allow sunlight to fall on the body of the dryer.

3.6.1 Light Dependent Resistor (LDR)

A light dependent resistor is a photo diode which changes its conductivity based on the amount of light in its surrounding. A simple circuit has been created which will allow us to modify the sensitivity of the LDR sensor and adjust it accordingly. Figure 3.12 shows an image of the LDR sensor and Figure 3.13 shows the schematic for the circuit design.

Figure 3.12: LDR Sensor

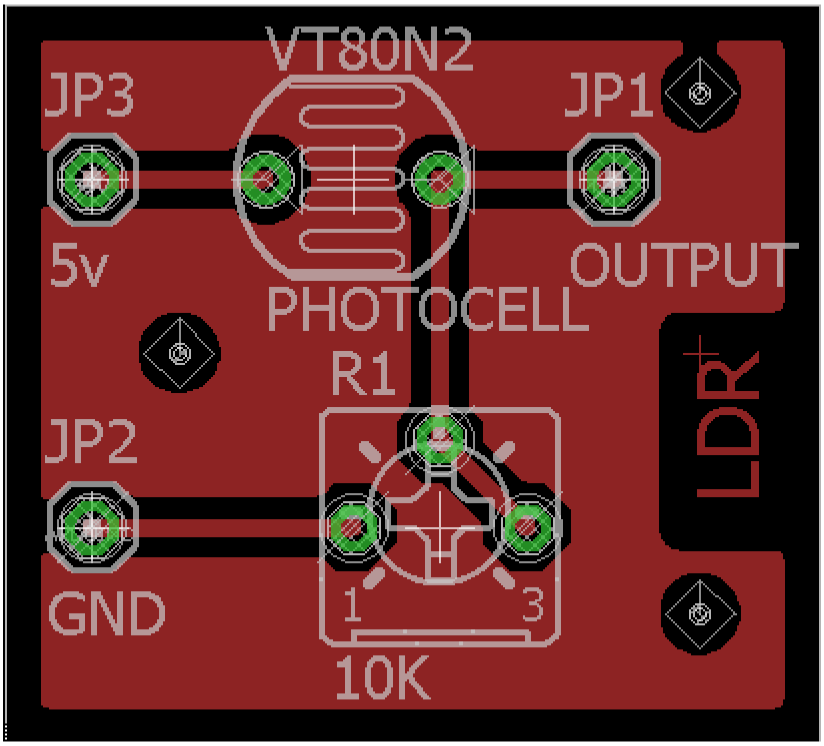


Figure 3.13: Schematic for the LDR Sensor

3.7 Protection from Rain

The purpose of this system will be lost if there isn’t a mechanism for it to protect the clothing from getting wet in the case of rain. For this reason, a rain sensor has been integrated into the system. When rain is detected, the dryer will head back into the residency and shut down itself until the rain meter sensor is cleared. Due to the distance the dryer might need to cover to get back into the residency, an immediate solution of protecting the clothes needs to be implemented. For this reason, a roller attached with a plastic sheet has been used on the sides to protect the clothes while the system is looking to retract into the house.

3.7.1 Rain Sensor

The rain sensor is a switching device which activates itself during rainfall. It consists of a copper plate attached to a circuit that measure the conductivity of the plate. When water falls onto the plate, conductivity increases and notifies the existence of rain. The circuit is made of an LM393 comparator. Figure 3.14 shows the rainmeter sensor.

Figure 3.14: Rain Meter Sensor

3.7.2 Shutters

The system has been equipped with shutters on both sides of the dryer to prevent the clothes from getting soaked in the rain while the dryer retracts back into the house. It uses a 12V DC with a higher RPM than the motors used to drive the dryer. Table 3.6 shows the specifications for the motor used for the shutters. Plastic sheets were used to cover the sides. Due to limitation of resources, only one side of the prototype has been covered for this experiment.

Table 3.6: DC Motors for Shutter

DC Motors Specifications for Shutter	
Motor Model :	JGB37-3530
Rated Speed :	111 RPM
Rated Torque :	3.4kg.cm
Rated Voltage :	12v DC
No load current :	0.5a
Stalling current :	1.4a

CHAPTER 4 SYSTEM IMPLEMENTATION AND DISCUSSION

This chapter of the report will elaborate on the compilation of the whole system as well as provide the algorithms and codes used for the functionalities of the system.

4.1 Introduction

The clothes drying rack proposed in this report consists of all the components explained in the previous chapter. The purpose of this system is to move within a given parameter to locate sunlight. Once positioned for optimal sunlight, the dryer will wait and the dry the clothes in the sunlight. If rain is detected, the system will retract into the household. In the meantime, shutters on both sides of the dryer will close instantly preventing the clothes from getting wet again. While performing all this, the system will constantly update the user on the state of the dryer. Figure 4.1 shows the dryer that was designed for this project. The idea was to make a transparent dryer but due to lack of materials this was made of plywood.

Figure 4.1: Clothes Dryer Rack Prototype

4.2 Motherboard

The system is built with Arduino MEGA R3 2560 at its core. Along with the Arduino, NodeMCU and 2 driver motors were used in this design. All 4 of these components has been put on 1 board for the convenience of having a central board to connect all the sensors and motors and provide a power supply to. Figure 4.2 shows the board onto which these circuit boards were attached to. This dryer will have 2 primary modes: Forward Mode and Reverse Mode. During Forward Mode, the dryer will be using only its front ultrasonic sensors and IR sensors. This mode is used when searching for sunlight. Reverse Mode will be activated the dryer is retracting back into the house. During this mode, the rear ultrasonic and IR sensors will be activated. More on these modes will be elaborated later on in the report.

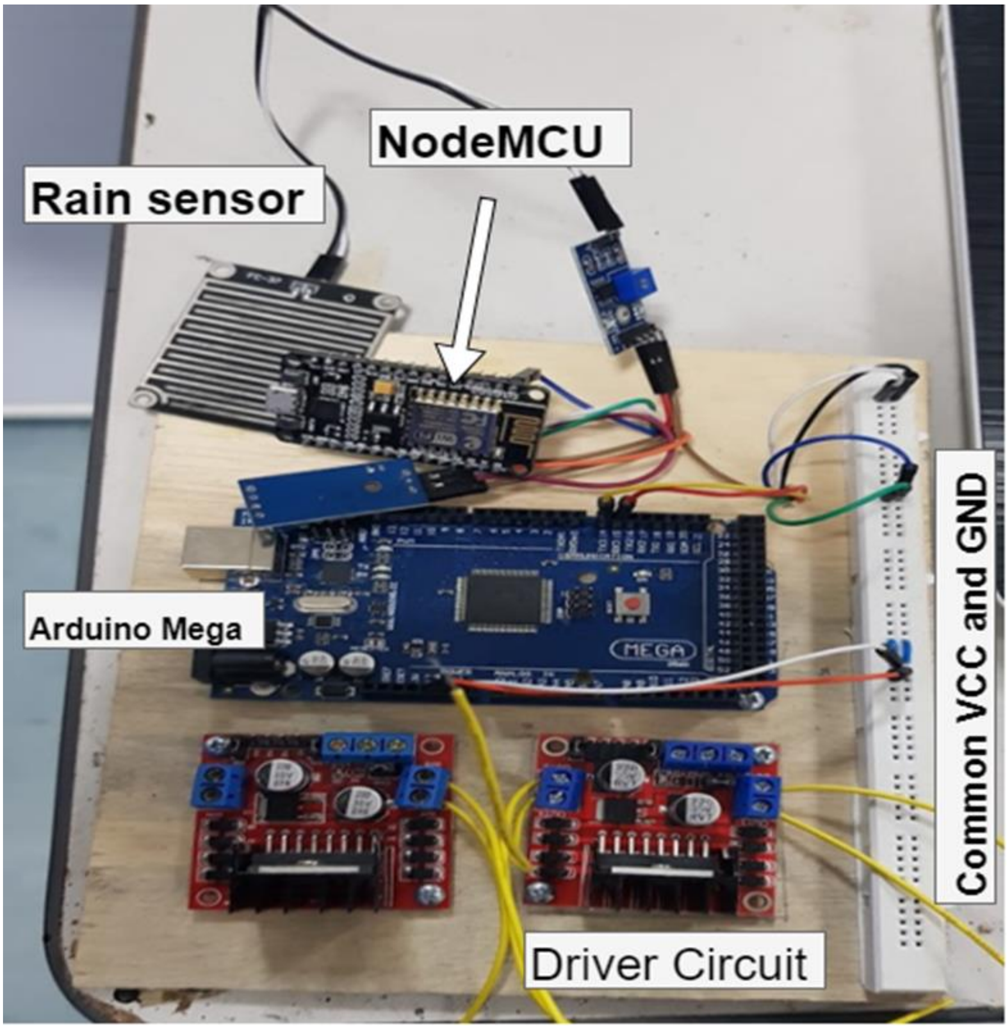


Figure 4.2: Motherboard

4.3 Moving Within the Perimeter

At the heart of the system is the Arduino MEGA R3 2560. This will be connected to the driver motors which will receive commands on certain movements. There are 2 DC motors connected to a driver circuit which is connected to the Arduino. Table 4.1 shows the connections of the Arduino with the driver motor.

Table 4.1: Arduino MEGA and Driver Motor Pin Connections

Arduino MEGA		Driver Motor 1
Port Pins	Pin Names	Pin Names
5V@0	5V	5V
GND@0	GND	GND
10	D10	In 1
11	D11	In 2
12	D12	En A
26	D26	In 3
28	D28	In 4
30	D30	En B

4.3.1 IR Sensors for Black Line Detection

For the dryer to remain within the boundary, IR sensors has been used at all 4 ends of the dryer which is shown in Figure The boundary has been distinguished with black tape. The IR sensors will receive a value of 300 or less when it comes in range with this black tape. This will trigger the sensor and command it to reverse and turn and thus remaining within the bounded region. Code listing 4.1 shows the program for this command and Figure 4.4 shows the flow chart. Figure 4.3 shows the IR sensors attached to the dryer.

Table 4.2: IR Sensors Testing Results

IR Sensor Sensitivity Test		
Trial	Color	Sensor Rating
1	Black	289
2	Black	250
3	Black	270
4	Black	235
5	Light Blue	703
6	Light Blue	713
7	White	889
8	White	876
9	Red	678
10	Red	663

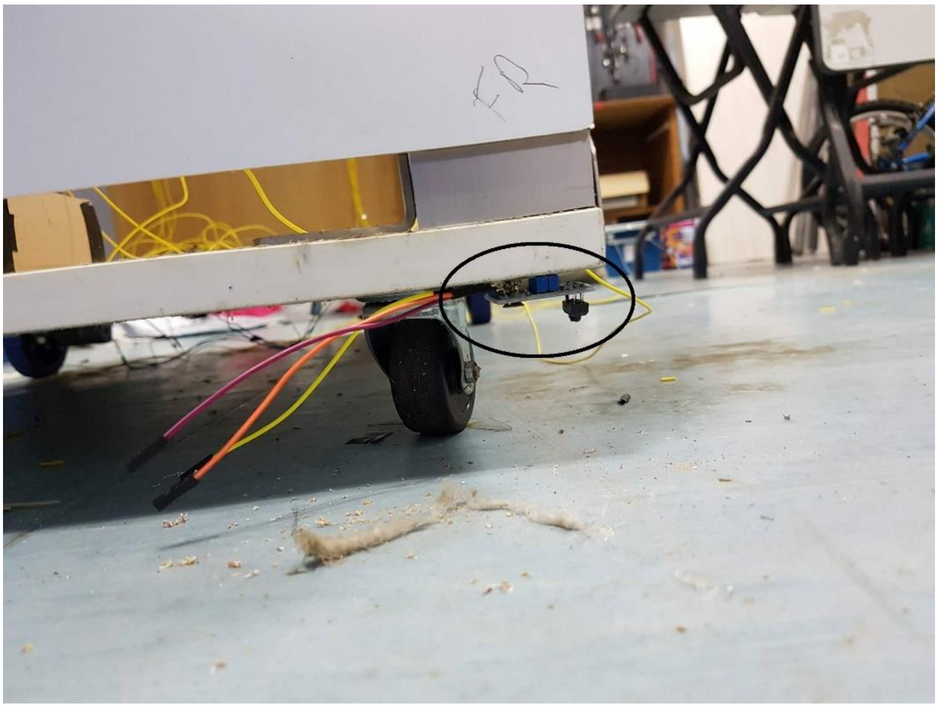


Figure 4.3: IR Sensors Attached to the Dryer

File Edit Sketch Tools Help

draft1

```
      //Get IR values
      IR_FR = analogRead(A1);   //Sensor connection to the arduino
      IR_FL = analogRead(A2); //Sensor connection to the arduino

//IR sensor
  if ((sensor_1 < ir_level) || (sensor_2 < ir_level)){
    for ( int pwm = reverse  ; pwm > 0; pwm--){ //REVERSE

      digitalWrite(in_4,LOW) ; //motor1 input 1
      analogWrite(in_5,pwm) ; //motor1 input 2
      digitalWrite(in_6,LOW) ; //motor2 input 1
      analogWrite(in_7,pwm) ; //motor2 input 2
      delay(5);
      }
      delay(2000);

      for ( int pwm = turn_rate ; pwm > 0; pwm--){ //Turn left
      digitalWrite(in_4,HIGH) ; //motor1 input 1
      digitalWrite(in_5,HIGH) ; //motor1 input 2
      digitalWrite(in_6,LOW) ; //motor2 input 1
      analogWrite(in_7,pwm) ; //motor2 input 2
      delay(5);
      }
       delay (3500);
  }
```

Code Listing 4.1: IR Sensor Black Line Detection

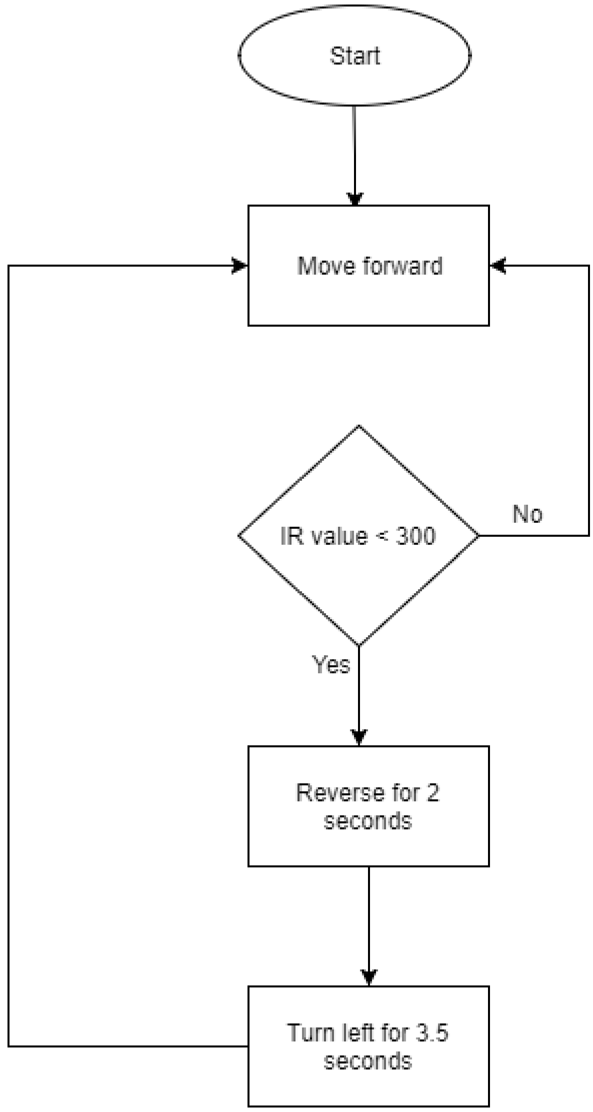


Figure 4.4: IR Sensor Black Line Detection

4.3.2 Ultrasonic Sensor for Collision Detection

The ultrasonic sensor will be responsible for detecting collision as well as assisting in parking the dryer inside the house. During Forward Mode, the front ultrasonic sensors will solely be used for detecting and avoiding obstacles. However, in Reverse Mode, the rear ultrasonic sensors will park the dryer whenever it sees an obstacle. For this reason, one of the edges of the black line has to be drawn on the edge of the wall the user wants the dryer to be parked by. The ultrasonic sensor will trigger at a distance of 40cm. Code Listing 4.2 shows the code for the ultrasonic sensor and Figure 4.5 shows the flowchart of the ultrasonic sensor for Forward and Reverse Modes. Figure 4.6 shows the position of the ultrasonic sensors on the dryer.

```
File  Edit  Sketch  Tools  Help

draft1 §

 //Forward mode: searching for optimal sunlight

   ////Get ultrasonic sensor values
       long duration_FR, distance_FR;
          digitalWrite(trigpin_FR, LOW);
          delayMicroseconds(2);
          digitalWrite(trigpin_FR, HIGH);
          delayMicroseconds(10);
          digitalWrite(trigpin_FR, LOW);
          duration_FR = pulseIn(echopin_FR, HIGH);
          distance_FR = (duration_FR/2) / 29.1;

          long duration_FL, distance_FL;
          digitalWrite(trigPin, LOW);
          delayMicroseconds(2);
          digitalWrite(trigPin, HIGH);
          delayMicroseconds(10);
          digitalWrite(trigPin, LOW);
          duration_FL = pulseIn(echopin_FL, HIGH);
          distance_FL = (duration_FL/2) / 29.1;
```

Code Listing 4.2: Ultrasonic Sensors

The Code Listing 4.2 shows the structure of usage of the ultrasonic sensor. The 'trigpin' sends out a signal then after a 10ms delay, the echo pin reads the signal that bounces off any object within the range of the ultrasonic sensor. The value is then converted to centimeters and stored in the 'distance_FL' variable.

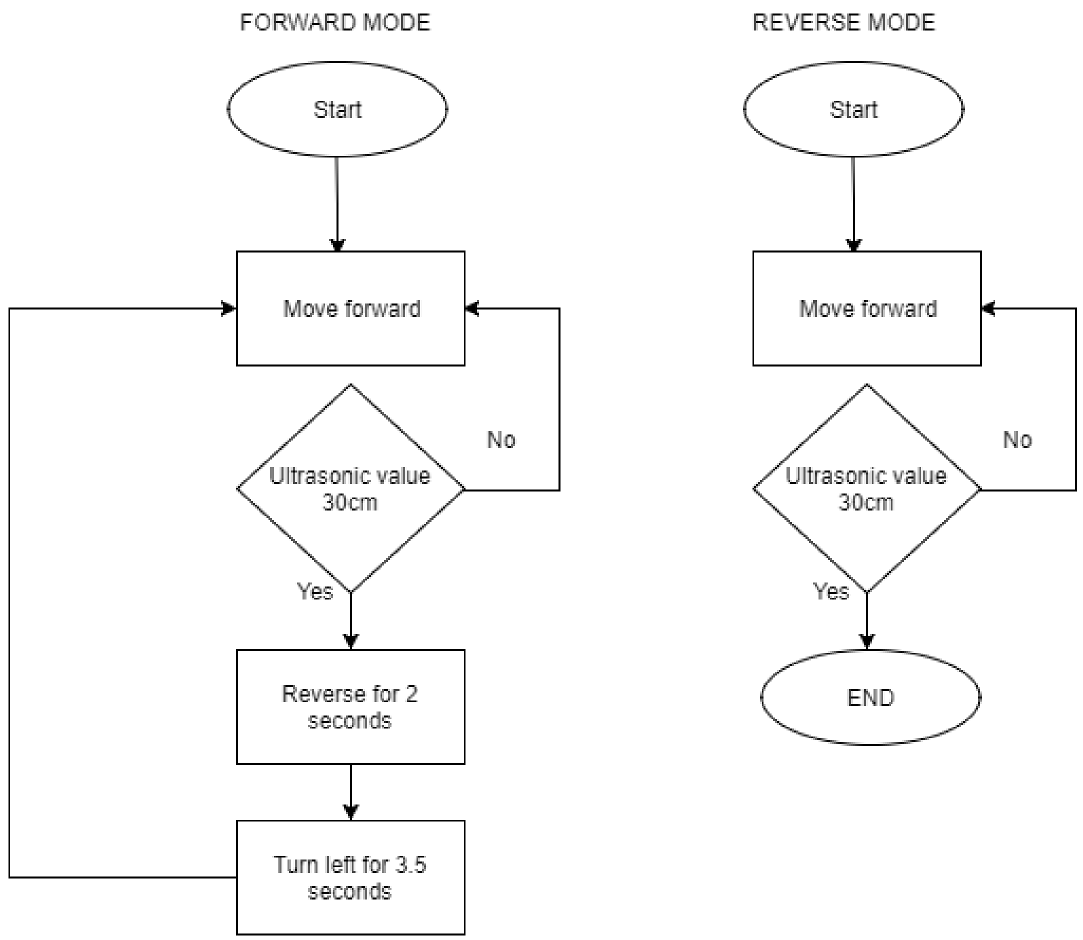


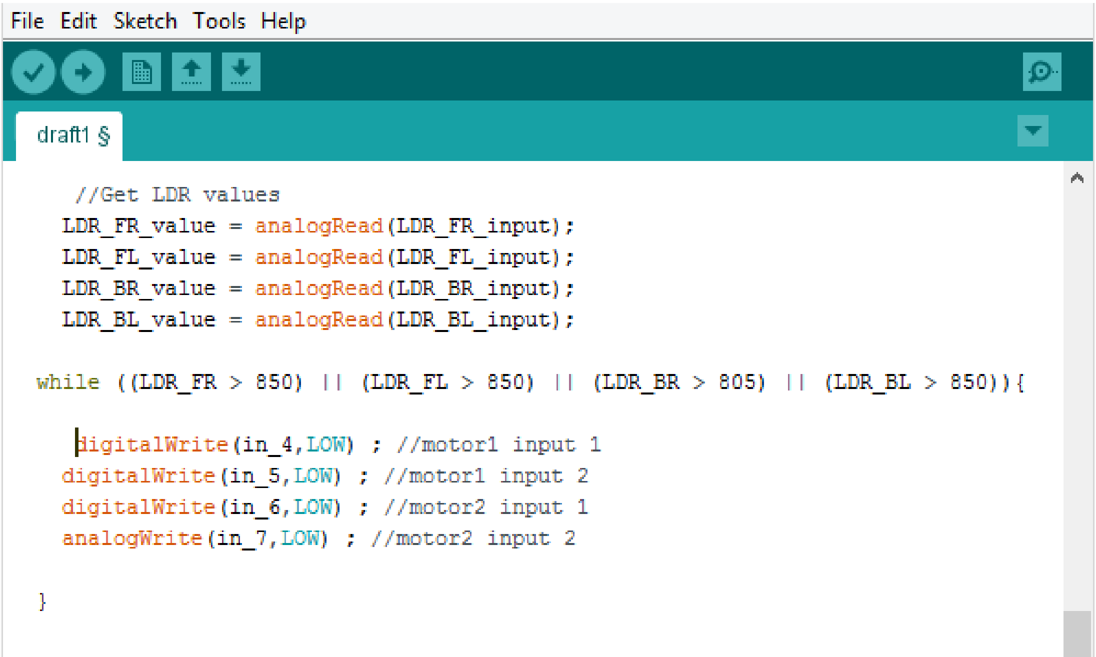
Figure 4.5: Forward and Reverse Modes

Figure 4.5 above shows the flow of the program in both reverse and forward mode. It should be noted that during forward mode, the IR and ultrasonic sensors connected to the front of the system are active while the ones in the rear are deactivated. This is because the front sensors will be in contact with any of the elements being measured first. Turning the sensors off saves power as well. The sensors activity is reversed in the reverse mode. Even though the IR and ultrasonic sensors are active and inactive in pairs, the purpose for the sensors are same in both the front and the back.

Figure 4.6: Ultrasonic Sensors on the Dryer

4.3.3 Searching Optimal Sunlight using LDR Sensor

The LDR sensors were placed on the roof of the dryer which is shown in Figure 4.7. The condition set was that as long as 1 sensor detects sunlight, the system will stop and remain in place until further commands are given. The LDR sensors value increases in the presence of bright light. The value set for triggering the sensor is 850. In the case of detecting rain, the LDR sensors are not taken into consideration anymore. Figure 4.8 shows the flowchart of the system. Code Listing 4.3 shows the code for receiving the value of the LDR.




```
  //Get LDR values
  LDR_FR_value = analogRead(LDR_FR_input);
  LDR_FL_value = analogRead(LDR_FL_input);
  LDR_BR_value = analogRead(LDR_BR_input);
  LDR_BL_value = analogRead(LDR_BL_input);

while ((LDR_FR > 850) || (LDR_FL > 850) || (LDR_BR > 805) || (LDR_BL > 850)){

   digitalWrite(in_4,LOW) ; //motor1 input 1
  digitalWrite(in_5,LOW) ; //motor1 input 2
  digitalWrite(in_6,LOW) ; //motor2 input 1
  analogWrite(in_7,LOW) ; //motor2 input 2

}
```

Code Listing 4.3: LDR Sensor Code for Detecting Sunlight

Figure 4.7: LDR Sensors on the Dryer

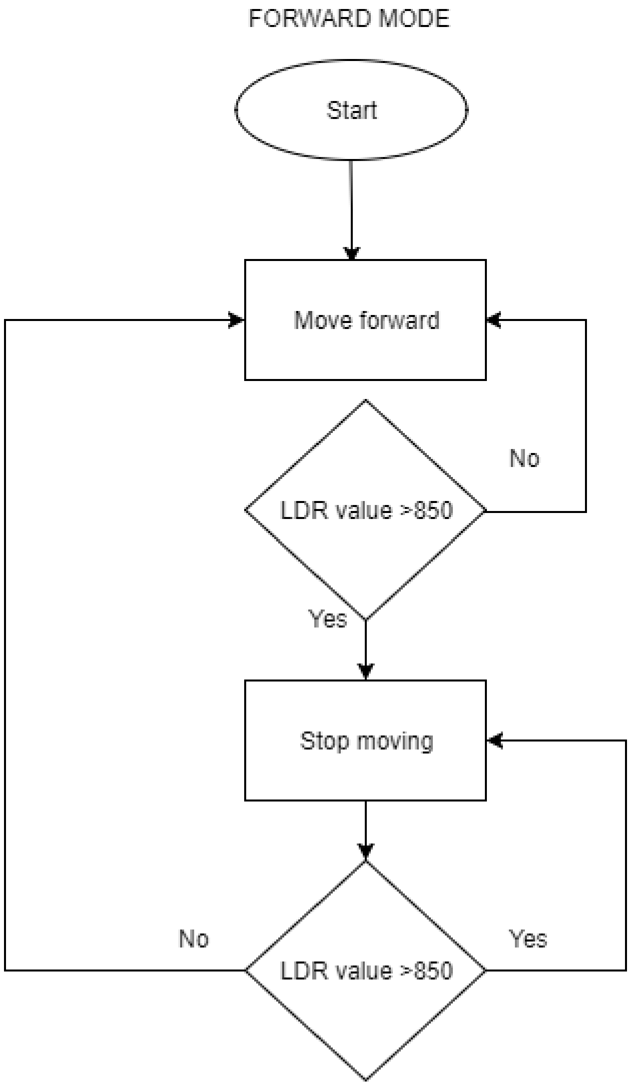
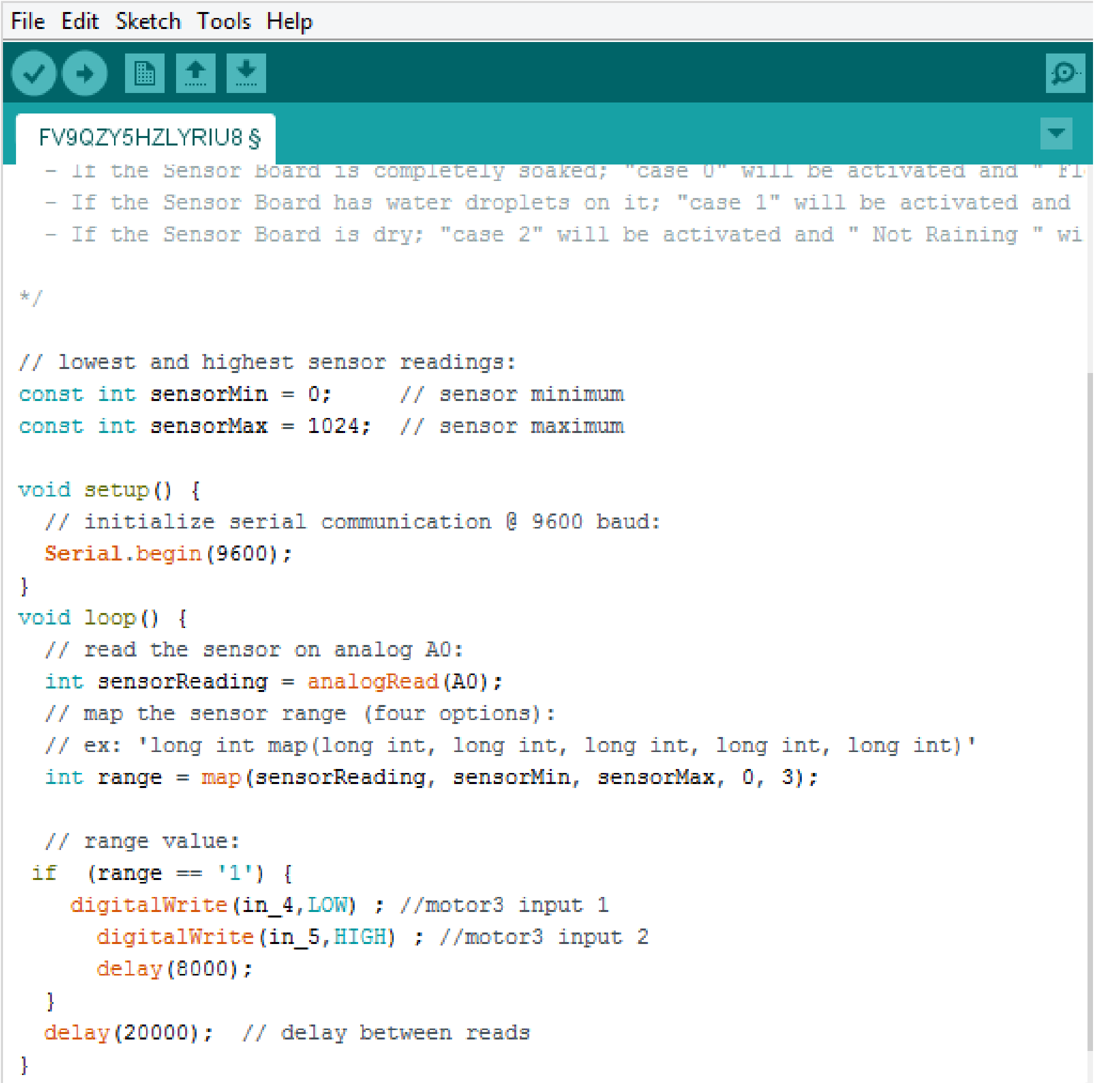


Figure 4.8: LDR Sensors Forward Mode

4.3.4 Protection from Rain

Two different measures has been taken to ensure the clothes don't get wet in the case of rain. When the rain meter sensor detects the presence of rain, the dryer will be turned into Reverse Mode in which it will look for the wall to retract back into the house. One added feature is a shutter on both sides of the dryer. While the dryer is looking to go back into the house, this shutter will prevent the rain from soaking the clothes again. Due to limitation of resources, the shutters were installed on one side only of the prototype. Figure 4.9 shows the shutter. The mechanism for the shutters lies all on timing the signal. The length of the shutter is about a 100cm. The diameter of the pole used is 2.5cm resulting in a circumference of 7.85cm. The mechanism is using a 111rpm DC motor which takes approximately 6.8 seconds to roll down completely. In this system, and 8 second delay has been set to allow the motor enough time to roll down the shutter. Code listing 4.4 shows the rain sensor detection and shutters rolling down code. Figure 4.10 shows the flowchart for the system.

Figure 4.9: Shutter on the Dryer




```
  - If the Sensor Board is completely soaked; "case 0" will be activated and " Fl
  - If the Sensor Board has water droplets on it; "case 1" will be activated and
  - If the Sensor Board is dry; "case 2" will be activated and " Not Raining " wi

*/

// lowest and highest sensor readings:
const int sensorMin = 0;     // sensor minimum
const int sensorMax = 1024;  // sensor maximum

void setup() {
  // initialize serial communication @ 9600 baud:
  Serial.begin(9600);
}
void loop() {
  // read the sensor on analog A0:
  int sensorReading = analogRead(A0);
  // map the sensor range (four options):
  // ex: 'long int map(long int, long int, long int, long int, long int)'
  int range = map(sensorReading, sensorMin, sensorMax, 0, 3);

  // range value:
 if  (range == '1') {
    digitalWrite(in_4,LOW) ; //motor3 input 1
      digitalWrite(in_5,HIGH) ; //motor3 input 2
      delay(8000);
  }
  delay(20000);  // delay between reads
}
```

Code Listing 4.4: Rain Sensor Code for Shutters

The rain sensor data is collected using an analog input of the Arduino. The value is represented from 0 – 1024 with 0 being no rain and 1024 being completely soaked. This is determined from the conductivity of the copper as water increases the conductivity. The ‘if’ loop in Code Listing 4.4 suggest that if the value of ‘range’ is one, then the sensor is wet and it will perform the action of rolling the shutters down. This will trigger variables ‘in_4’ and ‘in_5’ which will command the motors to perform the action.

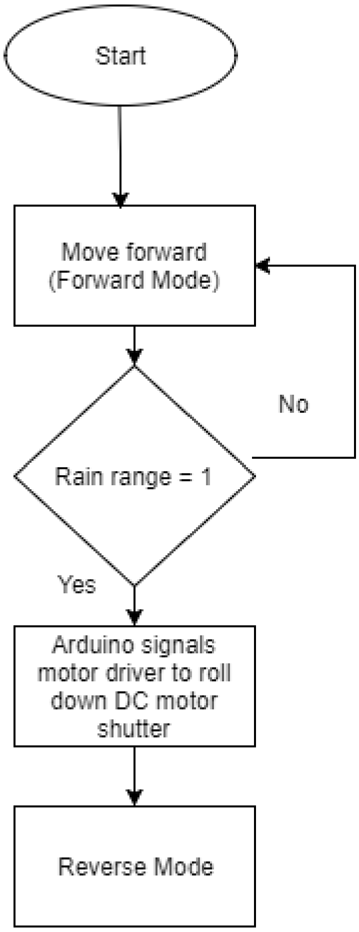


Figure 4.10: Flow Chart for Rain Sensor

Figure 4.10 shows the flow chart in the case of triggering the rain sensor. Once the system is in forward mode, the rain sensor will constantly be checked after a delay of 5 seconds. If rain is detected then the value of ‘range’ would be 1. Under this condition, the shutters will close on both sides of the dryer and the system will trigger reverse mode. The dryer will remain in reverse mode until it detects the parking wall of the residence in which case it will stop and roll the shutters back up as the dryer is back in it’s safe zone.

CHAPTER 5 CONCLUSIONS

5.1 Summary and Conclusions

The system was built to detect optimal sunlight, avoid collision and protect the clothes from getting wet in case of rain. The dryer moves at a steady pace of 5inches per minute, the design is compact and can handle around 9kg of clothing. Equipped with ultrasonic sensors, it can avoid collision as well as park itself inside a designated area in time of need. LDR sensors allowed the dryer to find optimal sunlight which sped up the drying process. The rain sensor was able to detect the presence of rain and command the dryer to roll down the shutter and locate back to its original position.

Along with the hardware, from the software end, the user will be able to control the system using their smartphone. This allows them to remotely monitor their clothing during the day from anywhere. The additional built in sensors will allow the user to make better decisions while using this system.

Although the system fulfilled the necessary objectives, there were a few limitations. One of them was the inability for the rack to distinguish the house. For this reason, parameters were set where the rack would stay within a black taped, enclosed area using IR sensors. For the rack to retract back to its position in the house, it would require a wall or object that would be detected by the ultrasonic sensors.

5.2 Areas of Future Research

There are still developments being made in this field. The hardware itself can have a better design that allows more clothing to fit into the closet. Limitations on locating residence can be solved with the help of a camera and deep learning algorithms. Also, since the LDR sensors are used to detect sunlight, solar panels can be installed onto the system which can further save energy consumption.

REFERENCES

[1] A. Kumar and R. Singh, "AUTOMATIC COLLISION DETECTION FOR AN AUTONOMOUS ROBOT USING PROXIMITY SENSING TECHNOLOGY ON AN AVR HARDWARE PLATFORM," in eastjournals.net, 2014. [Online]. Available: http://esatjournals.net/ijret/2014v03/i06/IJRET20140306039.pdf. Accessed: Jan. 7, 2017.

[2] P. A.C, K. Arun, R. Chandrakant, N. Suresh and N. Lalaso, "Review Paper on Design and Fabrication of Cloths Drying Machine", *IJESC*, vol. 7, no. 4, pp. 10440-10441, 2017.

[3] N. Pennycooke, "A Low-Cost Collision Detection System for Compact Vehicles," in praveens.mit.edu, 2011. [Online]. Available: http://praveens.mit.edu/~praveens/wp/wpcontent/uploads/2011/06/MAS836_Final_Presentation.pdf. Accessed: Jan. 10, 2017.

[4] Sajjad, R. E. Bravo, anil D. kumar, B. Raja, A. A. Abod, and patil rohini, "Rain Alarm Project," in Electronicshub, Electronics Hub, 2015. [Online]. Available: http://www.electronicshub.org/rain-alarm-project/. Accessed: Feb. 1, 2017.

[5] S. Shrivastava, "Dual Axis Solar Tracker," in Slideshare.net, 2013. [Online]. Available: http://www.slideshare.net/sweetswetansh/solar-tracker-report-swetansh. Accessed: Feb. 5, 2017.

[6] T. Yi, J. C. Dye, M. E. Shircliff, and F. Ashrafzadeh, "A New Physics-Based Drying Model of Thin Clothes in Air-Vented Clothes Dryers," *IEEE/ASME Trans. Mechatronics*, vol. 21, no. 2, pp. 872–878, 2016.

[7] J. Borenstein and Y. Koren, "MOTION CONTROL ANALYSIS OF A MOBILE ROBOT," in personal.umich.edu, 1986. [Online]. Available: http://www.personal.umich.edu/~johannb/Papers/paper02.pdf. Accessed: Feb. 5, 2017.

[8] "Reflective Optical Sensor with Transistor Output," in Robotshop, 2005. [Online]. Available: http://www.robotshop.com/media/files/PDF/vishay-TCRT5000L-infrared-reflector-specs.pdf. Accessed: Feb. 5, 2017.

[9] A. Lovelace, "Measuring light,". [Online]. Available: https://learn.adafruit.com/photocells/measuring-light. Accessed: Feb. 5, 2017.

[10] "Robot forum," 2016. [Online]. Available: http://www.societyofrobots.com/robotforum/index.php?topic=15065.0. Accessed: Feb. 5, 2017.

[11] "What is a motor driver, stepper motor drivers, dc, stepper motor drivers - Future Electronics", *Futureelectronics.com*, 2017. [Online]. Available:http://www.futureelectronics.com/en/drivers/motor-driver.aspx

[12] "IR Sensor | What is an IR Sensor?", *Education.rec.ri.cmu.edu*, 2017. [Online]. Available: http://education.rec.ri.cmu.edu/content/electronics/boe/ir_sensor/1.html. [Accessed: 07- Sep- 2017]."Arduino - ArduinoBoardMega", *Arduino.cc*, 2017. [Online]. Available: https://www.arduino.cc/en/Main/arduinoBoardMega. [Accessed: 07- Sep- 2017].

[13] "Ultrasonic Sensor | What is an Ultrasonic Sensor?", *Education.rec.ri.cmu.edu*, 2017. [Online]. Available: http://education.rec.ri.cmu.edu/content/electronics/boe/ultrasonic_sensor/1.html. [Accessed: 11- Sep- 2017].

[14] "Infrared sensors - Sensor Technology - Metropolia Confluence", *Wiki.metropolia.fi*, 2017. [Online]. Available: https://wiki.metropolia.fi/display/sensor/Infrared+sensors. [Accessed: 11- Sep- 2017].

[15] K. N. Vinay and S. M. Kusuma, "Home Automation Using Internet of Things," vol. Volume: 02, no. 03 | June-2015, pp. 1965–1970, 2015.

[16] T. Yi, J. C. Dye, M. E. Shircliff, and F. Ashrafzadeh, "A New Physics-Based Drying Model of Thin Clothes in Air-Vented Clothes Dryers," *IEEE/ASME Trans. Mechatronics*, vol. 21, no. 2, pp. 872–878, 2016.

[17] "IR Sensors | Types of IR Sensors & Working", Engineersgarage.com, 2017. [Online]. Available: https://www.engineersgarage.com/articles/infrared-sensors. [Accessed: 10- Sep- 2017].

[18] "Collision Detection", Jeffreythompson.org, 2017. [Online]. Available: http://www.jeffreythompson.org/collision-detection/. [Accessed: 13- Sep- 2017].

[19] "Photo resistor - Light Dependent Resistor (LDR) » Resistor Guide", Resistorguide.com, 2017. [Online]. Available: http://www.resistorguide.com/photoresistor/. [Accessed: 20- Sep- 2017].

[20] O. Terakura, A. Kurahashi, S. Wakabayashi, M. Tokunaga and M. Minakata, "Development of Rain Sensor for Automatic Wiper System", 2017. .

[21] M. Kelemen, I. Virgala, T. Kelemenová, Ľ. Miková, P. Frankovský, T. Lipták and M. Lörinc, "Distance Measurement via Using of Ultrasonic Sensor", Pubs.sciepub.com, 2017. [Online]. Available: http://pubs.sciepub.com/automation/3/3/6/. [Accessed: 07- Sep- 2017].