## Abstract

The "Autonomous Firefighting System" project uses cutting-edge robotics to pioneer a revolutionary approach to fire safety. The system, which consists of an Arduino Uno, a Flame sensor, and specialized motors, can detect and put out fires on its own and react quickly in a variety of settings. This initiative, which draws inspiration from worldwide fire crises and makes use of automation, not only introduces an innovative technology but also addresses the urgent need for improved firefighting capabilities in areas such as Nepal. It provides hope for a reduction in fire-related fatalities and the protection of lives and property.

"Autonomous Firefighting System" is an innovative response to alarming statistics from the United States and India, where fire-related incidents pose significant threats. In order to increase fire safety and protect human life, this diverse investigation promotes the use of robotic firefighting technology.

Table of Contents

## Table of Figures:



## Table of Tables:

# 1. Introduction:

The term "Internet of Things" (IoT) refers to a network of connected objects like appliances and devices that share information. These smart devices can talk to each other and work on their own, and you find them in homes and businesses. IoT is used for various things, like checking the environment, controlling traffic, and running machines in different areas like manufacturing, transportation, healthcare, and farming (IBM, 2023).

This Internet of Things project, called the "Autonomous Firefighting System," uses Arduino technology to improve fire detection and extinguishing. This project satisfies the need for quick and automated responses to fires in various settings and represents a major advancement in the use of technology to improve firefighting capabilities.

## 1.1. Current Scenario:

Wildfires are a major global concern that have affected many different regions. Certain regions, including portions of Southern Europe, Australia, and the United States, Nepal, India have experienced frequent and severe wildfires as a result of human activity, extended droughts, and climate change. Massive areas of forest have been destroyed as a result of these events, which have also harmed ecosystems and put human settlements in danger.

Our country Nepal suffers from a serious yearly fire crisis that puts lives and ecosystems in jeopardy, especially in the spring. Government data indicates that incidents related to forests and fires have claimed an average of 77 lives annually over the last ten years. A startling 18,772 fire incidents took place between 2014 and mid-March 2023, leaving NPR 22.23 billion in losses, 2,548 injuries, and 769 fatalities. Citing ineffective policy alignment with the growing wildfire scenarios, the National Disaster Risk Reduction Management Authority (NDRRMA) emphasizes the urgent need for sustainable forest fire management.

Nepal saw 2,363 fire incidents in 2022 alone; by March 15, 2023, that number had risen to 2,595. Government plans have encountered difficulties in spite of the growing number of incidents, and the fire crisis still poses a serious threat. Addressing Nepal's escalating fire crisis requires a call for improved public awareness and cutting-edge firefighting technology (Khatri, 2023).

### 1.2. Problem Statement and Project as a solution:

The study from June 2022 sheds light on major contributors to forest fires in Nepal: intentional burning (58%), negligence (22%), and accidents (20%). The prevalent issue revolves around people carelessly discarding lit cigarette butts, leading to fatal fire accidents in various locations, including factories and forests (Khatri, 2023).

During dry seasons, introducing small firefighting robot cars in high-risk areas could be a creative solution. These self-driving, robotic cars could quickly detect fires and shoot water to keep the ground moist and reduce the likelihood of fires. This system is a major improvement in places like Nepal where fire hazards are common because of things like summers in dry forests and people's carelessness, like leaving cigarette butts lying around. The main objective is to save lives while minimizing damage to property and the environment. The pressing need to address Nepal's recurrent fire hazards is what motivates this initiative. The idea of the "mini firefighter" has the power to change lives, particularly in difficult situations. Because of its versatility, it is positioned as an invention with wide-ranging effects. The "mini firefighter" is envisioned as an essential tool for firefighters, able to swiftly put out fires, access hazardous areas, and lower the risk to human counterparts.

## 1.3. Aim and Objectives:

### 1.3.1. Aim:

The main purpose of our project is to develop and run an intelligent system which is capable of detecting fires and also extinguish it.

### 1.3.2. Objective:

The main objective is developing a robotic gadget that is outfitted with state-of-the-art technologies are given below:

- To develop a reliable system that detects fires caused near surroundings on its.
- To detect the fire quickly and accurately by attaching sensors to the ends of the robotic system
- To target and put out fires by itself by creating a firefighting apparatus that is efficient.
- It uses an additional sensor (non-contactless temperature sensor) which help the fire-fighting robot to measure the accurate distance from fire more efficiently which can help to lessen the harms caused by fire in an instant.
- To improve the safety of the public and to lessen the harms that is caused by the fire every year.

# 2. Background:

## 2.1. System Overview:

The proposed IoT system is a fire extinguishing system that automatically overflows the pipe with water after detecting a fire. Many instruments and gadgets are used in this project, which made it easier to finish. The project is designed in a way that reduces the possibility of starting a large fire and simply puts out a smaller fire.

In this project, eight devices in all were used, all of which helped to make the system successful. Three flame sensors are part of the system for precise flame detection. Precise movement is provided to the system by four high-torque Bo Motors that are powered by an Arduino Uno R3 and an L298 driver. To connect and arrange other components, a micro breadboard serves as a central hub.

Temperature is sensed using the MLX 90614 infrared thermometer. Controlled movement of the pipe is made possible by the servo sg90, which allows for firefighting actions. An independent water supply is provided by a 5V water pump. The system needs a battery to function. Ultimately, jumpers were used to link the Arduino to the breadboard, relay module, flame sensor, and L298 driver.

### 2.2. Designing Diagrams:

This report section contains visually displayed diagrams related to the project. These diagrams, which offered visual representations of important parts, system architectures, and data flows, were essential in helping to complete the project.

#### 2.2.1. Hardware Architecture:

The physical architecture, which depicts the hardware elements and their connections, is seen through the lens of the hardware architecture (Steiner, 2012). The proposed hardware architecture for the project is mentioned below.

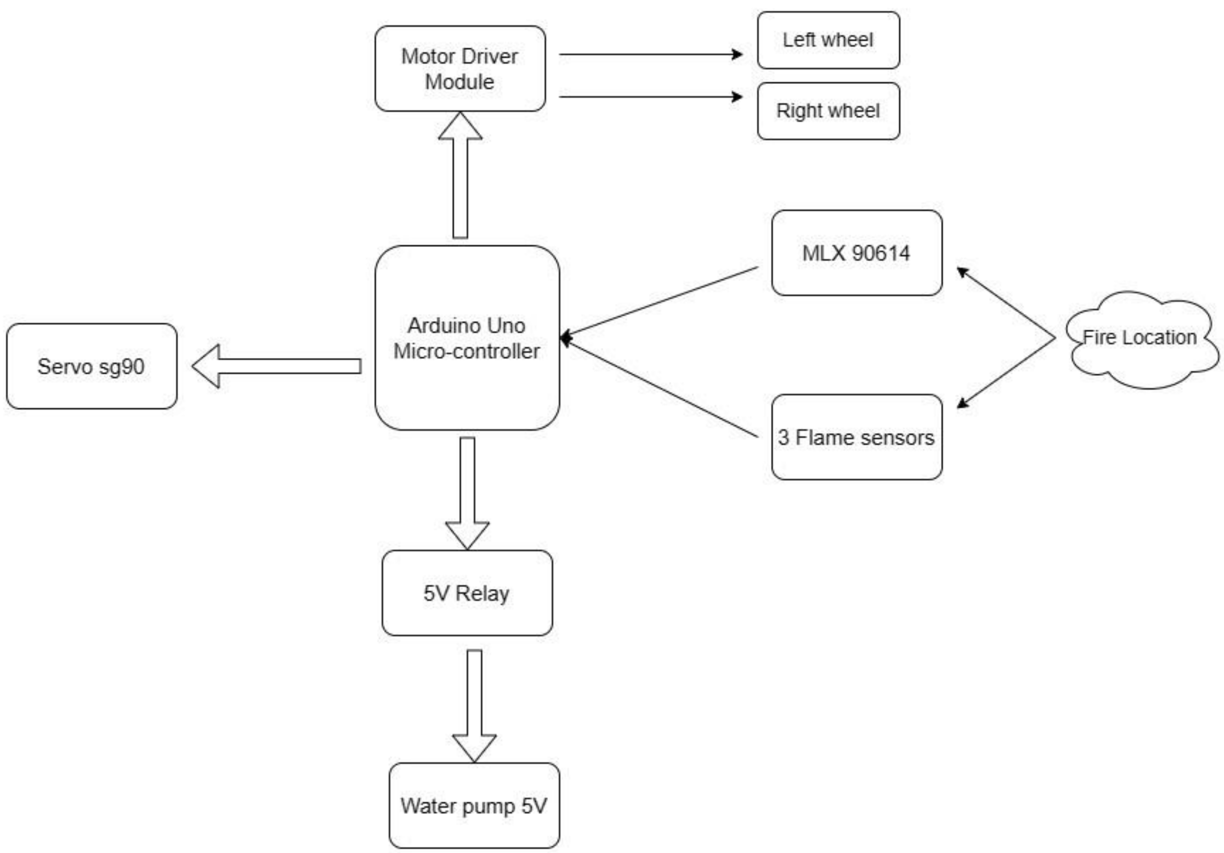


*Figure 1: Hardware Architecture of system*

### 2.2.2. System Architecture:

The conceptual layout and organization of a complex system are referred to as system architecture.

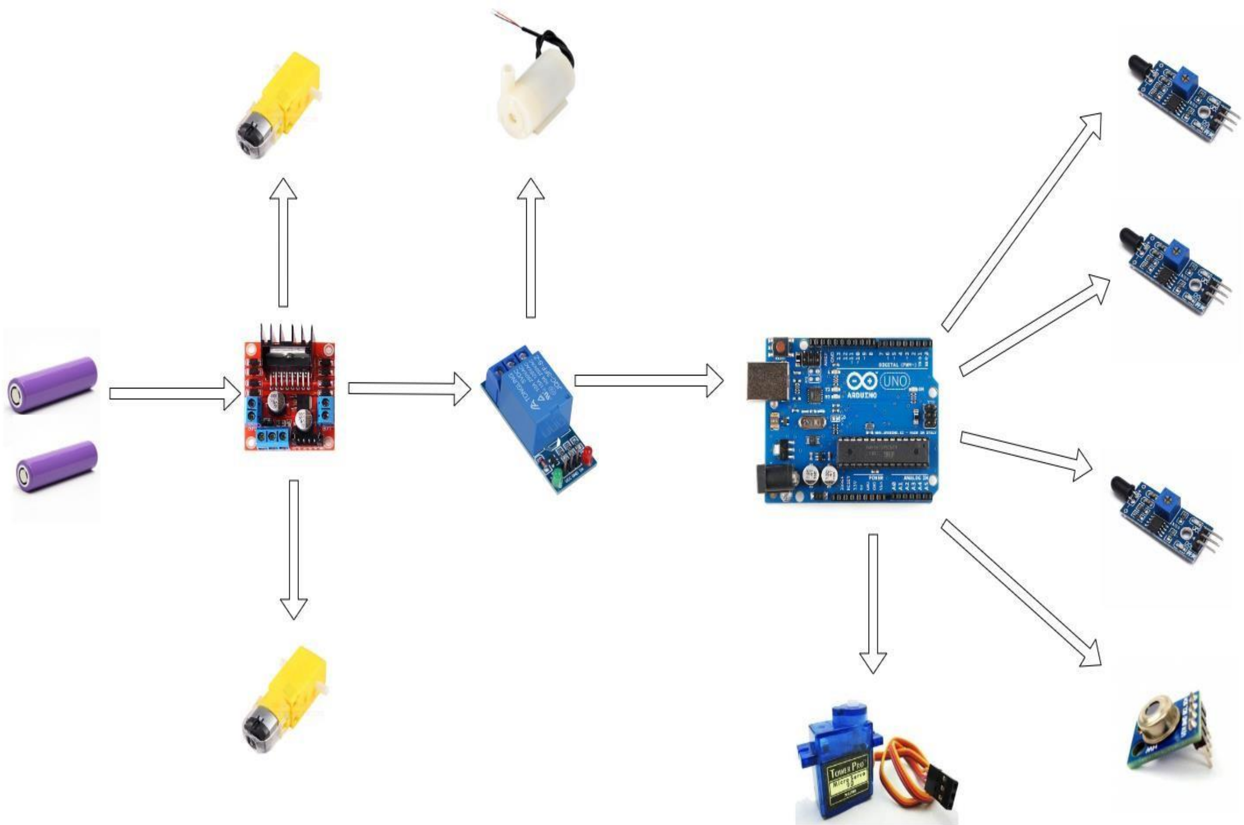

Figure 2: System Architecture of system

### 2.2.3. Circuit Diagram:

An electrical circuit is graphically represented by a circuit diagram. Other names for it include wiring diagram, electrical schematic, elementary diagram, and electronic schematic (testbook, 2023). The proposed circuit diagram for the project is mentioned below.

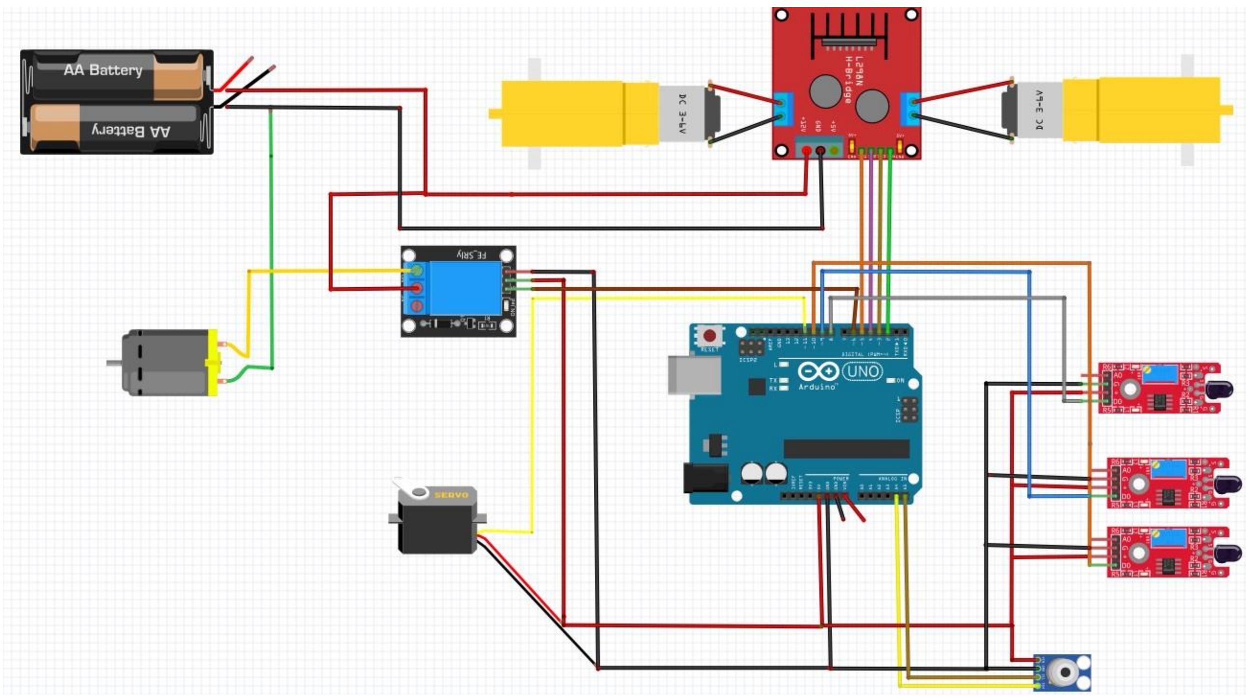


*Figure 3: Circuit Diagram of System*

### 2.2.4. Schematic diagram:

A schematic diagram is an image that uses abstract, frequently standardized symbols and lines to depict the parts of a procedure, apparatus, or other object (Lim, 2019).

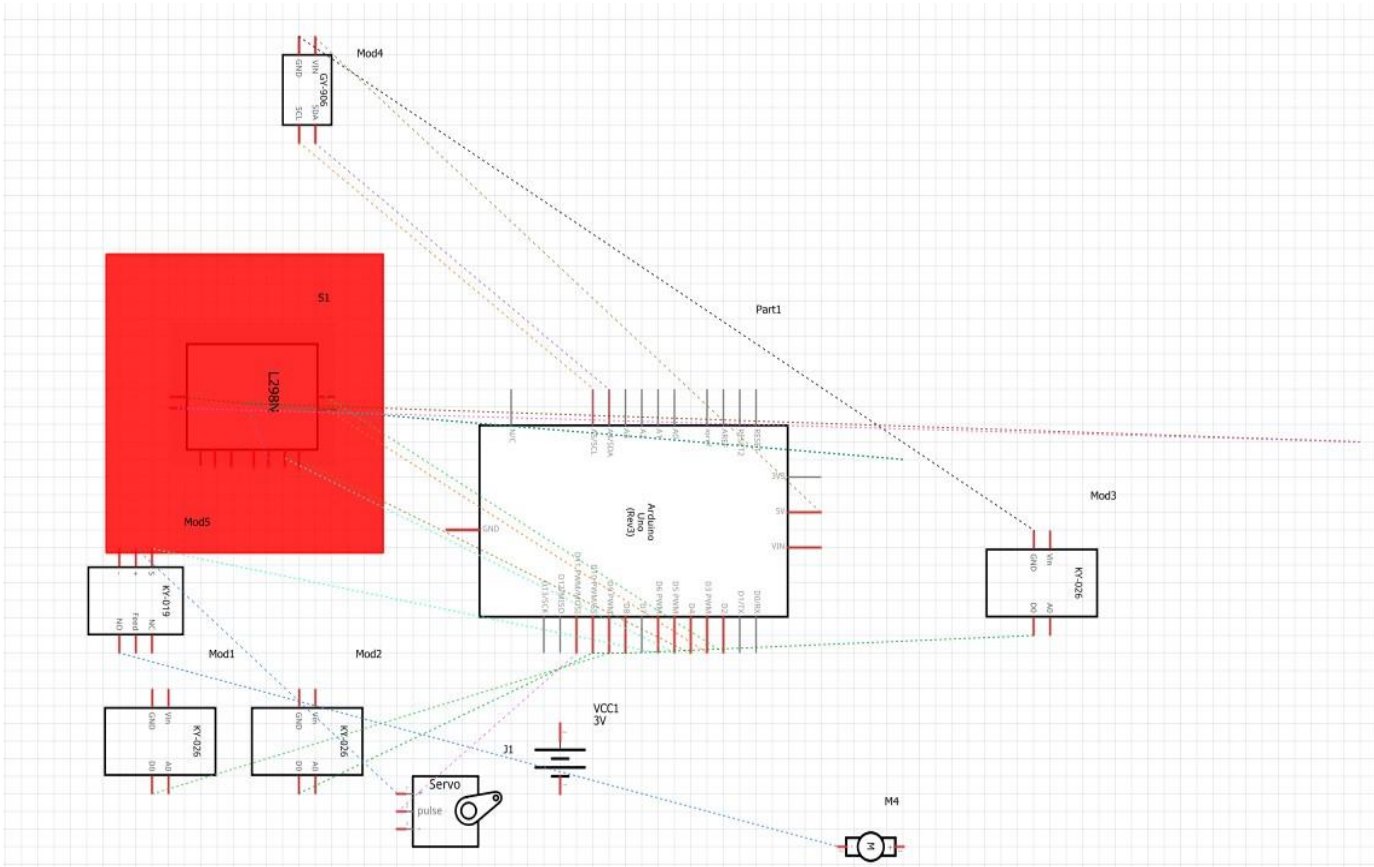


*Figure 4: Schematic diagram of system*

### 2.2.5. Flowchart:

A flowchart is merely a series of steps represented graphically. It is frequently used to demonstrate the workflow, processes, or algorithms in a step-by-step fashion (GeeksForGeeks, 2023).

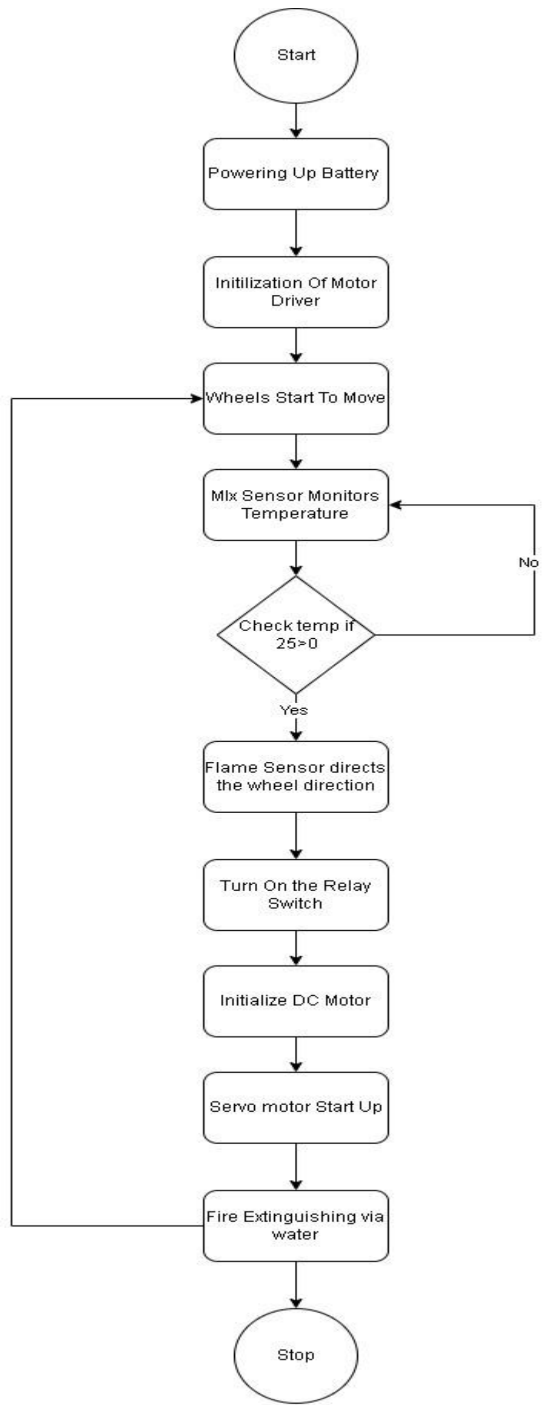


*Figure 5: Flowchart of system*

## 2.3. Requirement Analysis

### 2.3.1. Hardware components

- **Arduino Uno:** The Arduino Uno is a microcontroller board made by Arduino.cc that is based on the Atmega328 microcontroller. In order to provide professionals and students with an accessible and flexible means of learning embedded programming, David Cuartielles and Massimo Banzi initiated the first Arduino project in 2003 at the Interaction Design Institute in Ivrea (Nasir, 2018).


*Figure 6: Arduino Uno*

- **Flame Sensor:** The flame-sensor is one kind of detector whose main purpose is to identify and respond to flames or fires. The way it fits could influence how the flame detector responds (ELPROCUS, 2023).

*Figure 7: Flame sensor*

**L298 Motor Driver Module:** The high power L298N Motor Driver Module can drive DC motors and stepper motors. This module consists of an L298 motor driver IC and a 78M05 5V regulator. The L298N Module can control up to four DC motors or two DC motors with direction and speed control (COMPONENTS101, 2021).

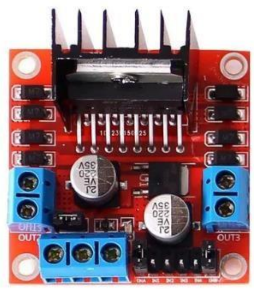


*Figure 8:L298 Motor Driver Module*

- **5V Relay Module:** A 5V relay module is an electrical component that makes it possible to use low voltage signals to control high voltage devices. They are widely used in robotics, automotive, and home automation applications (ELECTRONICSHACKS, 2023).


*Figure 9: 5V Relay Module*

**Servo sg90:** The servo SG90 is a tiny servo whose incredibly small dimensions allow it to fit into projects where there is limited space. Because of its low cost, ease of use, and extremely low energy consumption, it can also be applied to embedded, Internet of Things, and other low-power applications (Aus Electronics Direct, 2021).


*Figure 10: Servo sg90*

- **Micro Breadboard:** A breadboard is a plastic board that is rectangular and has many tiny holes in it. An electronic circuit with a battery, switch, resistor, and LED (light emitting diode) is an example of a prototype, which is constructed and tested in an early stage (SCIENCEBUDDIES, 2023)

*Figure 11: Micro Breadboard*

- **Infrared temperature sensor GY-906 MLX90614:** The MLX90614 model is an infrared thermometer for non-contact temperature readings. Both the IR sensitive thermopile detector chip and the signal conditioner ASIC are integrated into the same model TO-39 sensor packing (admin, 2019).

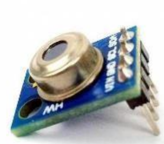

*Figure 12: Infrared Temperature Sensor*

**DC Water pump 5V submersible:** A low-voltage electric pump is called a DC water pump. They are quiet and have low energy consumption. They are used in many different places, including automobiles, homes, and water wells (Sawkare, 2023).

*Figure 13: DC Water pump 5v submersible*

### 2.3.2. Software components:

- **Arduino IDE 1.8.19:** The Arduino IDE is an open-source program that was created by Arduino.cc and is primarily used to write, compile, and upload code to practically all Arduino modules. Since it is an official Arduino program, even a layperson with no prior technical experience can begin learning how to compile code with ease (Watson, 2018)

- **Tinkercad:** Tinker cad is a 3D modelling program available to everyone. It is completely free to access and available online (MAKERINDUSTRY, 2022).

- **Draw.io:** Draw.io is a free online tool that works on multiple platforms and is also useful for desktop collaboration on Windows, Mac OS, and Linux (ClayTechnology World, 2021).

- **Microsoft Word:** It is the tool which is used for writing the proposal, documentation of the given projects.

- **Fritzing:** Fritzing is a free design tool that can be used to make schematics, PCBs, and circuit designs on breadboards.

# 3. Development:

## 3.1. Planning:

The team gathered for a meeting to discuss project ideas. After careful evaluation, we considered budget and practicality. The idea of a robot came up during this brainstorming session, fueled by our shared interest in exploring robotics. As we looked into the challenges faced by Nepal, the prominent issue of forest fires in dry summers caught our attention. Seeing the need for a solution, the concept of creating a robot took form.

Due to time constraints and our team's lack of IoT experience, the robot's initial scope was limited. Our first plan called for a stationary system for watering and detecting fires. But a big problem was that this system wasn't able to cover every area of homes, workplaces, factories, or even forests. As a result, we made the decision to give the system wheels, giving it a more robotic feature to improve mobility.

All of the team members agreed, so we moved forward and waited for the required parts to arrive. The project moved into the research phase once work assignments were set. During design, a simple scheme was implemented that ran the system on strong doubleA batteries. The Arduino would run the code uploaded to it and be connected to the DC motor, servo motor, and flame detection sensors. The L298N driver motor connected to the batteries would be used to spin the wheels. Our project's design phase began with this.

### 3.2. Resource planning:

The resource department provided the majority of the items we needed, but we had trouble finding DC motors, a particular infrared temperature sensor (MLX90614), a micro breadboard, double-A batteries, and a battery holder. In an attempt to find all the required parts, we went to Himalayan Solution in Baneshwor, Kathmandu, to address this. We were forced to order the MLX sensor through Daraz since, unfortunately, they were out of stock. Our resource gathering was finished once the product arrived, which gave us the green light to start the development process.

### 3.3. System Development:

The development process began with the team gathering all the needed parts and setting up the Arduino IDE. We connected our Arduino to the IDE for coding, learning the basics and resolving initial errors through online research.

In the second phase, we focused on the flame and infrared temperature sensor, connecting them to a breadboard and the Arduino which was still powered by the laptop at this stage.

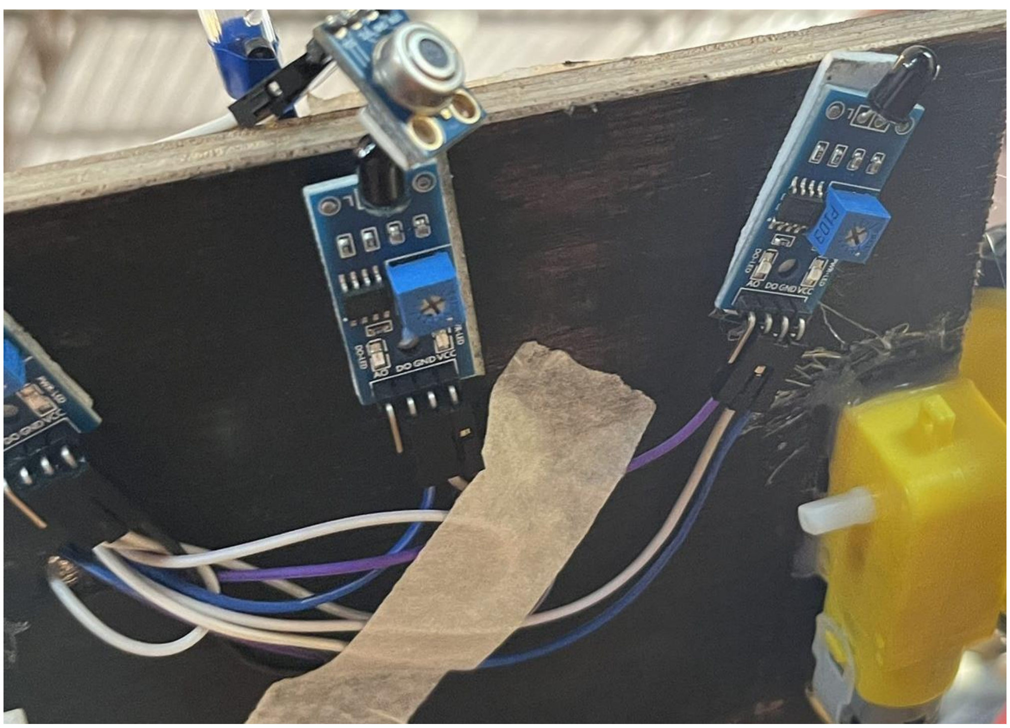

*Figure 14: Flame sensor connections*

Moving to the third phase, we attached the BO motors to the board, pairing them up for synchronization. The coding was adjusted to handle four motors connected in pairs. Wires were linked to the L298N driver.

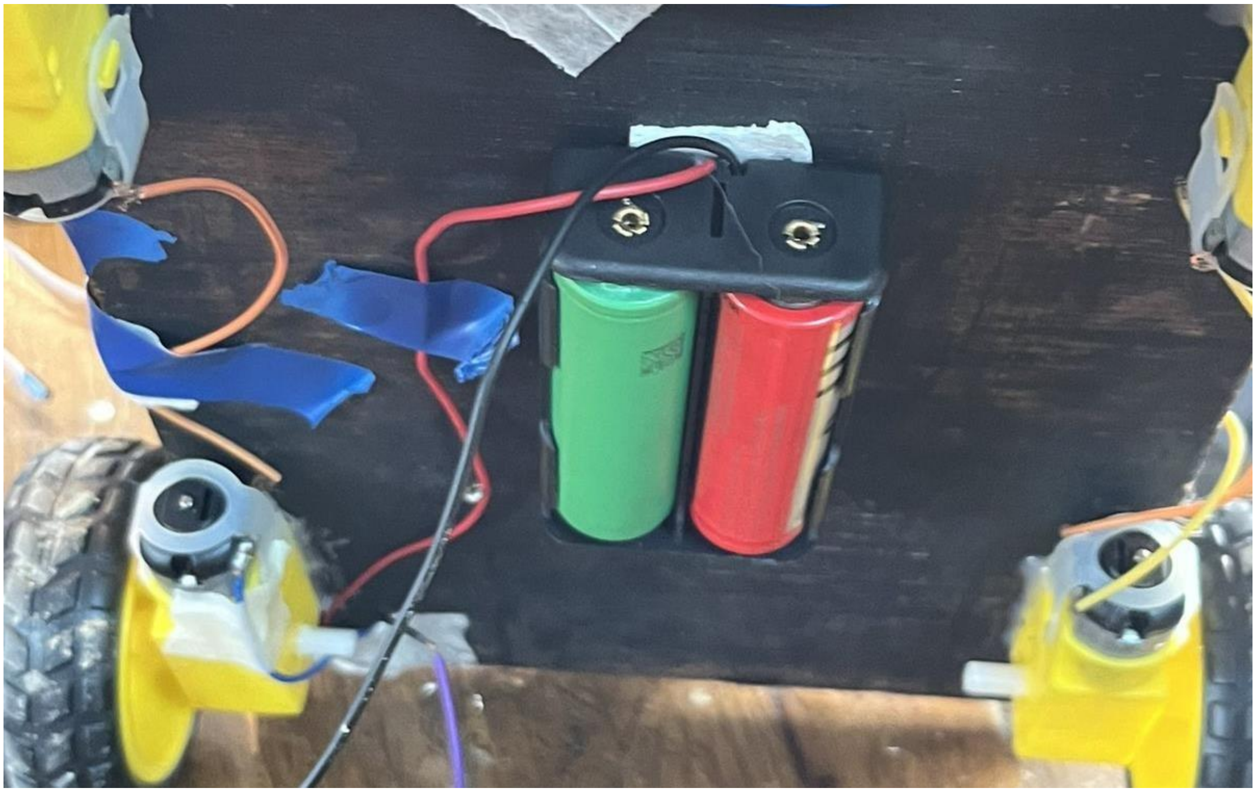

*Figure 15: Bo motor and battery connections*

For the fourth phase, we added batteries at the back of the board. The battery holder was glued securely, and jumpers were connected to power both the Arduino and motors through the L298N driver. Some wire cutting was needed due to length constraints, but we successfully powered up the system.

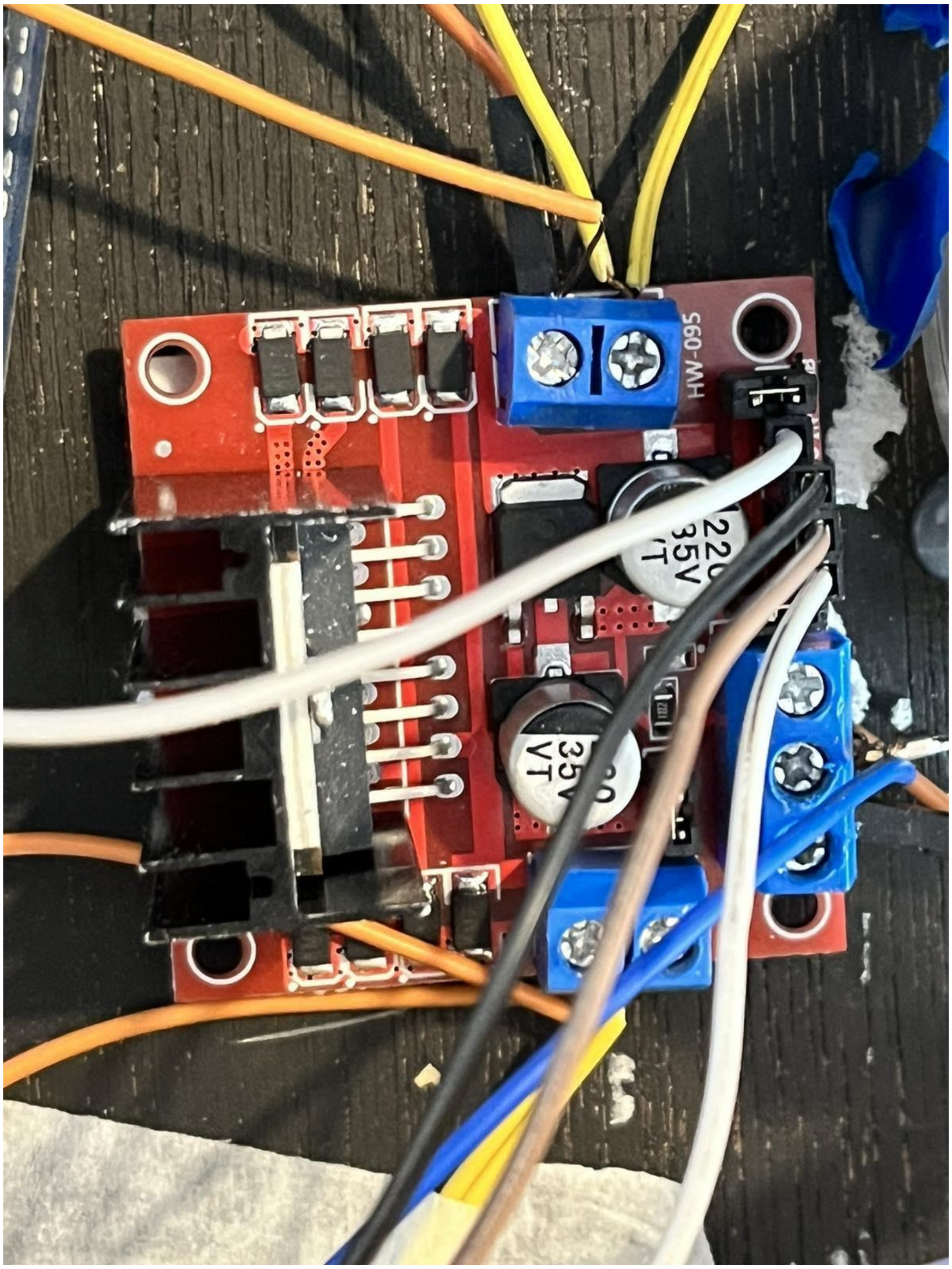


*Figure 16: Motor driver connections*

In the fifth phase, we added the relay, servo, and DC motor, along with a plastic bottle for water storage. The DC motor was connected to the relay, and the whole setup was linked to both the breadboard and Arduino, with the Arduino supplying power.

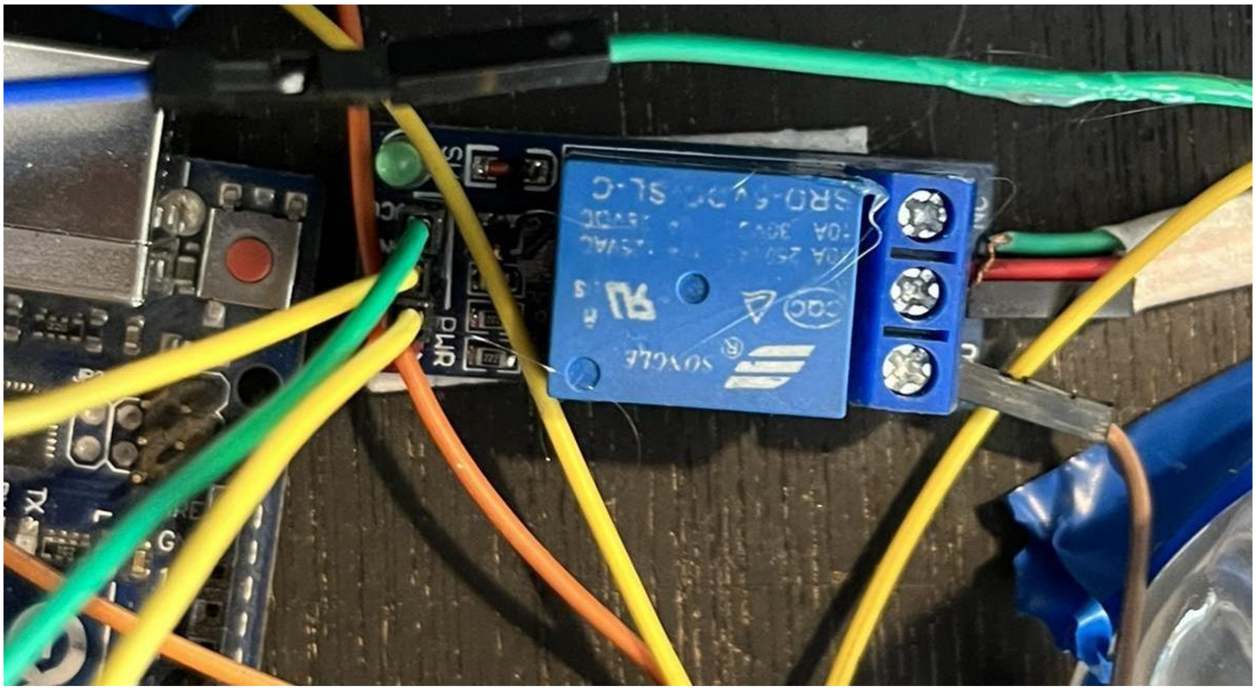

*Figure 17:Relay module connections*

Finally, we placed the battery, and the sensor's light, relay, and Arduino all lit up, indicating successful power-up.

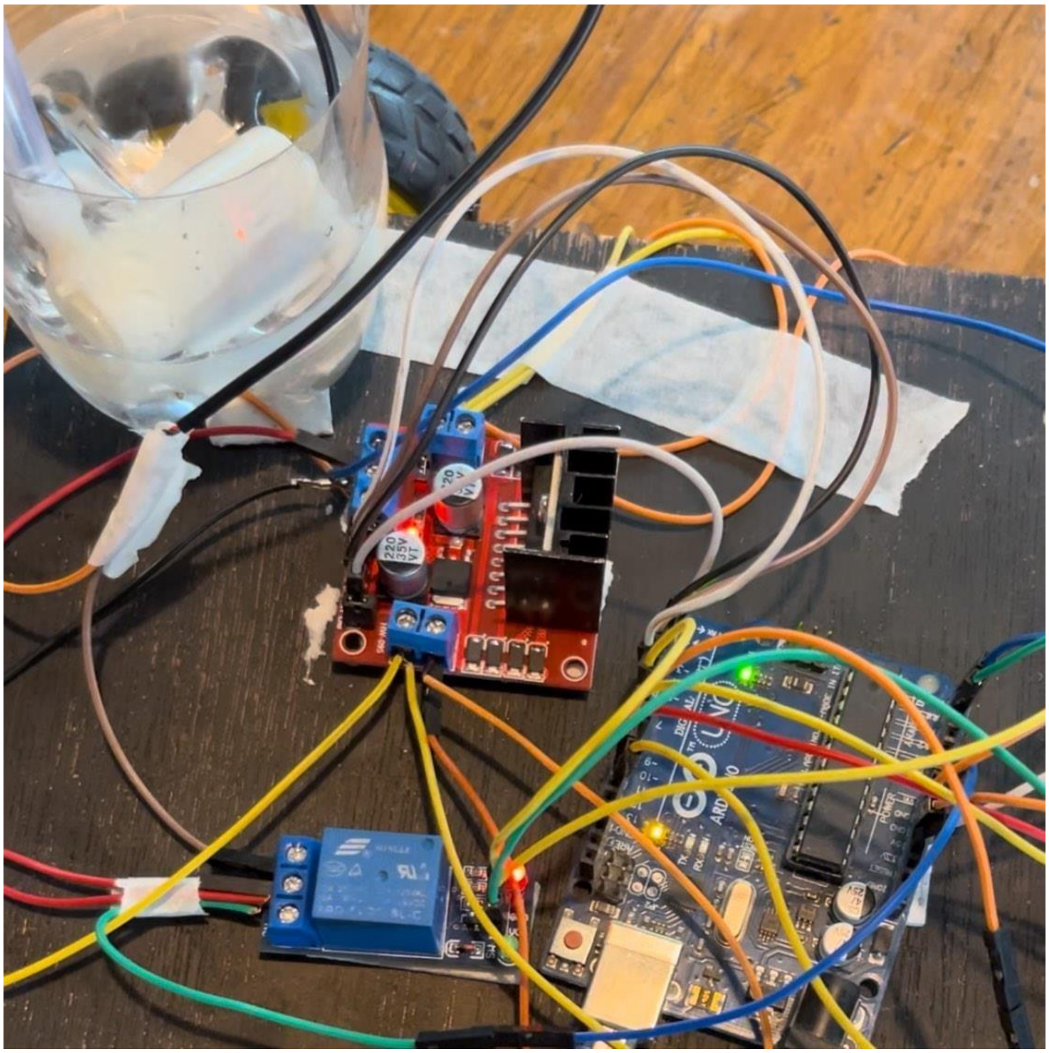

*Figure 18: System being lit up*

# 4. Results and Findings:

## 4.1. Results:

At the conclusion of the project, an IoT based autonomous firefighting system was developed that was capable of putting out a fire by draining the water from the pipe.

After completing the project, we conducted a number of tests to ensure its success. The tests have been listed below. This system detects a fire in the region surrounding it using the MLX infrared thermometer sensor, then it goes to the fire in order to put out it. Water is pumped from a water pump through a pipe connected to the Servo Motor, which causes a sweeping movement at an angle that is set. When the fire is extinguished, the water flow stops.

*Figure 19: Final System*

### 4.2. Findings:

In this section, different test cases are included to show the successful running of the project with 100% successful result. The test cases are mentioned below:

**4.2.1. Test 1:** Test if the MLX infrared sensor detects the temperature or not.

| Test | 1 |
|---|---|
| Objective: | To test MLX infrared thermometer sensor detects the temperature or not. |
| Action: | • Connect MLX sensor to the breadboard (Vin-5volts),(Gnd-Gnd) for power supply<br>• Connect to (Analog 4 – SDA, Analog 5 – SCL<br>• Verify Connections |
| Expected Outcome: | MLX infrared thermometer sensor detects the temperature and gives continuous temperature readings in degree Celsius. |
| Actual Outcome: | MLX infrared thermometer sensor detects the temperature, object temperature" ", Ambient temperature"". |
| Result: | The test is successful. |

*Table 1: Testing table of MLX sensor working properly*

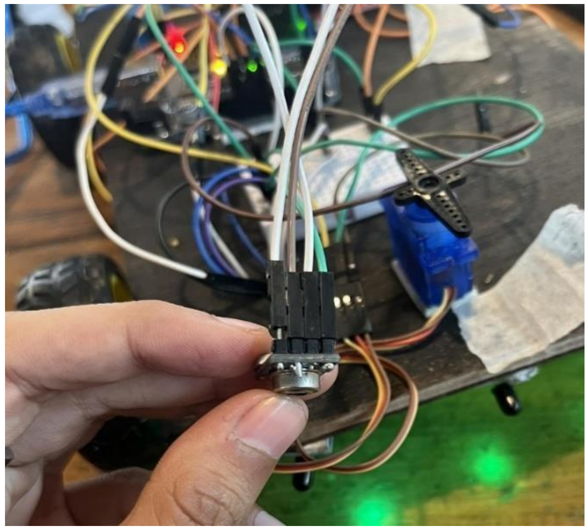

*Figure 20: MLX infrared sensor working*

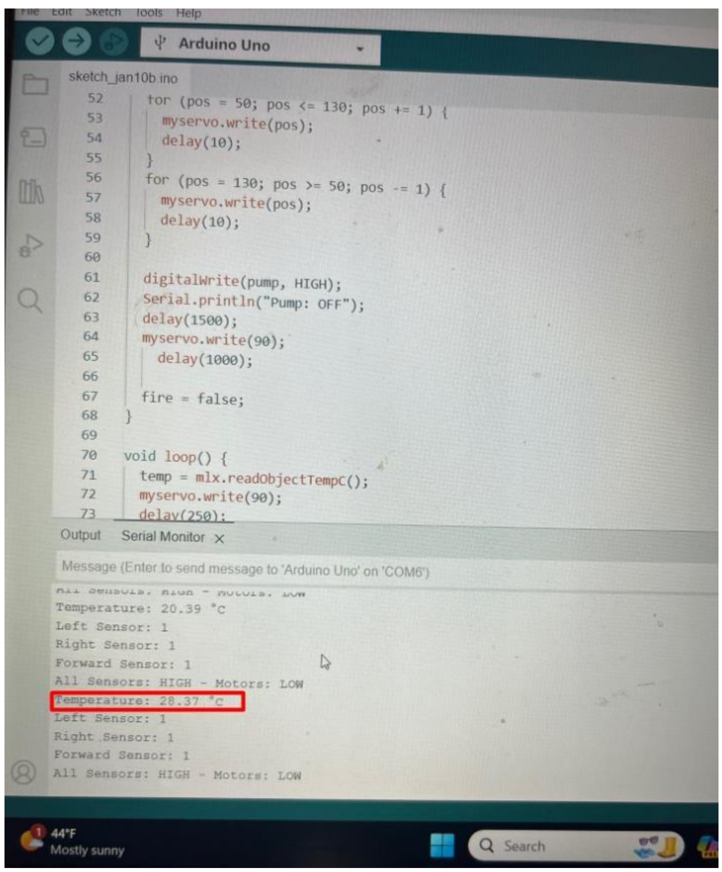


*Figure 21: Picture of MLX sensor recording the temperature*

### **4.2.2. Test 2** Test if the flame sensor works or not

| Test | 2 |
|---|---|
| Objective: | To test Flame Sensor. |
| Action: | • The code initializes the flame sensor pins( 1 ,2 3) as input pins<br>• Connect each Vin of flame sensor to 5V Arduino output<br>• Verify Connections |
| Expected Outcome: | Each outputs/data given from the sensor indicating the presence or absence of the flame is sent to the Arduino and later to the relay. |
| Actual Outcome: | Flame sensor detects or fails to detect a flame, displays the status and sends data to Arduino. |
| Result: | The test is successful. |

*Table 2: Testing table of flame sensor working*

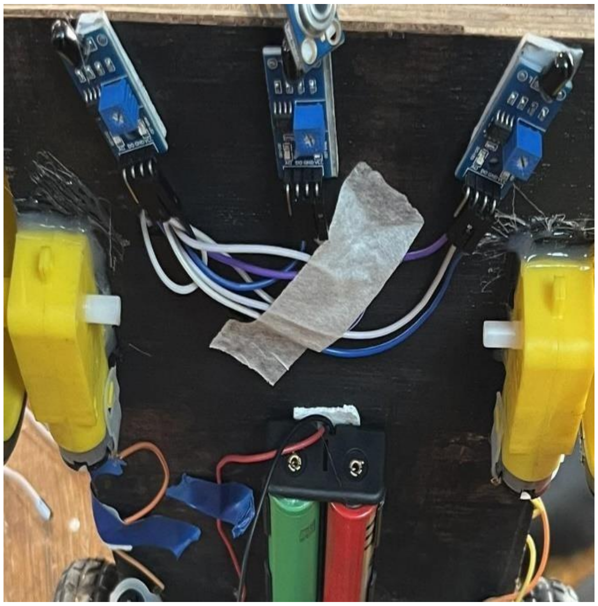

*Figure 22: Testing of flame sensors*

**4.2.3. Test 3** Test if the water pump is functioning correctly or not.

| Test | 3 |
|---|---|
| Objective: | To test the Water Pump is functioning correctly and as timed. |
| Action: | • Initialize the Pump Pin ( connected to the pump ) as an output pin<br>• Connect through Relay Unit which acts as a switch<br>• Verify Connections |
| Expected Outcome: | It should alternate the pump's operation between ON and OFF states, each lasting for the time set of 2.1 sec. |
| Actual Outcome: | Pump timing and functioning are accurate and timed at 2.1 sec as set per the code. |
| Result: | The test is successful. |

*Table 3: Testing table of water pump functioning correctly*

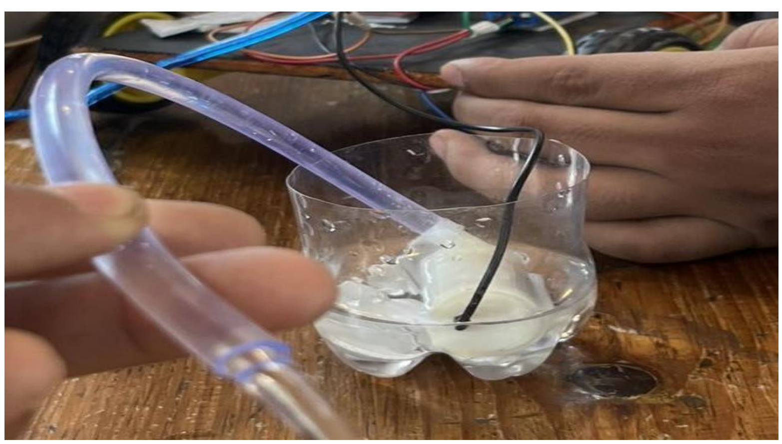

*Figure 23: Testing of DC motor pumping water*

**4.2.4. Test 4** Test if the motor running operations (forward, backward, left turn and right turn) connected through motor driver or not.

| Test | 4 |
|---|---|
| Objective: | To test the motor running operations (forward, backward, left turn and right turn) connected through motor driver. |
| Action: | • Set up the motors<br>• Connect to the motor driver input pins<br>• Verify Connections |
| Expected Outcome: | After execution, motor operations should run in specific directions for a predefined duration, followed by a pause between operations. |
| Actual Outcome: | The motors should execute the predefined movements and stop in a sequential manner |
| Result: | The test is successful. |

*Table 4: Testing table of motor running*

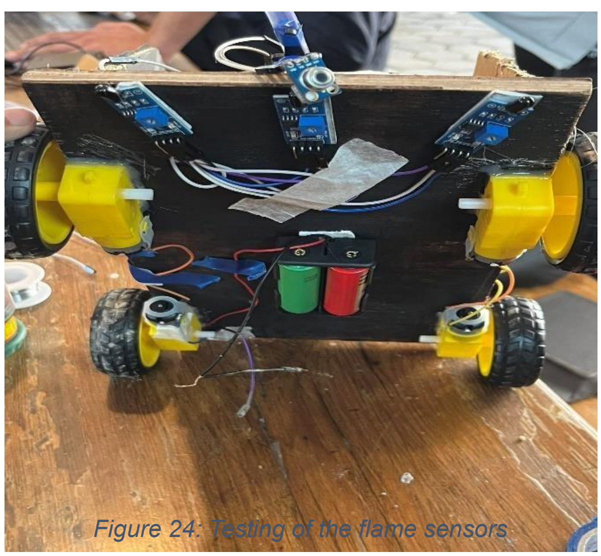

*Figure 24: Testing of the flame sensors*

**4.2.5. Test 5:** Test to check the Servo Motor movement within a specific angle range

| Test | 5 |
|---|---|
| Objective: | To test the Servo Motor movement within a specific angle range. |
| Action: | • Setup the Servo Motor<br>• Connect servo motor object to the specified pin in Arduino<br>• Verify connections |
| Expected Outcome: | The servo motor shaft should move left and right within a specific angle range, creating a sweeping motion. |
| Actual Outcome: | The Servo Motor executes the sweeping motion repeatedly between the set angles. |
| Result: | The test is successful. |

*Table 5: Test table to check servo motor movement*

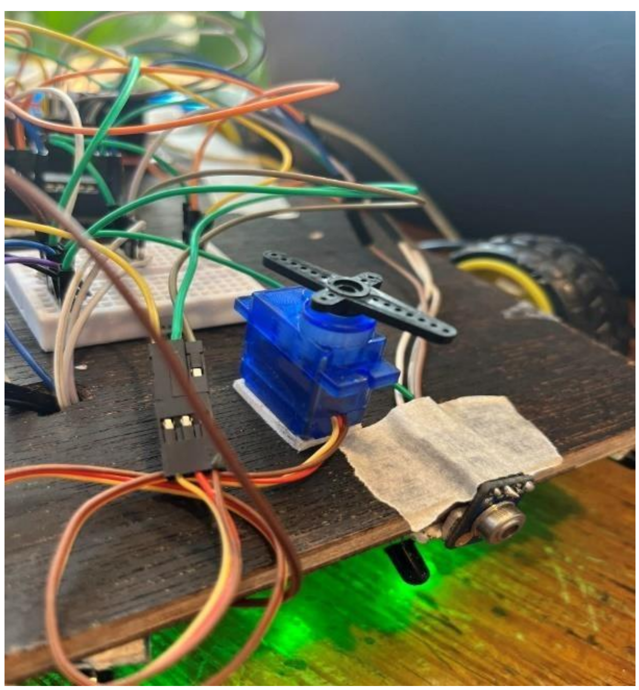

*Figure 25: Testing of Servo Motor movement*

#### **4.2.6. Test 6:** Test whether code runs or not

| Test | 6 |
|---|---|
| Objective: | To test whether the code works or not. |
| Action: | • Upload the code<br>• Run the Code<br>• Check for errors and fix them |
| Expected Outcome: | The code functions properly with the existing errors fixed. |
| Actual Outcome: | The code is functioning properly with data’s sent to function hardware components. |
| Result: | The test is successful. |

*Table 6: Testing table to check whether the code is running*

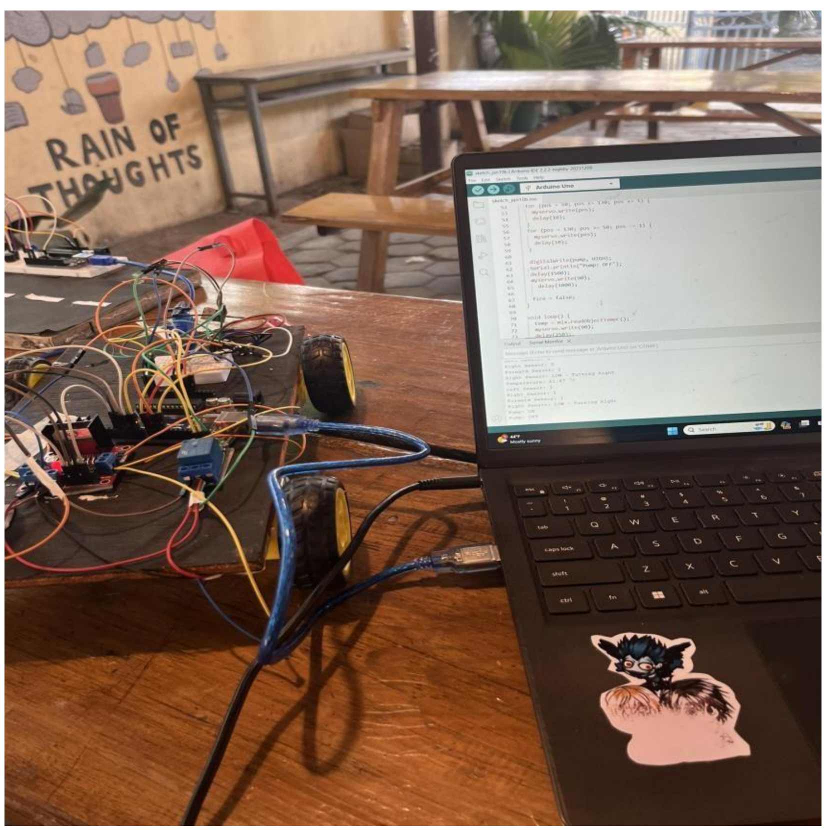

*Figure 26: Testing the code*

### 4.2.7. Test 7: Testing to check if the overall system is working or not

| Test | 7 |
|---|---|
| Objective: | To test the overall system. |
| Action: | Connect all the parts to the Arduino. |
| Expected Outcome: | The system detects fire on its own and puts out the fire as programmed. |
| Actual Outcome: | The system functioned properly and was able to put out the fire. |
| Test: | The test is successful. |

*Table 7: Testing table of overall system working*

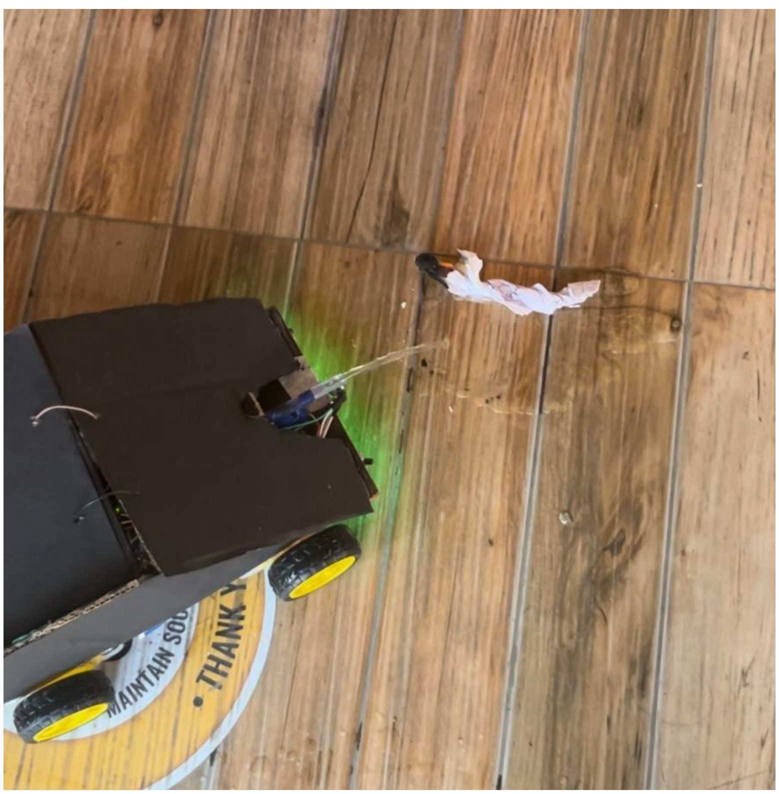


*Figure 27: Picture of overall system working*

## 5. Future Works:

The fire-fighting bot is a fully functional and operative bot. But there are some of the things that can be improved to make things easier and accurate. In the future, Next-generation emergency response robots, with an emphasis on improved sustainability, usability, and overall efficiency, are set to revolutionize emergency response.

This project is just a mini version of fire-fighting bot system which tells about how a fire fighting bot looks alike. So upgrading this project further, a giant size of bot can be developed for fire-fighting in any of the conditions and the upgraded version can have advanced firefighting capabilities With New-technology, emergency response will be revolutionized by firefighting robots. With the use of artificial intelligence algorithms and next generation sensors, these upgraded robots will be able to quickly evaluate fire conditions and plan the best extinguishing techniques. These automatic bots will traverse dangerous locations and detect fire origins and structure integrity by combining environmental sensors, smoke detection, and thermal imaging in the future which also include using specific targeted application of foam or water next-generation extinguishing agent. In order to minimize fire mishaps these bots will coordinate operations and provide real-time updates while interacting with emergency services and one another in a smooth way.

## 7. Conclusion:

This project is centered on the (IOT) Internet of Things. As there is always a risk of loss of life of the firefighters and for them to be present on every corner of the city is not possible. So, these robots are equipped with sensors and technologies specifically developed for fire detection, allowing them to operate and minimize the risk in potentially hazardous or difficult-to-access regions until further assistance shows up. However, the efficacy may not be always the desired which depends on the environment and the situation of the danger. In addition, these robots are cheaper, function able and more practical in today’s world, with incredible outputs.

Numerous obstacles arose while carrying out this project, involving hardware malfunctions which required to be changed several times, as well as challenges with circuit design concepts and documentation. The project kicked off with an idea raised during team discussions and was made possible with the assistance of our Tutors and Module Leader. They were there to guide me till the last minute. It was a wonderful experience and a learning curve for my team.

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# 9. Appendix

**Code**

```
#include <Wire.h>
#include <Servo.h>
#include <Adafruit_MLX90614.h>

Adafruit_MLX90614 mlx = Adafruit_MLX90614();
Servo myservo;

int pos = 0; boolean
fire = false; double
temp;

#define Left 10        // left sensor
#define Right 8        // right sensor
#define Forward 9      // front sensor

#define LM1 2          // left motor
#define LM2 3          // left motor
#define RM1 5          // right motor
#define RM2 4          // right motor
#define pump 6

void setup() {
Serial.begin(9600);
pinMode(Left, INPUT);
pinMode(Right, INPUT);
```

```
pinMode(Forward, INPUT);
pinMode(LM1, OUTPUT);
pinMode(LM2, OUTPUT);
pinMode(RM1, OUTPUT);
pinMode(RM2, OUTPUT);
pinMode(pump, OUTPUT);
digitalWrite(pump, HIGH);

  mlx.begin();
myservo.attach(11);
myservo.write(90);   delay(500);
}

void            put_off_fire()           {
delay(1000);

  digitalWrite(LM1, LOW);
digitalWrite(LM2, LOW);
digitalWrite(RM1, LOW);
digitalWrite(RM2, LOW);

  digitalWrite(pump, LOW);
Serial.println("Pump: ON");
delay(500);

  for (pos = 50; pos <= 130; pos += 1) {
myservo.write(pos);     delay(10);
  }
```

```
  for (pos = 130; pos >= 50; pos -= 1) {
myservo.write(pos);     delay(10);
  }

  digitalWrite(pump, HIGH);
Serial.println("Pump: OFF");
delay(1500);
myservo.write(90);
delay(1000);

  fire = false;
}

void loop() {   temp =
mlx.readObjectTempC();
myservo.write(90);   delay(250);

  Serial.print("Temperature: ");
  Serial.print(temp);
  Serial.println(" °C");

  Serial.print("Left Sensor: ");
  Serial.println(digitalRead(Left));

  Serial.print("Right Sensor: "); Serial.println(digitalRead(Right));

  Serial.print("Forward Sensor: ");
  Serial.println(digitalRead(Forward));
```

```
  if (digitalRead(Left) == 1 && digitalRead(Right) == 1 && digitalRead(Forward) == 1) {
digitalWrite(LM1, LOW);     digitalWrite(LM2, LOW);     digitalWrite(RM1, LOW);
digitalWrite(RM2, LOW);
    Serial.println("All Sensors: HIGH - Motors: LOW");

  } else if (digitalRead(Forward) == 0) {
digitalWrite(LM1, HIGH);
digitalWrite(LM2, LOW);
digitalWrite(RM1, HIGH);
digitalWrite(RM2, LOW);
    Serial.println("Forward Sensor: LOW - Moving Forward");

  } else if (digitalRead(Left) == 0) {
digitalWrite(LM1, HIGH);
digitalWrite(LM2, LOW);
digitalWrite(RM1, LOW);
digitalWrite(RM2, HIGH);
    Serial.println("Left Sensor: LOW - Turning Left");
  } else if (digitalRead(Right) == 0) {
digitalWrite(LM1, LOW);
digitalWrite(LM2, HIGH);
digitalWrite(RM1, HIGH);

  digitalWrite(RM2, LOW);
    Serial.println("Right Sensor: LOW - Turning Right");
  }
```

```
  if (temp > 25) {
put_off_fire();
} else {     fire =
false;
delay(1000);
  } // Adjust delay time as needed for monitoring
}
```