An-Najah National University

Faculty of Engineering & Information Technology

Department of Computer Engineering

Hardware Graduation Project

Fire Fighter X

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Contents

1- Disclaimer

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2- Acknowledgment

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3- Abstract

Fires pose a significant risk to human life and property, and firefighting can be a dangerous and challenging task. In recent years, robotics has emerged as a promising solution to this problem, enabling the development of autonomous fire-fighting robots that can navigate through indoor environments and extinguish fires. This project focuses on the design and development of a fire-fighting robot.

The fire-fighting robot developed in this project utilizes a range of sensors and actuators to detect and respond to fires. These include infrared sensors for fire detection and a water-based fire suppression system. The robot is equipped with a wireless communication system that allows it to be remotely controlled by a human operator, as well as the development of control algorithms and software to enable autonomous operation.

4- Introduction

Firefighting is a dangerous and complex task that often puts human lives at risk. In recent years, the use of robots in firefighting has become increasingly popular, as they can help reduce the danger to human firefighters and improve the effectiveness of firefighting operations.

The goal of this graduation project is to design and develop a fire-fighting robot that can assist human firefighters in combating fires.The robot will be equipped with sensors and cameras to detect and navigate through the fire environment, as well as a variety of tools to extinguish fires. The robot can be controlled remotely by human operators or by autonomous operation, allowing it to be operated from a safe distance.

The successful development of a fire-fighting robot has the potential to revolutionize the way in which indoor fires are fought and managed. It can help save humans lives especially families, reduce property damage, and increase the efficiency and effectiveness of firefighting operations.

In this report, we will describe the design and development process of the fire-fighting robot, including the selection of components, the design of the robot's chassis and mechanism, and the programming of the robot's control system.

5- Literature Review

5.1 Introduction

Fires are one of the most significant hazards that threaten human life and property, causing significant damage and loss of life worldwide. Firefighting is a dangerous and challenging task, and often requires firefighters to enter hazardous environments. Robotic systems have the potential to address this challenge by enabling the development of autonomous fire-fighting robots that can navigate through hazardous environments and extinguish fires. This literature review provides an overview of the research that has been conducted in the field of fire-fighting robots, with a particular focus on the design and development of autonomous systems.

5.2 State of art

Fire-fighting robots have been the subject of extensive research in recent years, and a range of systems has been developed for various applications. These systems can be broadly classified into two categories: aerial and ground-based systems.

1- Aerial systems typically consist of unmanned aerial vehicles (UAVs) equipped with sensors and cameras that can be used to detect fires and assess the damage. These systems can also be used to deliver water or fire retardants to the affected area. However, these systems are limited by their flight time and payload capacity, and are less effective in confined spaces.

2- Ground-based systems, on the other hand, are more suitable for indoor environments and can operate in confined spaces. These systems typically consist of wheeled or tracked vehicles equipped with a range of sensors and fire suppression systems. Many ground-based systems use a water-based fire suppression system, which can be effective in extinguishing fires. However, these systems are limited by their mobility and ability to navigate through complex environments.

5.3 Recent Development

Recent research has focused on the development of autonomous fire-fighting robots that can navigate through complex environments and extinguish fires without human intervention. These systems typically use a range of sensors, including thermal and optical sensors, to detect fires and assess the environment. They are also equipped with fire suppression systems, such as water or foam, to extinguish fires.

6- Constrains

1- Environmental constraints: Fire-fighting robots must be able to operate in a variety of environments, including indoor and outdoor settings. These environments may include areas with high temperatures, smoke, and other hazardous conditions

2- Sensor constraints: The robot's sensors are critical for detecting fires and assessing the environment. These sensors may include thermal cameras, optical sensors, and gas detectors. They must be able to operate in a variety of conditions, and provide accurate and timely information to the robot's control system.

3- Power constraints: The robot's power source is another constraint, as it must be able to operate for an extended period without requiring frequent recharging or replacement.

4- Communication constraints: The robot must be able to communicate effectively with its operators, both in terms of transmitting data and receiving commands. The communication system must be reliable and able to operate in a variety of environments, including areas with limited connectivity or interference.

5- Cost constraints: The cost of developing a fire-fighting robot is a significant constraint, as it must be affordable and practical for deployment in real-world scenarios. The cost of components, such as sensors and actuators, as well as the cost of development and manufacturing.

7- Methodology

The purpose of this chapter is to summarize the developments that took place within the Smart Cleaner Robot project and put them in a larger scientific and technological context.

7.1 Equipment and components

7.1.1 ESP32-CAM

We used this Component for real-time video streaming: The ESP32-CAM's built-in camera allows the fire-fighter robot to capture live video footage of the fire scene. This video feed can be streamed wirelessly to a remote control station or a monitoring system, enabling firefighters to assess the situation and make informed decisions.

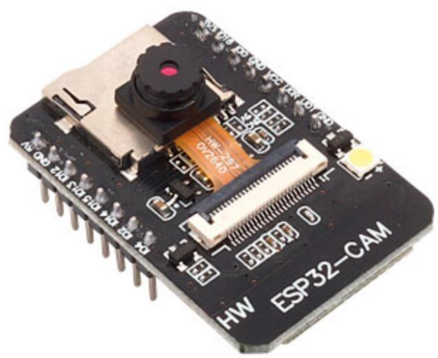

Figure 1: ESP32-CAM

7.1.2 ESP-WROOM

One of the most important components of our project, we used this chip as a 32 bit microcontroller it contains and supports the most functionalities that we need, so we used it to connect the drivers and motors together and give the robot the logic it needed to move. We also connected it to the Ultrasonic Sensor, LCD, IR sensor, Flame sensor, and power supply. It also supports Wi-Fi connectivity so we used it for controlling robot manually in wireless mode.

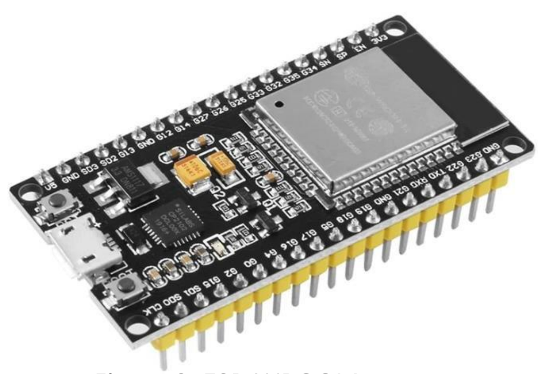

Figure 2: ESP-WROOM

7.1.3 Arduino mega

It has 54 digital input/output pins, 16 analog inputs, 4 UARTs. Some chips like lcdmvoltage and water sensors were not compatible esp32 wroom so we used arduino mega to connect these chips on it

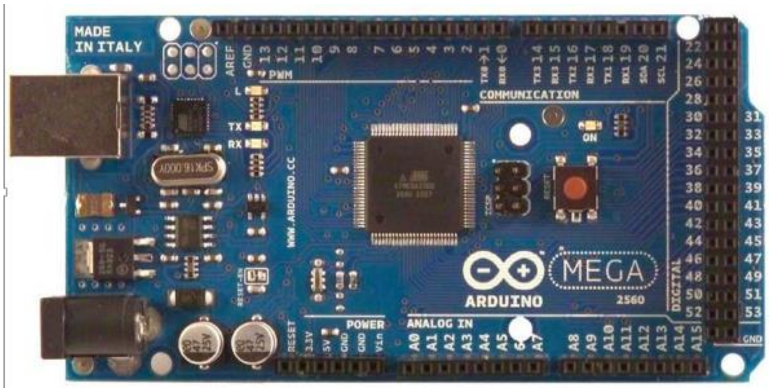

Figure 3: Arduino mega

7.1.4 DC Motor

The driving power of our project when connected with the L298N driver we can control the movement of the robot. Each one of the four motors was connected to a wheel that allows the robot to move smoothly.

Figure 4: DC motor

7.1.5 Rubber Wheel

We used 4 wheels of this type as it bears heavy loads and it was connected to a DC motor to move the robot.

Figure 5: Rubber wheel

7.1.6 IR flame sensor

The IR flame sensor module is a crucial component for serving the purpose of fire detection and localization with real-time feedback. We used three IR sensors; the sensor utilizes infrared radiation to detect the presence of flames. When integrated into a fire-fighter robot, it can swiftly identify the flames' presence and intensity, allowing the robot to navigate towards the fire source

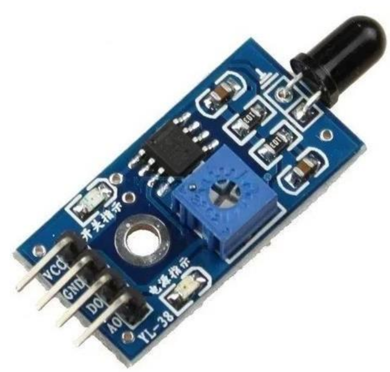

Figure 6: IR flame sensor

7.1.7 Ultrasonic sensor

The ultrasonic sensor plays a valuable role in the robot we used five of it for providing distance measurement and obstacle detection capabilities. It emits high-frequency sound waves and measures the time taken for the waves to bounce back after hitting an object. This information helps the robot determine the distance between itself and obstacles in its path, enabling it to navigate through complex environments and avoid collisions.

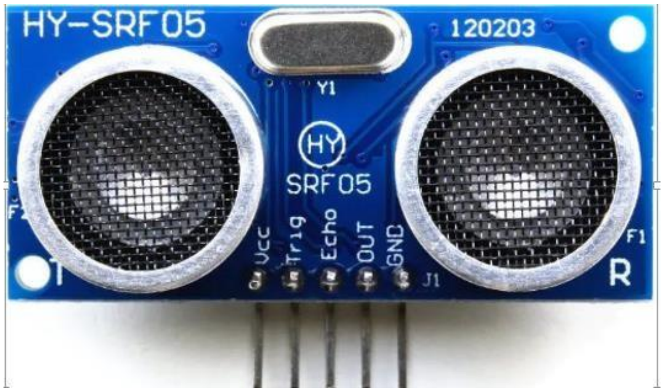

Figure 7: Ultrasonic sensor

7.1.8 Water Pump

The water pump enables the robot to sprinkle water or other fire-retardant substances to extinguish fires. It is supplied by one motor drive and Integrated with the robot's system, so it pumps water into the roller from a reservoir and the roller propels it with sufficient force to effectively combat the flames.

Figure 8: Water Pump

7.1.9 Single Cell Lithium-ion Batteries

Arguably, our main power supply on our project, we have used three of these in order to power our engines, motors and most of the components we mentioned before. We connected three batteries inside a battery parallel case to have 12v then we glued it on the body of the robot.

Figure 9: Li-ion battery

7.1.10 Breadboard

The breadboard provides a structured platform for arranging and organizing the various electronic components we mentioned, reducing the risk of loose connections and making rapid assembly and disassembly of circuits, facilitating the integration of different components into the fire-fighter robot system.

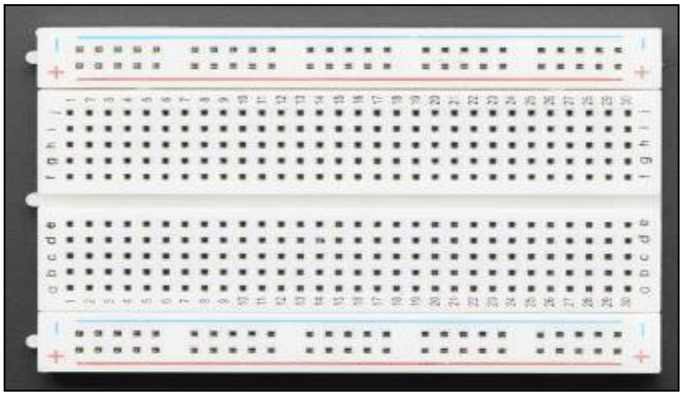

Figure 10: Breadboard

7.1.11 Voltage Sensor

Arguably, our main power supply on our project, we have used three of these in order to power our engines, motors and most of the components we mentioned before. We connected three batteries inside a battery parallel case to have 12v then we glued it on the body of the robot.

Figure 11: Voltage Sensor

7.1.12 LCD 16*2

It was used to display the percentage of battery charge as well as the percentage of water in the tank.

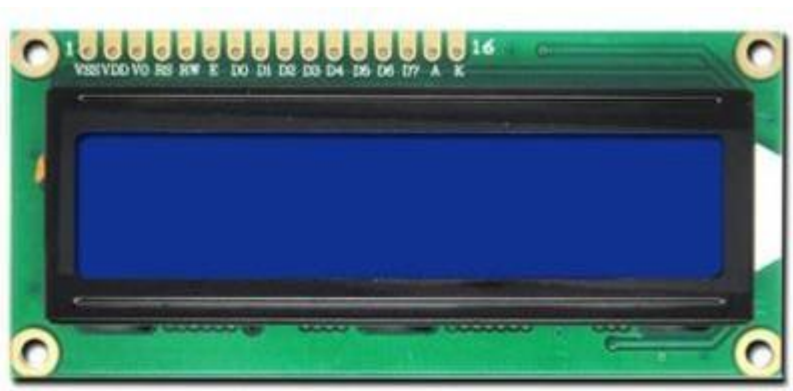

Figure 12: LCD

7.1.13 LM2596 Module

It is Adjustable Step Down Buck Converter that is used to regulate and convert higher input voltages to lower and adjustable output voltages, so it provide a reliable and stable power supply for the mentioned components

Figure 13: LM2596 Module

7.1.14 8 Pole Lever Connecter

It was used as an assembly point, so any piece that needed 12 volts and ground would be plugged into the lever.

Figure 14: 8 pole lever connecter

7.1.15 Water Level Sensor Module

The main use of the Water Level Sensor Module is to provide accurate and real-time information about the water level. It consists of probes or sensors that come into contact with the water or liquid being measured. We used it to measure the percentage of water in the tank.

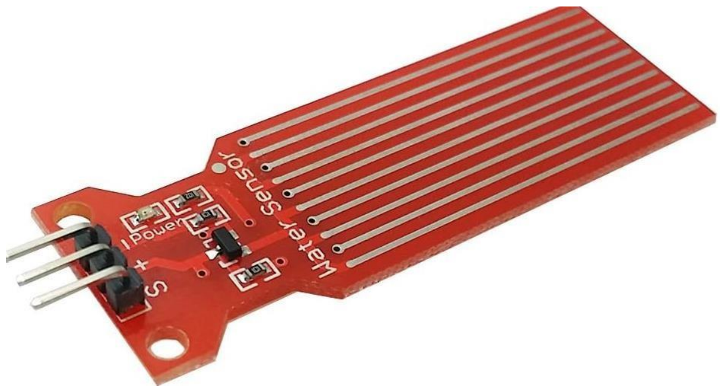

Figure 15: Water level sensor

7.1.16 L298N Driver

The L298N is a dual H-Bridge motor driver which we used to control speed and direction of 4 DC motors atthe same time. We used two of the L298N one to control all four of our DC motors, which will be used to drive the robot around. And the other motor drive was used for the water pump.

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Figure 15: L298N driver

7.2 Implementation

The implementation phase of the fire-fighter robot project involved transforming the conceptual design into a functional robot capable of effectively combating and extinguishing fires. The implementation involved the integration of hardware components such as sensors for fire detection, obstacle avoidance, and navigation, actuators for movement and fire suppression mechanisms, so we will outline the procedure that the robot goes in.

1- The microcontroller which is the key chip where it was used to control and integrate a majority of components:

- ESP CAM that gives live streaming video.
- Five ultrasonic sensors for avoiding obstacles.
- Three IR flame sensors for fire detection.
- Two motor drivers one of them for controlling dc motors and the other was used for water pump.
- Four DC motors connected to the four rubber wheels to ensure the movement of the robot.
- Voltage and water sensors that measures battery life and water level percentage.
- LCD that displays readings.

2- The robot is powered by three batteries each one is 4v to have 12v in total.

3- The robot depends on the motors for ensuring its movement.

4- The robot moves with ultrasonic waves that are used to measure the distances around it, and when the robot approaches barriers and obstacles, it moves away from them and goes in different direction.

5- During the movement of the robot, IR sensors keep sensing if there is a close fire or flames and when it catch any of it the robot change its direction toward the flame, water pump turns on automatically and it pumps water from the tank into the roller that sprinkle the liquid on the flame.

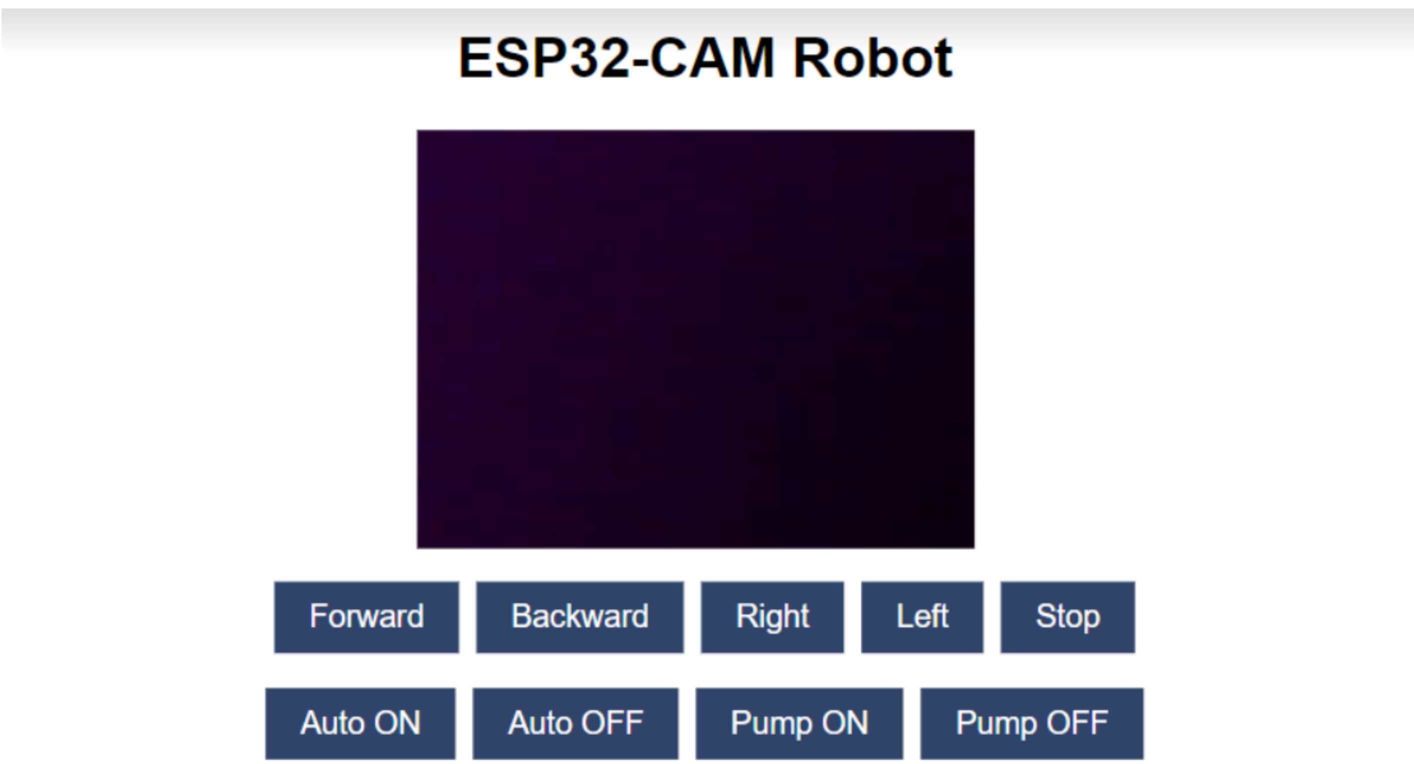
6- The amount of remaining water in the reservoir is measured and shown on the LCD.

7- During the process, the battery charge percentage is measured and displayed on the LCD. When the charge rate reaches 40%, the robot sends an alert that it needs to be charged.

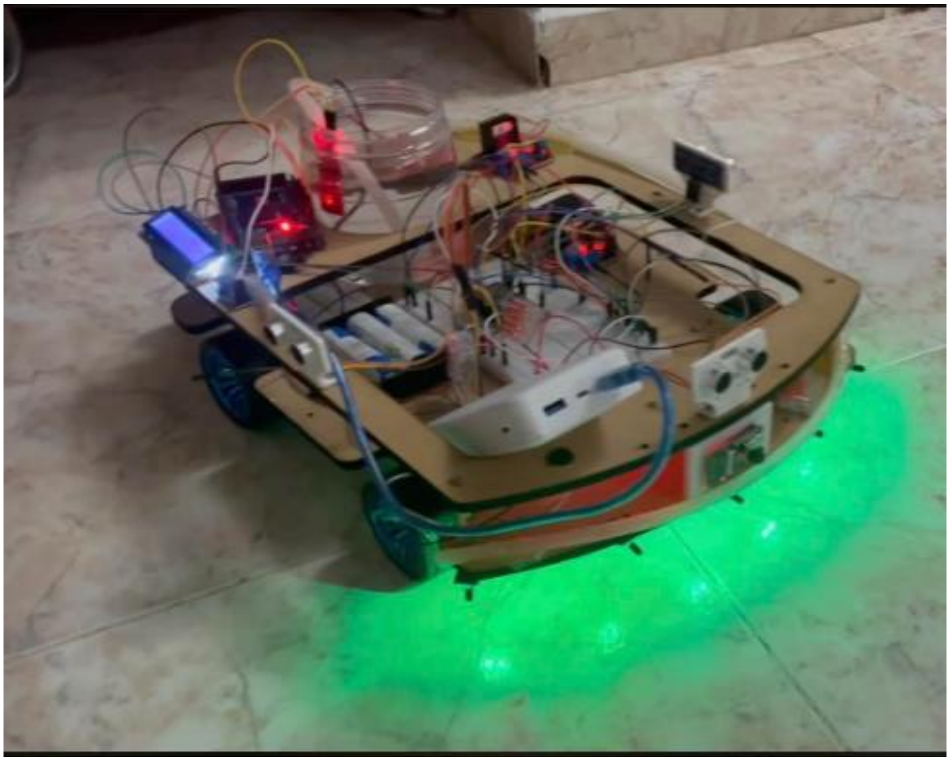
The fire-fighting robot works on two modes where the esp cam broadcasts a live video streaming on html page:

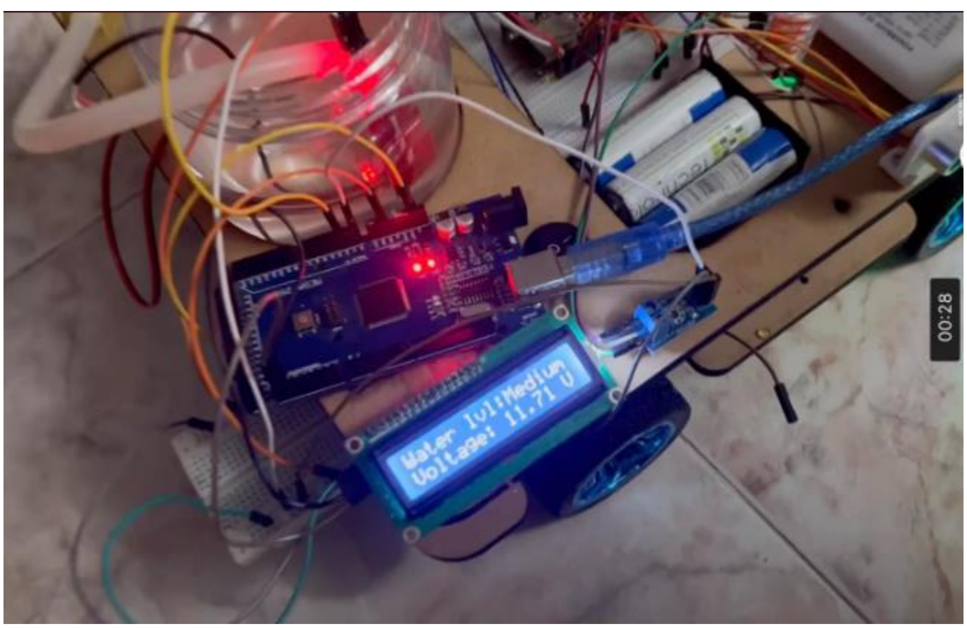
1- **wireless mode:** Using the wireless mode we can use the html page that has the following buttons to control the direction and the movement of the robot manually:
   - **Start**: to start pumping water.
   - **End**: to stop pumping water.
   - **F**: Move the robot Forward.
   - **B**: Move the robot Backward.
   - **R**: Move the robot to Right.
   - **L**: Move the robot to Left.
2- **Autonomous mode:** the robot movies randomly by itself searching for any flames to sprinkle water on it and it use the ultrasonic sensors to avoid obstacles as we mentioned, and by using these buttons we can control this mode to turn it on/off.
   - **Start**: to start pumping water.
   - **End**: to stop pumping water.
   - **Auto on**: to start the movement of the robot autonomously.
   - **Auto off**: to stop the movement of the robot autonomously.

Each time we press any of these buttons a request is sent to the microcontroller that has a software applies the requested functionality.



Robots Pics:





8- Results and Discussions

8.1 Results and features

- The robot was able to navigate autonomously through a simulated fire scenario and detect the fire using a combination of sensors (such as flame sensors and cameras).

- The robot was able to extinguish the fire using liquid water and foam.

- The robot was able to effectively communicate with a human operator and receive commands through a wireless connection.

- The robot was able to avoid obstacles and move efficiently through the environment.

- The robot has lcd that shows the battery charge percentage of the robot.

- The robot has lcd that shows the percentage of water remaining in the tank.

- A web page to control the robot manually using Wireless Module.

- Life video streaming using esp32-cam.

8.2 Analysis

- The results show that the fire-fighting robot is a promising solution for addressing the challenges of fighting fires in hazardous and difficult-to-reach environments especially indoor ones where children mess with flammable materials.
- The accuracy and reliability of its sensors, as well as the effectiveness of its communication with the operator affected the performance of the robot.
- The use of machine learning algorithms for sensor fusion and decision-making could improve the performance of the robot in detecting and extinguishing fires.
- The design of the robot should also be optimized for different types of environments and fire scenarios, and the materials used should be resistant to high temperatures and flames.

9- Conclusions and Future work

9.1 Summary

- The fire-fighting robot developed in this project shows a promising potential for use in indoor environments, where fires can be particularly challenging to fight due to restricted access and poor visibility.
- The robot was able to navigate autonomously, detect fires using a combination of sensors, and extinguish the fires using water and foam.
- The robot's communication with the operator was effective in ensuring successful fire fighting, particularly in indoor environments.
- The development of fire-fighting robots has significant potential to improve fire-fighting safety and efficiency, particularly in hazardous environments.

9.2 Future work

- We can exploit the use of machine learning algorithms for sensor fusion and decision-making to improve the performance of the robot in detecting and extinguishing fires.
- The robot's design could be optimized for different types of indoor environments and fire scenarios, such as high-rise buildings, hospitals, and warehouses.
- The materials used to build the robot could be further improved to withstand the indoor environment, including high temperatures, flames, and smoke, while remaining lightweight and agile.
- The robot's communication with the operator could be further improved through the use of advanced technologies such as augmented reality and voice recognition.
- We can increase the range of flame sensor.
- Further testing and evaluation of the robot in real-world fire scenarios could help validate its effectiveness and identify areas for improvement.

10- References

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