A Research Paper on Fire Fighting Robot Using Arduino

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Abstract- Fire accidents are the most dangerous hazards, and that causing loss of life, major property damage, and environmental harm by fire accidents. In high-risk areas such as industries, chemical plants, oil refineries, gas storage units, and laboratories, fire incidents can lead to serious consequences and make rescue operations difficult. To reduce these risks and improve safety, researchers have developed firefighting robots that can detect and extinguish fire with minimal human involvement. These robots are designed to operate in hazardous environments where direct human access is dangerous, thereby protecting both firefighters and civilians.

This research paper presents an overview of firefighting robots developed using Arduino and related control systems. It examines the working principles, major components, and technologies commonly used in such robots, including flame sensors, motor drivers, DC motors, water pumps, and wireless control modules. The paper also discusses the applications, advantages, limitations, and future scope of firefighting robots in improving fire safety and emergency response. The review highlights how Arduino-based robotic systems provide a low-cost, efficient, and practical solution for fire detection and suppression in risky environments.

***Keywords*: IoT Technology, Autonomous Navigation, Fire Detection, Obstacle Avoidance.**

I. LITERATURE REVIEW

1.Tawfique Rakib et al. (2021) presented a comprehensive design and fabrication of an autonomous firefighting robot that integrates multiple sensors for effective fire detection and suppression. Their model features a robust base platform constructed from kerosene wood, equipped with an LM35 temperature sensor and flame sensors to accurately detect the presence of fire and elevated heat levels within the environment. The robot employs a PID controller to regulate its movement and response dynamics, ensuring stable navigation toward fire sources. Additionally, the system includes a 1-liter water container to extinguish detected fires, demonstrating a practical approach to automated firefighting. The study highlights the potential of combining sensor fusion and control strategies to enhance the robot's ability to detect and respond to fire hazards autonomously, contributing valuable insights to the development of intelligent fire safety solutions.

2. Saravanan P. et al. (2021) developed an Android-controlled integrated semi-autonomous firefighting robot using the ATmega2560 microcontroller, designed to enhance user interaction and system functionality. The robot is structured into three functional units—navigation, fire detection, and control—which work in coordination to achieve semi-autonomous operation. The navigation unit enables basic movement and steering based on commands received from an Android interface, while the fire detection unit integrates sensors to identify fire sources and trigger appropriate responses. Communication between the Android application and the microcontroller allows users to remotely control the robot's operations in real time, enhancing flexibility and responsiveness. This model demonstrates the effective integration of mobile technology with embedded systems to create a user-friendly firefighting robot capable of assisting in hazardous environments.

3. Shakthi Priyanka et al. (2020) presented an Android-controlled fire-fighting robot based on the Arduino UNO R3 microcontroller, emphasizing simple and cost-effective remote operation. In their design, the

robot's movements and firefighting actions are controlled through an Android application that communicates wirelessly with the Arduino platform. The system integrates basic fire detection sensors to identify flames and trigger the extinguishing mechanism, enabling users to navigate and operate the robot in potentially hazardous environments without direct exposure to danger. This study demonstrates the feasibility of combining mobile control technology with a widely accessible microcontroller to create an intuitive and functional fire-fighting robotic system, making it suitable for educational and practical applications in basic fire response scenarios.

4. Nagesh M. S. et al. (2021) proposed a fire extinguishing robot that utilizes DTMF (Dual Tone Multi-Frequency) technology for remote navigation, allowing the robot to be controlled via tone signals transmitted over a mobile network. The system integrates a flame sensor to detect the presence of fire and trigger the extinguishing mechanism, enabling timely response to fire incidents. By relying on DTMF for movement commands, the robot can be maneuvered without the need for complex wireless modules, making the design cost-effective and straightforward. This approach highlights the use of readily available communication methods for robotic control, demonstrating a practical solution for basic fire-fighting tasks in environments where conventional control technologies may be limited.

5. Sushrut Khajuria et al. (2022) presented an Arduino-based fire fighter robot that employs RF (Radio Frequency) remote control for operating both the robot's movement and its water pump mechanism, enabling wireless control without line-of-sight limitations. The design integrates essential fire detection sensors to identify flame presence and activate the pump for fire suppression, while the RF remote provides intuitive directional and functional commands to the robot. This approach emphasizes simplicity and reliability by utilizing affordable and readily available RF technology, making the system practical for basic firefighting applications where cost and ease of control are key considerations. The study contributes to the field by demonstrating how wireless communication can effectively enhance the maneuverability and responsiveness of fire-fighting robots.

6. Chaithanya K. et al. (2025) proposed an IoT-based fire-fighting robot built around the ESP32 microcontroller, capable of operating in both automatic and manual modes to enhance flexibility and responsiveness in fire emergency scenarios. The system integrates the Blynk IoT platform for remote monitoring and control, allowing users to view live data and send operational commands through a smartphone interface. In automatic mode, the robot uses onboard sensors to detect fire conditions and make real-time decisions, while manual mode enables direct user control for navigation and actuation. By leveraging IoT connectivity, this design offers improved accessibility and situational awareness compared to traditional remote-controlled robots, demonstrating a practical application of cloud-enabled robotics for fire safety.

II. INTRODUCTION

Fire accidents are among the most serious hazards, causing significant loss of human life, damage to property, and environmental destruction. Such incidents frequently occur in residential areas, industrial plants, petroleum refineries, chemical factories, gas storage units, and other hazardous environments, where the consequences can be severe. In many cases, conventional firefighting methods expose firefighters and rescue personnel to dangerous conditions such as extreme heat, dense smoke, toxic gases, and explosive materials. Therefore, the development of advanced technologies for fire detection and suppression has become essential to improve safety and enhance the efficiency of emergency response systems.

In this context, firefighting robots have emerged as an effective technological solution for minimizing human involvement in hazardous fire situations. These robots are designed to detect fire, navigate toward the affected area, and activate extinguishing mechanisms with limited human intervention. Among the various embedded platforms, Arduino-based systems have gained considerable attention due to their low cost, simplicity, flexibility, and ease of implementation. This review paper focuses on the study of Arduino-based firefighting robots by examining their design, components, working principles, applications, advantages, limitations, and future scope. It aims to highlight the role of such robotic systems in improving fire safety and supporting modern emergency management practices.

III. METHODOLOGY

3.1 Block Diagram Representation

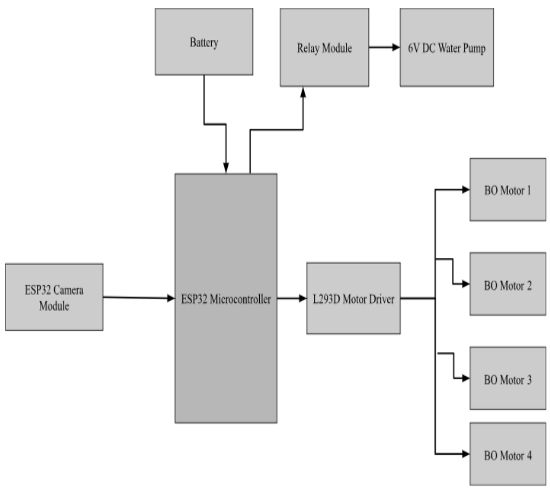

Fig 3.1: Block Diagram of the System

In this block diagram, we have used the NodeMCU ESP32 as a microcontroller. And an ESP32 Camera module as an input device. Four BO Motors, L293D Motor Driver, 6V DC Water Pump, and a Relay is connected as an output device to the microcontroller. A Battery is used for power supply.

3.2 Flowchart

Fig. 3.2 Flow chart of the system

3.3 Circuit Diagram

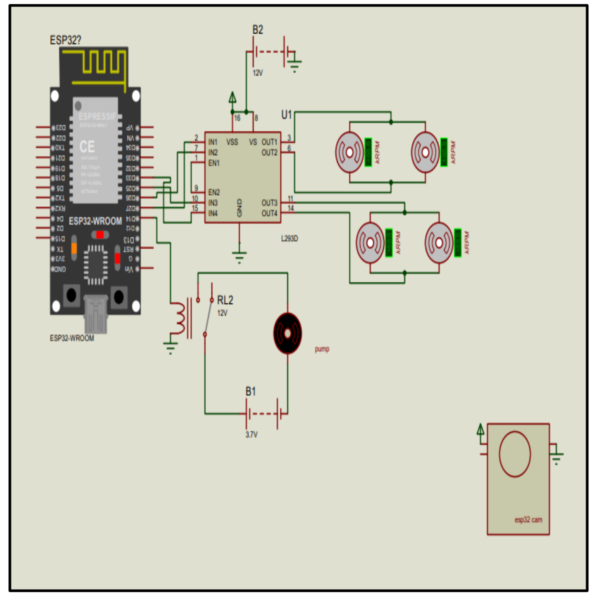

Fig. 3.3: Circuit diagram of the system

3.4 Components

3.4.1 ESP 32: ESP32 is the SoC (System on Chip) microcontroller that has gained massive popularity recently. Whether the popularity of ESP32 grew because of the growth of IoT or whether IoT grew because of the introduction of ESP32 is debatable.

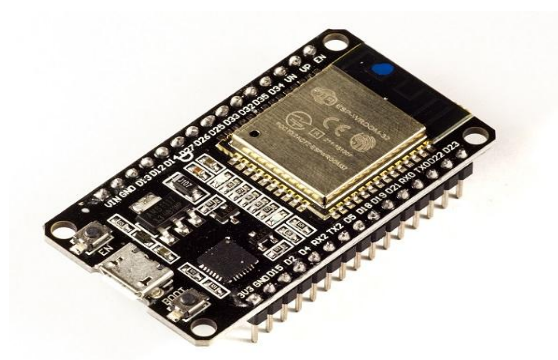

Fig 3.4.1: ESP 32

Before we delve into the actual reasons for the popularity of ESP32, let's take a look at some of its important specifications. The specs listed below belong to the ESP32 WROOM 32 variant.−

1. Integrated Crystal− 40 MHz
2. Module Interfaces− UART, SPI, I2C, PWM, ADC, DAC, GPIO, pulse counter, capacitive touch sensor

3. Integrated SPI flash− 4 MBROM− 448 KB (for booting and core functions)
4. SRAM− 520 KB
5. Integrated Connectivity Protocols− WiFi, Bluetooth, BLE
6. On−chip sensor− Hall sensor
7. Operating temperature range− −40 − 85 degrees Celsius
8. Operating Voltage− 3.3V
9. Operating Current− 80 mA (average)

With the above specifications in front of you, it is very easy to decipher the reasons for ESP32's popularity. Consider the requirements an IoT device would have from its microcontroller (μC). If you've gone through the previous chapter, you'd have realized that the major operational blocks of any IoT device are sensing, processing, storage, and transmitting. Therefore, to begin with, the μC should be able to interface with a variety of sensors. It should support all the common communication protocols required for sensor interface: UART, I2C, and SPI. It should have ADC and pulse-counting capabilities. ESP32 fulfills all of these requirements. On top of that, it also can interface with capacitive touch sensors. Therefore, most common sensors can interface seamlessly with ESP32.

3.4.2 ESP 32 CAM:

Fig 3.4.2: ESP 32 CAM

- The ESP32-CAM is a small size, low power consumption camera module based on ESP32. It comes with an OV2640 camera and provides onboard TF card slot. The ESP32-CAM can be widely used in intelligent IoT applications such as wireless video monitoring, WiFi image upload, QR identification, and so on.
- ESP32-CAM can be widely used in various IoT applications. It is suitable for home smart devices, industrial wireless control, wireless monitoring, QR wireless identification, wireless positioning system signals and other IoT applications. It is an ideal solution for IoT applications.

3.4.3 MINI WATER PUMP

A mini water pump is a 3v, 5v, 6v, 12v, 24v dc water pump motor or 110v, 220v, 240v ac water pump that use centrifugal force to transfer, boost or circulate water for various water application systems or machines.

A small water pump is a 24v, 12v dc motor water pump or 120v, 230v, 240v, 380v ac water pump that plays the role of transfer, lift or pressurise water, fuel, coolant in various water circulation, booster systems. Include small submersible water pump, small solar water pump, etc.

Fig 3.4.3: Mini Water Pump

When the water hits the rotating impeller, energy of the impeller is transferring red to the water, forcing the water out (centrifugal force). The water is displaced outward, and more water can now enter the suction side of the pump to replace the displaced water.

3.4.4 RELAY

A relay is an electrically operated switch. Relays are the switches that aim at closing and opening the circuits electronically as well as electromechanically. The primary purpose of a relay is to protect the electrical system from too high of a voltage or current, allowing the safe operation of any equipment it connects to.

Fig 3.4.4: Relay

3.4.5 BO MOTOR

BO (Battery Operated) lightweight DC geared motor which gives good torque and rpm at lower voltages. This motor can run at approximately 150 RPM when driven by a single Li-Ion cell.

This single shaft plastic geared motor gives good torque and rpm at lower operating voltages, which is the biggest advantage of these motors. Small shaft with matching wheels gives optimized design for your application or robot. Mounting holes on the body & light weight makes it suitable for in-circuit placement. This motor is a perfect choice for light weight robots.

Fig 3.4.5: BO Motor

3.4.6 VOLT LI-ION RECHARGEABLE BATTERY

The 3.7V lithium-ion rechargeable battery is a versatile power source commonly utilised in various electronic devices. With a nominal voltage of 3.7 volts, these batteries offer a stable and reliable energy supply. They operate on lithium-ion chemistry, featuring high energy density and rechargeability, making them ideal for portable applications.

Fig 3.4.6: Volt Li-Ion Rechargeable Battery

Available in capacities ranging from a few hundred milliampere-hours (mAh) to several thousand mAh, these batteries cater to diverse power requirements. Safety features like overcharge and over-discharge protection ensure secure operation. Typically designed for use within a temperature range of -20°C to 60°C, they offer reliable performance across different environments. These batteries are crucial components in devices such as smartphones, tablets, laptops, and digital cameras, providing efficient and long-lasting power solutions for everyday use.

3.4.7 L293D MOTOR DRIVER

L293D Motor Driver Module is a medium power motor driver perfect for driving DC Motors and Stepper Motors. It uses the popular L293 motor driver IC. It can drive 4 DC motors on and off or drive 2 DC motors with directional and speed control. The driver greatly simplifies and increases the ease with which you may control motors, relays, etc from micro-controllers. It can drive motors up to 12V with a total DC current of up to 600mA.

Fig 3.4.7: L293d Motor Driver

IV. WORKING

The robot begins operation by continuously monitoring its surroundings while moving autonomously in the environment. As it navigates, it avoids obstacles in real time by adjusting its direction to ensure smooth and safe movement. Simultaneously, the live visual feed allows the operator to observe the area remotely and take control if required. When a fire is detected, the robot immediately halts its motion and triggers the firefighting action by activating the water pump, directing water precisely toward the affected spot.

V. EXPERIMENTAL SETUP & RESULT

Experimental Setup

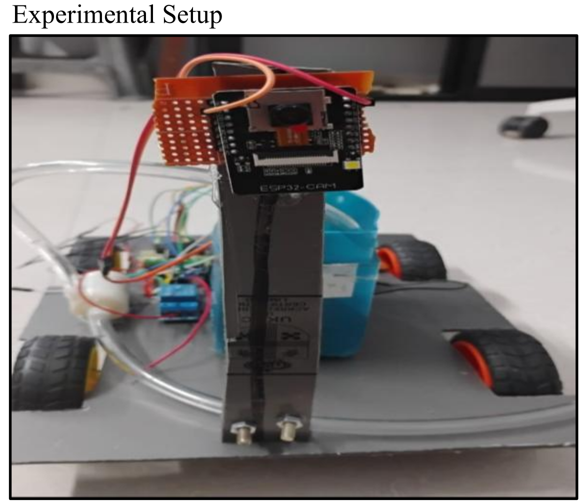

Fig. 5. (i) Experimental setup of the proposed system

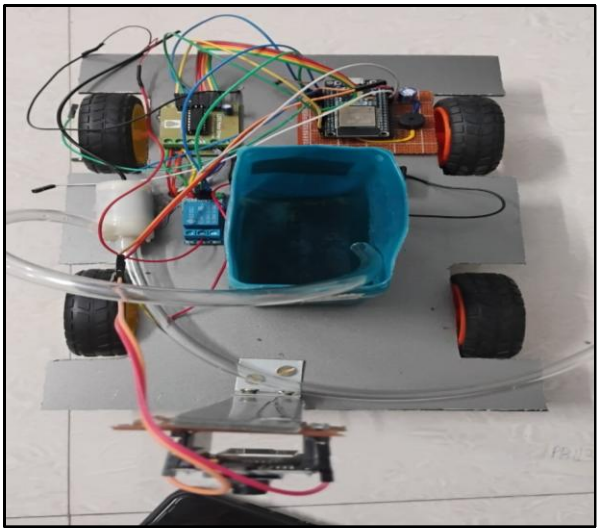

Fig. 5 (ii) Top view of experimental setup

Result

The Fire-Fighting Robot using Arduino successfully demonstrated reliable real-time fire response and remote monitoring capabilities. The ESP32 microcontroller effectively coordinated all system operations, ensuring smooth motor control, accurate obstacle avoidance, and timely activation of the firefighting mechanism. The L293D-driven BO motors enabled agile navigation in dynamic environments, while the ESP32-CAM provided a clear live video feed through the web-based dashboard for remote supervision and control. Upon fire detection, the single-channel relay precisely activated the 6V DC water pump, delivering immediate and targeted fire suppression. Overall, the integrated system proved efficient in detecting fires, maneuvering safely around obstacles, and executing rapid firefighting actions with minimal human intervention.

VI. CONCLUSION

The development of this multifaceted fire-fighting robot represents a significant stride towards proactive fire safety measures. By precise motor control mechanisms, and intelligent decision-making through the microcontroller, this system showcases a promising solution to the challenges of early fire detection and rapid intervention. The integration of an agile water deployment system underscores the system's capability to swiftly identify and mitigate fire hazards. This innovation stands as a testament to the potential of robotics and sensor technology in revolutionising firefighting strategies, offering a proactive approach to safeguard lives and property in the face of fire emergencies.

VII. APPLICATION

1. Industrial Fire Safety: Used in factories, warehouses, and chemical plants to handle fire emergencies safely.
2. Residential Fire Protection: Can assist in extinguishing fires in homes and apartments during early stages.
3. Fire Rescue Operations: Supports firefighters by reaching hazardous or confined areas.
4. Disaster Management Systems: Useful in fire accidents caused by earthquakes or industrial disasters.
5. Military and defence Areas: Operates in high-risk zones where human presence is dangerous.

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