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IOT Based Fire Fighting Robot

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Abstract:

Fire hazards pose a serious risk to lives and infrastructure, necessitating advanced, automated solutions for rapid detection and suppression. This project presents an ESP32-based IoT fire-fighting robot that operates in both automatic and manual modes, integrating Blynk IoT for remote monitoring and control. The system is equipped with IR flame sensors to detect fire sources, DC motors for mobility, and a servo-controlled water pump for extinguishing fires.In automatic mode, the robot continuously scans its surroundings for fire, moves toward the detected source, and activates the water pump to extinguish the flames. The servo motor adjusts the water spray direction to ensure efficient fire suppression. Once the fire is eliminated, the robot resumes patrolling. In manual mode, users can remotely navigate the robot and control fire suppression using the Blynk mobile app, which provides real-time sensor data and operational status.The ESP32 microcontroller ensures seamless Wi-Fi connectivity, allowing real-time updates and remote operation via Blynk. The integration of motor drivers (L298N), flame sensors, and actuators ensures reliable performance in dynamic environments. Experimental results demonstrate the effectiveness of this robot in detecting and responding to fire hazards, with successful implementation of remote control and autonomous navigation.Future enhancements could include thermal imaging for precise fire detection, AI-based path planning for autonomous navigation, and integration with LoRaWAN or GSM for long-range connectivity. This project contributes to the advancement of IoT-based fire safety solutions, offering a scalable and efficient approach to fire management in hazardous environments.

Keywords:wifi,esp32,IoT,DC motors

I. INTRODUCTION

Fire accidents remain one of the most dangerous hazards in both residential and industrial environments, causing significant loss of life and property. Conventional fire-fighting methods often rely on human intervention, which may not always be effective due to delayed response time, inaccessibility to hazardous locations, and high risk to firefighters. To address these challenges, autonomous fire-fighting robots have emerged as an advanced solution for rapid and precise fire detection and suppression.

This project presents an IoT-based fire-fighting robot powered by the ESP32 microcontroller, capable of operating in both automatic and manual modes. The system is equipped with IR flame sensors to detect fire sources, DC motors for mobility, and a servo-controlled water pump for extinguishing fires. The integration of Blynk IoT technology allows users to remotely monitor sensor data and control the robot's movements and fire-extinguishing mechanism through a mobile application.

In automatic mode, the robot autonomously patrols the area, scanning for fire using its flame sensors. Upon detecting a fire, it stops, orients itself towards the source, and activates the servo-controlled water pump to extinguish the flames. The robot continuously monitors the environment to determine whether the fire is successfully suppressed before resuming patrol.

In manual mode, users can remotely navigate the robot using the Blynk mobile application, with directional controls for movement (Forward, Backward, Left, Right, and Stop) and a manual activation switch for the water pump. This feature ensures precise control, allowing operators to tackle fires in specific locations that may not be efficiently handled by automation alone.

The ESP32 microcontroller ensures seamless Wi-Fi connectivity, enabling real-time data exchange between the robot and the user interface. The Blynk cloud platform provides a dashboard for live monitoring of sensor readings, mode selection, and command execution. This project is designed to be a cost-effective, scalable, and efficient solution for fire safety in various applications, including:

- Industrial Fire Safety – Deploying robots in factories or chemical plants to detect and suppress fires in hazardous areas.
- Residential Fire Prevention – Assisting in smart home fire detection and emergency response.
- Disaster Management – Supporting firefighters by navigating through high-risk zones without endangering human lives.
- Warehouses and Data Centers – Providing early fire suppression in facilities where traditional fire-extinguishing methods may be slow or ineffective.

This project demonstrates the potential of IoT, automation, and remote control in enhancing fire-fighting efficiency while minimizing risks to human personnel. Future enhancements may include AI-based navigation, thermal cameras for precise fire detection, and obstacle avoidance mechanisms to improve the robot's effectiveness in complex environments.

II. RELATED WORK

Sr. No	Reference	Title	Key Focus	Year
1	Syed Musthak Ahmed et al.	Domestic Smart Fire Fighting Robot with Multisensory Fire Detection and Warning System Using Python IDE	Multisensory fire detection using Python IDE for smart fire-fighting robots	2022
2	Mrunalini B. Morwal et al.	Design & Implementation of RF based Fire Fighting Robot	RF-based control system for firefighting robots	2019
3	Madhavi Pednekar et al.	Voice Operated Intelligent Fire Extinguishing Vehicle	Voice-controlled fire extinguishing robot	2015
4	S. Jakhti Priyanka et al.	Android controlled Firefighting Robot	Android-based control for firefighting robots	2017
5	C. Xin et al.	Design and Implementation of Debris Search and Rescue Robot System Based on IoT	IoT-based rescue robot system	2017
6	P. Rajasekar et al.	Wi-Fi Combined Visible Light Communication for Intelligent Transportation System	Integration of Wi-Fi and visible light communication in ITS	2020
7	J. Ahn et al.	Remote collaboration using a tele-presence mobile projector robot tele-operated by a smartphone	Smartphone-controlled tele-presence robot	2016
8	R Yashaswini et al.	Fire Fighting Robot Using Various Wi-Fi Module: A Review	Review on Wi-Fi-based firefighting robots	2021
9	-	Robotics in Industry—Their Role in Intelligent Manufacturing	Role of robotics in industrial manufacturing	2018
10	P. Saravanam	Design and Development of Integrated Semi-Autonomous Fire Fighting Mobile Robot	Semi-autonomous firefighting robot	2015
11	W. Durfee	Arduino Microcontroller Guide	Guide to Arduino microcontrollers	2014
12	S. Nandhini et al.	Automatic Detection of Leaf Disease Using CNN Algorithm	CNN-based leaf disease detection	2021
13	Jeremy Blum	Exploring Arduino: Tools and Techniques for Engineering Wizardry	Arduino-based engineering techniques	2004
14	Sang-Uk Park et al.	Wireless image communication system for fire-fighting robots	Wireless image transmission for firefighting robots	2010
15	Shivam Agrawa et al.	Interfacing of robot with android app for to and fro Communication	Android app-based robot control	2016
16	A. Hassanein et al.	An autonomous firefighting robot	Autonomous firefighting robot design	2015
17	P. Sridhar et al.	A New Approach for Fire Pixel Detection in Building Environment Using Vision Sensor	Vision sensor-based fire pixel detection	2021

III. PROBLEM STATEMENT

Fire accidents pose a serious risk to human life, property, and the environment. Conventional fire-fighting methods rely on human intervention, which can be dangerous and inefficient, especially in hazardous or hard-to-reach areas. Existing fire detection systems provide alerts but lack immediate autonomous response mechanisms. Additionally, manual fire-fighting robots often require constant human control, limiting their effectiveness in emergency situations.

This project addresses these challenges by developing an **IoT-based fire-fighting robot using the ESP32 microcontroller**. The robot operates in **both autonomous and manual modes**, enabling real-time fire detection and suppression. In **automatic mode**, it navigates towards the fire, activates the extinguishing mechanism, and ensures timely response without human intervention. In **manual mode**, users can remotely control the robot via the **Blynk IoT platform**, allowing flexible operation in complex fire scenarios.

By integrating **IR flame sensors, motorized navigation, a servo-controlled water pump, and Blynk-based remote monitoring**, the system aims to improve the efficiency, safety, and accessibility of fire-fighting operations. This solution is particularly useful in industrial environments, warehouses, and remote areas where fire hazards need to be managed effectively.

IV. EXISTING SYSTEM

The common conventional firefighting methods involve fire brigades, portable fire extinguisher (hand held) and sprinklers. These conventional methods consume lot of time to reach the place of the mishap like the fire brigade must be deployed from the fire station and should get through the traffic and reach the fire struck area, the portable extinguisher is also no gift because it is generally place at one off the corners of the building which may be difficult to reach and it needs constant maintenance. On the other hand the sprinkler and smoke detector set up is very non reliable method because the sprinkler pipes has any defect may not provide enough pressure and it is suited to cover large areas.

V. OBJECTIVES

The primary goal of this project is to design and implement an ESP32-based fire-fighting robot that can autonomously detect and extinguish fires while also providing remote control functionality through the Blynk IoT platform. The specific objectives include:

1. Develop an IoT-enabled fire-fighting robot using the ESP32 microcontroller to ensure real-time connectivity and remote monitoring.
2. Implement dual operational modes:
    - Automatic Mode: The robot autonomously detects fire, moves toward the source, and activates the fire-extinguishing mechanism.
    - Manual Mode: The user can control the robot's movement and fire suppression system via the Blynk mobile application.
3. Integrate IR flame sensors to detect fire sources accurately and trigger necessary actions.
4. Enable precise movement control using DC motors and an L298N motor driver, ensuring the robot can navigate toward fire hazards effectively.
5. Automate the fire-extinguishing process with a servo-controlled water pump, ensuring an efficient and targeted response.

6. Develop a user-friendly interface using the Blynk IoT platform to:
    - Display real-time sensor data.
    - Enable mode selection (Automatic/Manual).
    - Provide remote directional control of the robot.
    - Allow manual activation of the fire suppression system.
7. Ensure real-time data transmission and remote accessibility by leveraging ESP32's Wi-Fi capabilities.
8. Validate system performance by testing fire detection accuracy, movement efficiency, and water spray effectiveness.
9. Enhance scalability and future adaptability by designing a modular system that can integrate additional sensors (e.g., ultrasonic sensors for obstacle detection or thermal cameras for advanced fire detection).

VI. HARDWARE AND SOFTWARE REQUIRMENTS

Hardware Specifications:

- **ESP32 Microcontroller**: The main processing unit, handling sensor data and communication.
- **IR Flame Sensors**: Detects fire by sensing infrared radiation.
- **L298N Motor Driver**: Controls the movement of DC motors.
- **DC Motors**: Enables the robot to navigate towards the fire.
- **Servo Motor**: Adjusts the water nozzle direction for accurate fire extinguishing.
- **Water Pump**: Pumps water to extinguish the detected fire.
- **Power Supply (Li-Ion Battery 12V)**: Provides necessary power to all components.
- **Wi-Fi Module (Built-in ESP32)**: Enables communication with the Blynk IoT platform.

Software Specifications:

- **Arduino IDE**: Used for coding and uploading firmware to the ESP32.
- **Blynk IoT Platform**: Provides remote control and monitoring features.
- **Arduino Libraries**:
    - **BlynkSimpleEsp32.h**: Enables communication with Blynk.
    - **WiFi.h**: Handles Wi-Fi connectivity.
    - **Servo.h**: Controls the servo motor.
    - **SimpleTimer.h**: Manages timed operations efficiently.

VII. IMPLEMENTATION

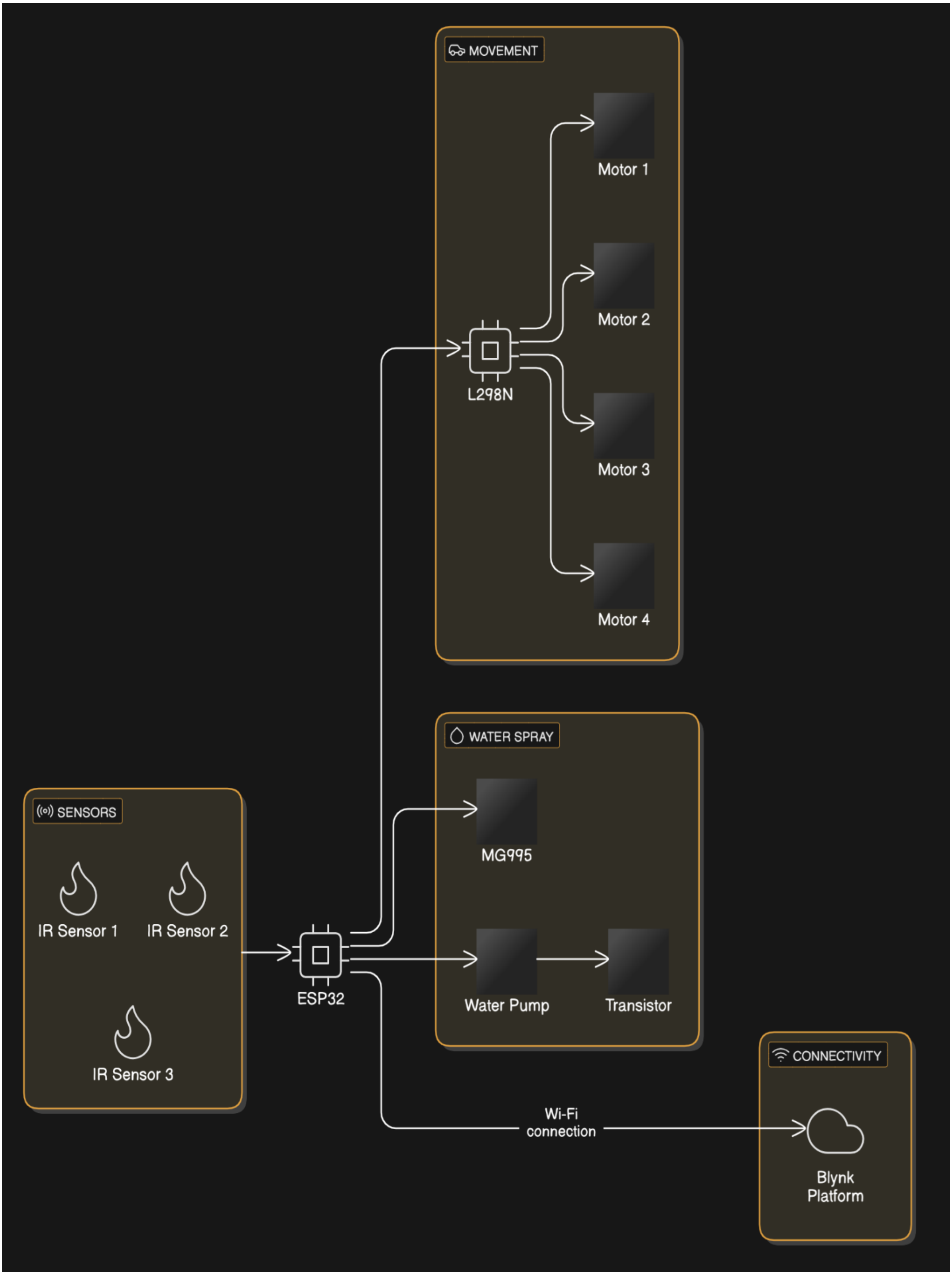

Fig 1,Architechture of IOT based fire fighting robot

The **ESP32-based fire-fighting robot** is designed to detect and extinguish fires using an **IR flame sensor**, a **water pump**, and a **servo motor** for directional control. The robot can function in both **automatic and manual modes**, controlled via the **Blynk IoT platform**.

a. Automatic Mode

- The **IR flame sensors** continuously scan for the presence of fire.
- When a fire is detected, the **ESP32 microcontroller** processes the sensor data.
- The robot **stops its movement** and positions itself toward the fire.
- The **water pump** is activated, and the **servo motor** adjusts to direct the water spray.
- Once the fire is extinguished, the robot resumes its operation, continuing fire detection.

b. Manual Mode

- Users can control the robot remotely via the **Blynk app**.
- The app provides buttons for movement (**Forward, Backward, Left, Right, Stop**).
- The **water pump can be manually activated** when the user identifies a fire.
- Real-time **sensor data and robot status** are displayed on the **Blynk dashboard**.

c. Communication and Control

- The **ESP32 microcontroller** connects to **Wi-Fi**, enabling remote control through Blynk.
- Movement commands from the app are sent to the **L298N motor driver**, which controls the **DC motors**.
- The **servo motor** ensures the water is sprayed accurately toward the detected fire.
- The **Blynk dashboard** provides live updates, allowing users to monitor fire incidents remotely.

d. Safety Mechanisms

- The system prevents **unnecessary water usage** by activating the pump only when fire is detected.
- If multiple fires are detected, the robot prioritizes the closest one first.
- Future upgrades can include **obstacle detection** to prevent collisions while navigating.

This system ensures **efficient and autonomous fire control**, reducing human intervention and improving safety in hazardous environments

VIII. SYSTEM DESIGN

a. Flow chart

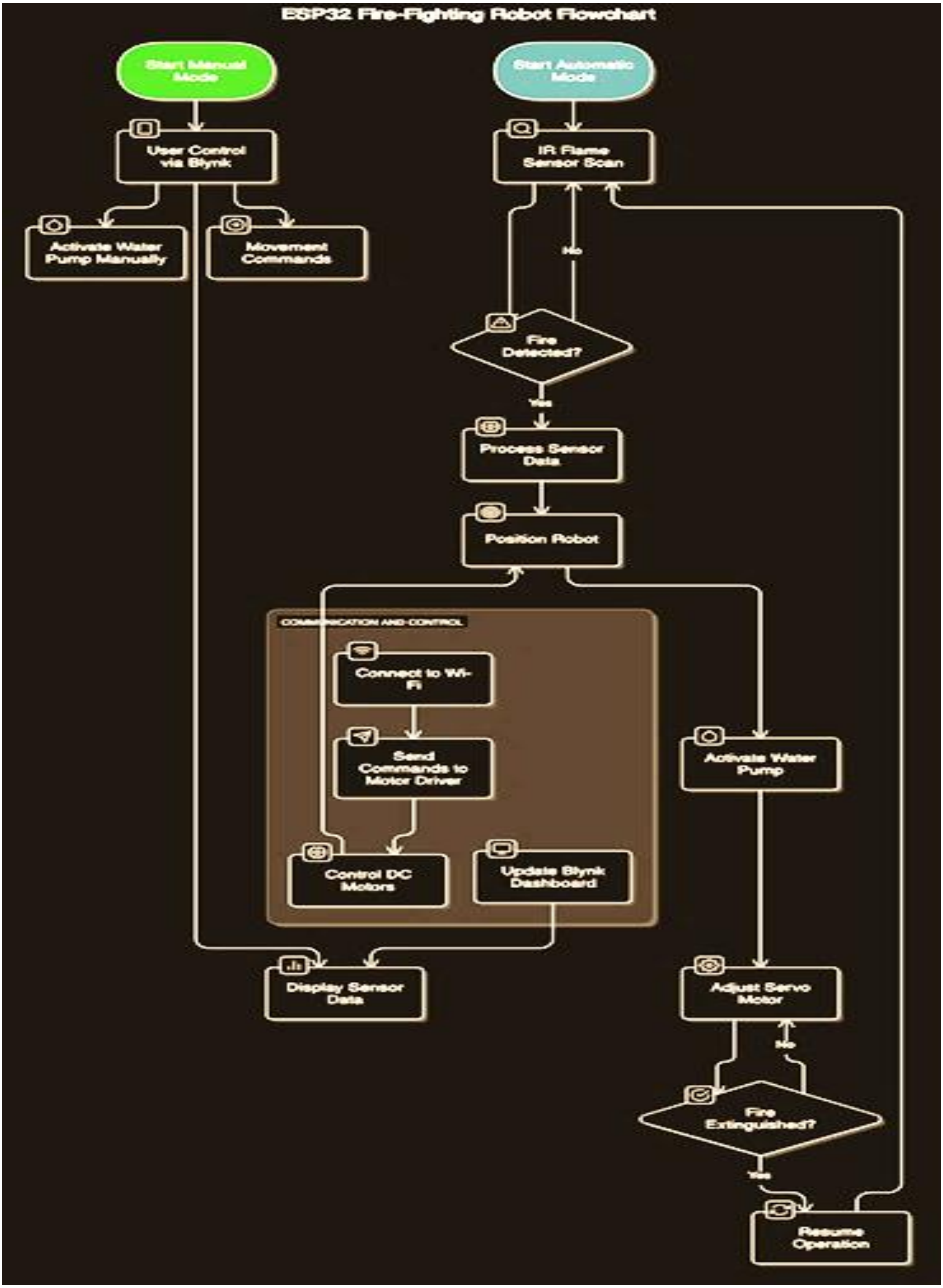

Fig 2,The flowchart illustrates the working mechanism of the **ESP32 Fire-Fighting Robot** in both **manual and automatic modes**, integrating **Blynk** for remote control and monitoring.

Here's a breakdown:

Manual Mode (Left Section)

1. **Start Manual Mode** - The user initiates manual mode via the Blynk app.
2. **User Control via Blynk** - The user can control the robot's movement and water pump manually.
3. **Movement Commands** - The user sends directional commands to navigate the robot.
4. **Activate Water Pump Manually** - The user can trigger the water pump manually to extinguish a fire.

Automatic Mode (Right Section)

1. **Start Automatic Mode** - The robot begins autonomous operation.
2. **IR Flame Sensor Scan** - The system continuously scans for fire.
3. **Fire Detected?**
   - **Yes** → The robot processes the sensor data and moves towards the fire.
   - **No** → It continues scanning.
4. **Process Sensor Data** - The ESP32 processes fire location data.
5. **Position Robot** - The robot adjusts its movement towards the fire.

Communication and Control (Middle Section)

1. **Connect to Wi-Fi** - The ESP32 connects to the internet for data transmission.
2. **Send Commands to Motor Driver** - The robot moves in the detected fire direction.
3. **Control DC Motors** - The motors receive movement instructions.
4. **Update Blynk Dashboard** - The Blynk app is updated with sensor data and fire status.
5. **Display Sensor Data** - Fire detection and robot position data are displayed in real-time.

Fire Extinguishing Process

1. **Activate Water Pump** - Once the robot reaches the fire, the pump is activated.
2. **Adjust Servo Motor** - The servo adjusts the nozzle direction.
3. **Fire Extinguished?**
   - **Yes** → The robot resumes its normal operation.
   - **No** → The extinguishing process continues.

Key Takeaways

- The **manual mode** allows remote control via Blynk.
- The **automatic mode** ensures fire detection and autonomous firefighting.
- **Wi-Fi communication** enables real-time updates.

- The robot integrates **sensor processing, motor control, and Blynk IoT features**.

IX. RESULT AND DISCUSSION

- The robot successfully detects fire and moves toward it.
- The water pump and servo mechanism effectively extinguish the fire.
- Manual mode allows precise control via the Blynk app.
- Real-time sensor data is displayed on the Blynk dashboard.
- The ESP32 ensures fast and reliable Wi-Fi-based communication.

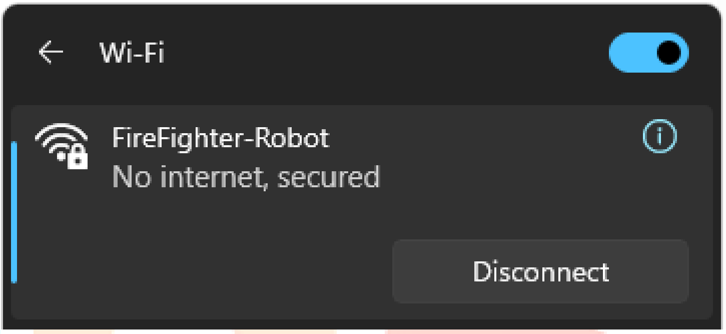

Fig 3, Connecting wifi of the fire fighting robot

Intially the robot need connected with wifi once the pc or mobile is connected successfully ,the user can proceed to browser to invoke html page web application present with robot noide mcu .the template is explained in next image Fig5.

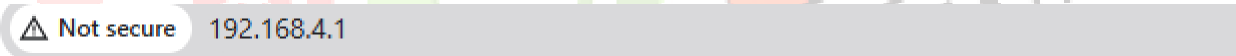

Fig 4,reprents the Url to connect control application

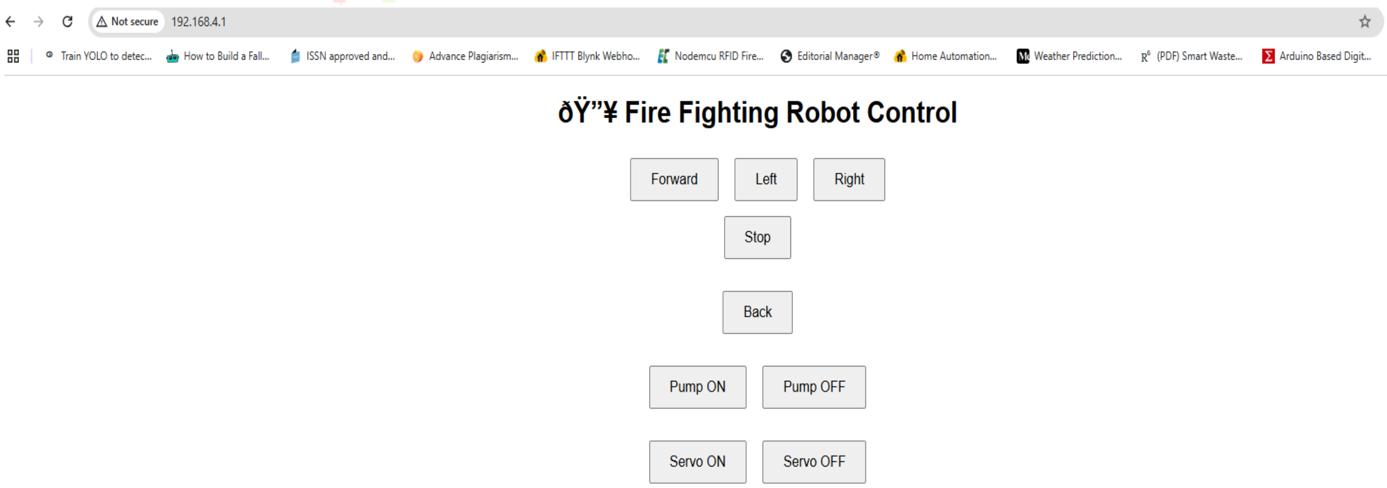

Fig 5, web application for IoT based fire detection system

As to run our project with manual Mode the web application plays a very important role where the user control functions like movement, pump control and servo system with remote access using wifi.

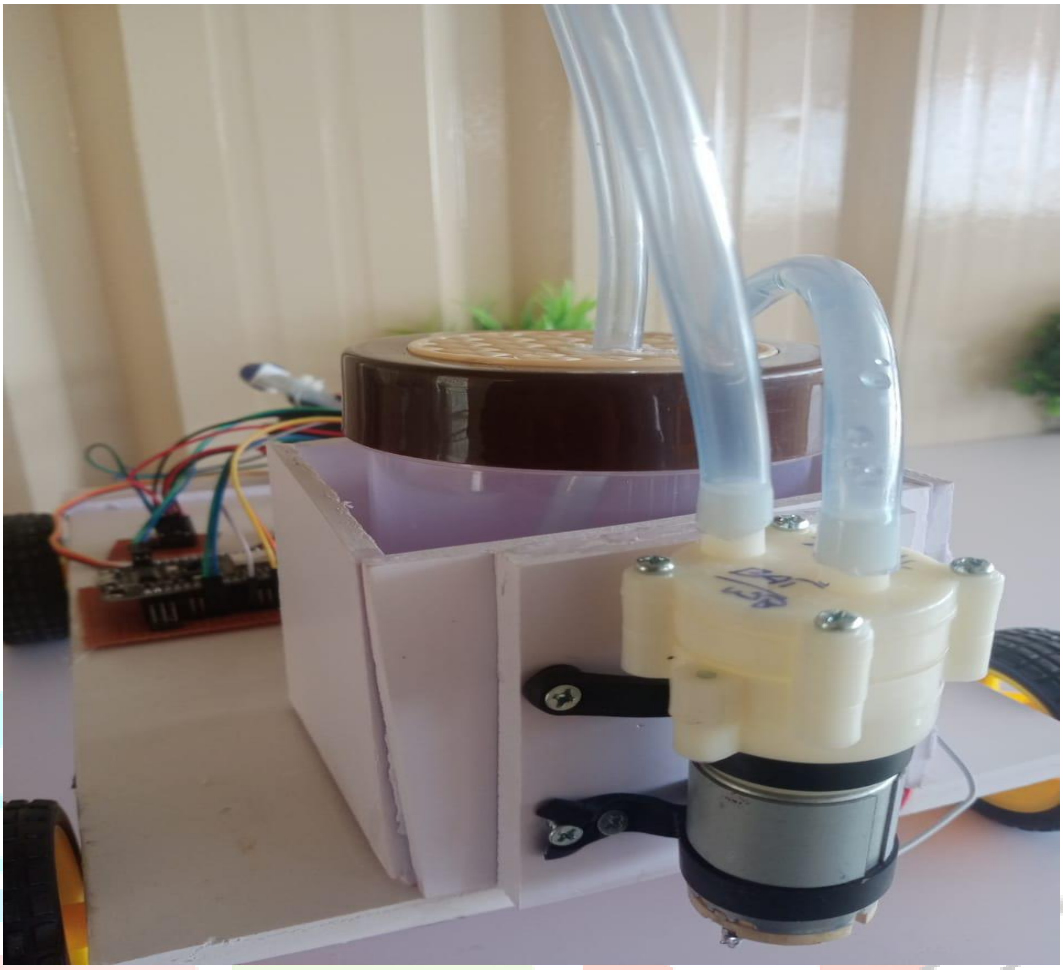

Fig6:Water pump assembly for spray unit

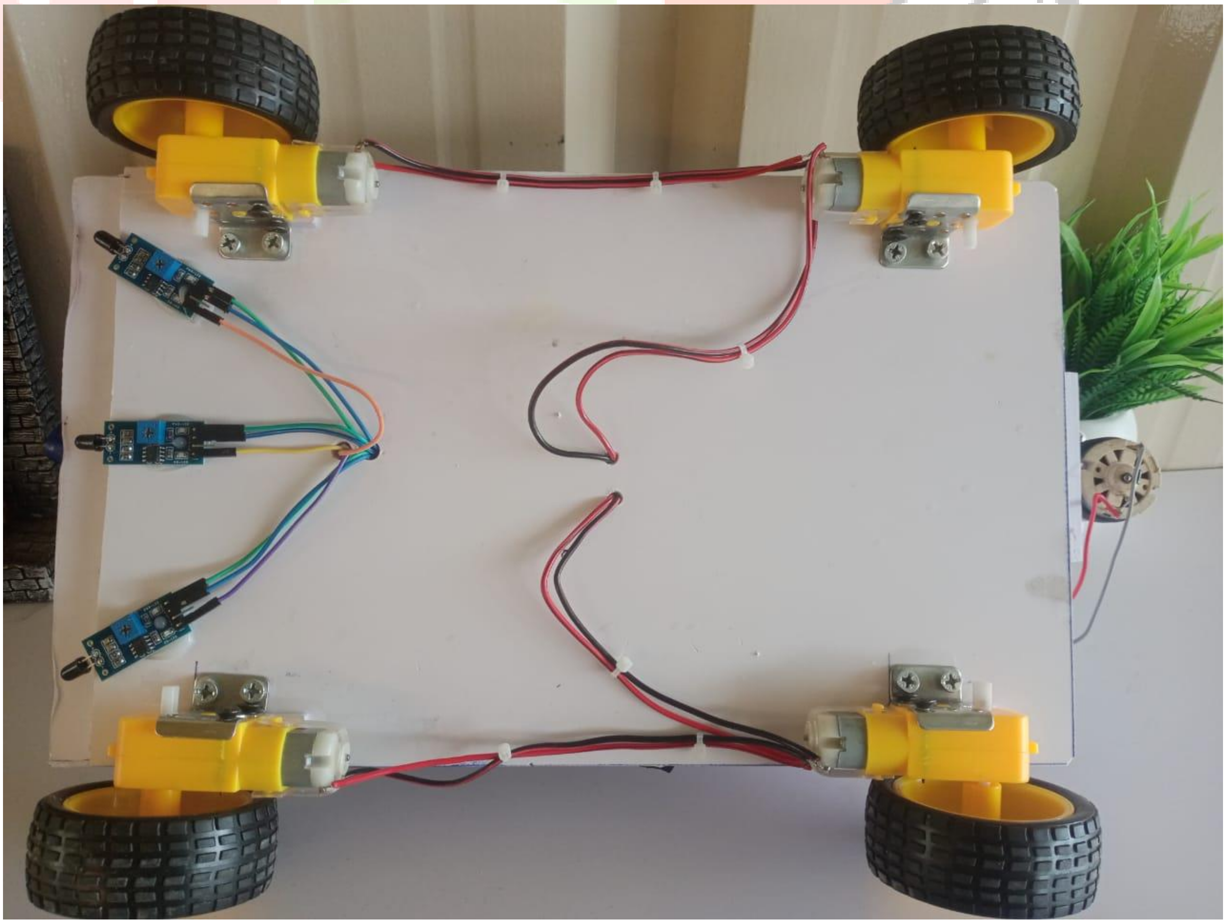

Fig 7:flame sensor assembly to detect fire and 4 dc motor used for movemnt and direction actuatation

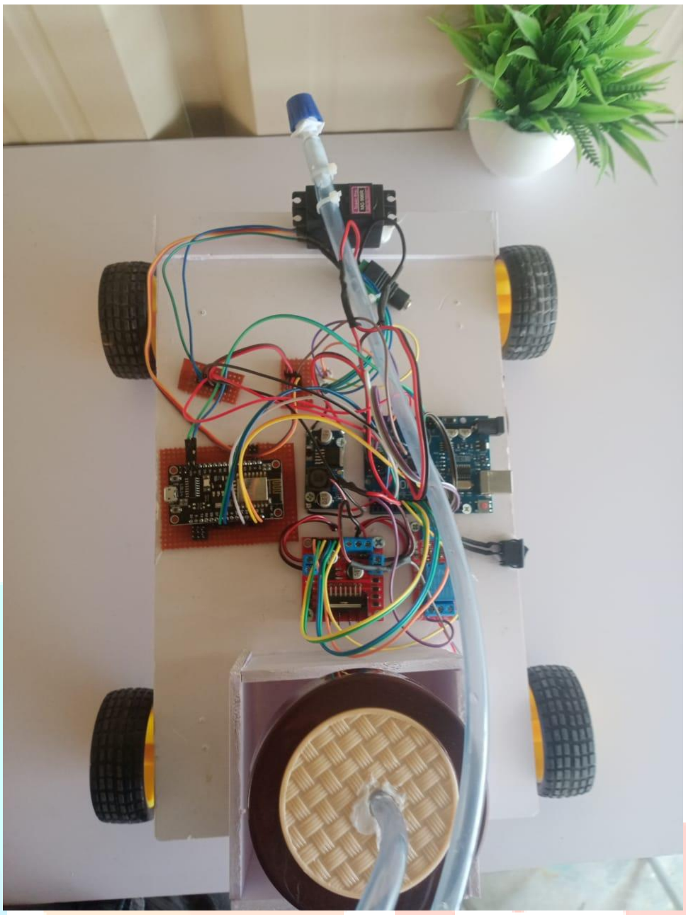

Fig8,IoT based fier Fighting robot complete assembly

Fig 9, Iot based firefighting robot at Auto mode

X. CONCLUSION

The IoT-based Fire Fighting Robot designed using the ESP32 microcontroller successfully demonstrates the potential of automation and IoT in enhancing fire safety measures. By operating in both automatic and manual modes, the robot efficiently detects and extinguishes fires with minimal human intervention. The integration of IR flame sensors, DC motors, a servo-controlled water pump, and real-time remote monitoring via the Blynk platform ensures rapid response, precise fire suppression, and enhanced safety in hazardous environments. Experimental validations confirmed the system's effectiveness in detecting fires, navigating toward the source, and extinguishing flames, making it a viable solution for industrial, residential, and disaster management applications. This project showcases the powerful combination of IoT technologies and robotics in addressing critical fire safety challenges.

Future Scope

- **Integration of Thermal Imaging:** Implementing thermal cameras can improve fire detection accuracy by identifying heat signatures even before visible flames appear.
- **Obstacle Detection and Avoidance:** Adding ultrasonic or LIDAR sensors will allow the robot to navigate more complex environments without collisions.
- **AI-based Path Planning:** Using AI algorithms, the robot can autonomously plan optimal paths to reach fire sources quickly and efficiently.
- **Enhanced Connectivity:** Incorporating technologies like LoRaWAN, GSM, or 5G will extend the robot’s operational range beyond local Wi-Fi networks.
- **Solar-powered Operation:** Integrating renewable energy solutions like solar panels can make the system more sustainable and suitable for long-duration deployments.
- **Swarm Robotics:** Developing multiple coordinated fire-fighting robots working together can cover larger areas and handle multiple fire sources simultaneously.
- **Advanced Fire Suppression Systems:** In addition to water, future models could use foam or CO_2 sprays for different types of fire classes (A, B, C, etc.).
- **Autonomous Charging Dock:** Creating a self-charging station will ensure the robot can recharge automatically, enabling continuous 24/7 operations.

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