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Fire Extinguisher Robot

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Abstract: ***A wireless, vision-based fire extinguisher robot is designed and developed using an ESP32 microcontroller and a normal USB camera module. The robot operates in two modes: manual mode, controlled remotely through a WiFi dashboard, and autonomous mode, where it roams and automatically extinguishes detected fire. The camera feed is processed (on an external processor or ESP-based module) to detect fire via color and pixel intensity analysis. Upon detection, the ESP32 triggers a relay to activate a 12V water pump for a fixed duration, while a motor driver (L298N motor driver) controls two BO-type DC motors to steer the robot. This design removes dependence on IR sensors and Bluetooth modules, enhancing detection accuracy, operational range, and safety. The entire system is powered by a 12V battery with regulated 5V/3.3V supply, making the robot portable and suitable for indoor or small-scale industrial environments. The project demonstrates an effective, low-cost solution for automated fire detection and suppression, combining real-time vision, IoT control, and mechanical actuation. This project integrates computer vision, robotics, and IoT-based control to create an intelligent fire-extinguishing system. Unlike conventional fire detection methods that rely on IR or flame sensors, this robot uses a USB camera for real-time image capture, ensuring higher accuracy and wider detection coverage. The captured video is processed externally, and the fire detection signal is transmitted to the ESP32, which controls the robot's movement and activates the extinguishing mechanism. The WiFi dashboard provides a user-friendly interface to manually operate the robot or monitor its autonomous activity. By combining powerful components such as ESP32, BO motors, L298N motor driver, relay module, and a 12V water pump, the system becomes efficient, portable, and capable of fast response. This approach offers improved safety for humans by allowing remote operation in hazardous areas and demonstrates how smart automation can assist in emergency situations.***
Keywords: Fire detection, ESP32 Microcontroller, Autonomous and manual fire fighting robot, Robotics and Automation.

I. INTRODUCTION

Fire accidents are common hazards in residential, commercial, and industrial environments, often resulting in significant property damage, injuries, and loss of human life. Traditional firefighting methods require human intervention, which can expose firefighters and other individuals to dangerous situations. To overcome these challenges, this project focuses on developing an IoT-enabled Fire Extinguisher Robot that can detect and extinguish fire while reducing direct human involvement. The system uses an ESP32 microcontroller as its main control unit and a USB camera for real-time, vision-based fire detection using computer-vision techniques. Unlike conventional systems that rely on infrared or flame sensors, this approach uses camera input to identify the presence of fire. The robot operates in two modes: manual mode and autonomous mode. In manual mode, users can control the robot's movement and water pump through a Wi-Fi-based dashboard. In autonomous mode, the robot continuously monitors its surroundings and activates the water pump for a fixed duration when fire is detected. BO motors and an L298N motor driver enable movement in multiple directions, while a relay module controls the 12V water pump. A 12V battery and buck converters provide the necessary power to the motors, pump, ESP32, and other electronic components. Overall, this project combines IoT, computer vision, embedded systems, and robotics to provide a low-cost and portable firefighting solution. It aims to improve fire response, minimize human exposure to hazardous environments, and demonstrate the potential of automated fire detection and suppression systems.

II. OBJECTIVES

The primary goals of this project are:

1) Fire Detection and Response: Detect fire quickly and activate the water pump to extinguish it automatically.
2) Remote Control Operation: Enable users to control the robot remotely through a Wi-Fi-based dashboard.
3) Autonomous Movement: Allow the robot to move and respond to detected fire without continuous human intervention.

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III. EXISTING SYSTEM

The existing fire-extinguishing systems mainly rely on traditional firefighting methods, fire alarms, smoke detectors, and sensor-based fire detection technologies. Conventional systems use infrared (IR) sensors, flame sensors, or smoke detectors to identify fire and alert people through alarms or notifications. Some automated systems activate sprinklers or water pumps when fire is detected, while remote-controlled firefighting robots allow users to control the movement and operation of the robot manually. However, these systems may have limitations in fire detection range, mobility, flexibility, and effectiveness in hazardous environments. Sensor-based systems may also face difficulties in detecting fire under certain environmental conditions. Traditional firefighting methods require human intervention, which can expose people to dangerous situations and delay the response in inaccessible areas. Some robotic systems provide remote operation but may lack autonomous fire detection and response capabilities. Therefore, there is a need for an improved firefighting system that combines real-time fire detection, remote control, and autonomous operation to enhance safety and efficiency. Our proposed IoT-enabled Fire Extinguisher Robot addresses these limitations by integrating an ESP32 microcontroller, a USB camera for vision-based fire detection, a Wi-Fi dashboard for remote control, and a water pump for fire suppression. The system supports both manual and autonomous modes, providing a portable and cost-effective solution to reduce human involvement in hazardous firefighting situations.

IV. PROPOSED SOLUTION

The proposed system aims to develop an IoT-enabled Fire Extinguisher Robot that can detect and extinguish fire while minimizing human involvement in hazardous environments. The system uses an ESP32 microcontroller as the main control unit and a USB camera for real-time fire detection using computer-vision techniques. The robot operates in two modes: manual mode and autonomous mode. In manual mode, users can control the robot's movement and water pump through a Wi-Fi-based dashboard from a safe distance. In autonomous mode, the system monitors the surroundings for fire and activates the water pump through a relay module for a fixed duration when fire is detected. BO motors controlled by an L298N motor driver enable the robot to move in multiple directions. A 12V battery supplies power to the motors and pump, while buck converters regulate the voltage required by the ESP32 and other electronic components. The proposed system integrates IoT, computer vision, embedded systems, and robotics to provide a low-cost, portable, and efficient firefighting solution. It aims to improve fire response, reduce human exposure to dangerous situations, and support safer fire detection and suppression.

V. METHODOLOGY

The proposed Fire Extinguisher Robot uses an ESP32 microcontroller as its main control unit and operates in manual and autonomous modes. A front-mounted USB camera continuously captures video, which is processed using computer-vision techniques to detect fire based on its color and intensity. When fire is detected, a signal is sent to the ESP32 to initiate the required actions. In manual mode, the user controls the robot's movement and water pump through a Wi-Fi dashboard, while in autonomous mode, the robot responds automatically to fire detection. The ESP32 controls the BO motors through the L298N motor driver to enable movement in different directions. A relay module is used to activate the 12V water pump for 10 seconds to spray water on the fire, after which the pump stops automatically and the robot returns to its normal state. A 12V battery supplies power to the motors and pump, while a buck converter regulates the voltage for the ESP32 and other low-voltage components. This methodology integrates computer vision, IoT, and embedded systems to achieve efficient fire detection and suppression.

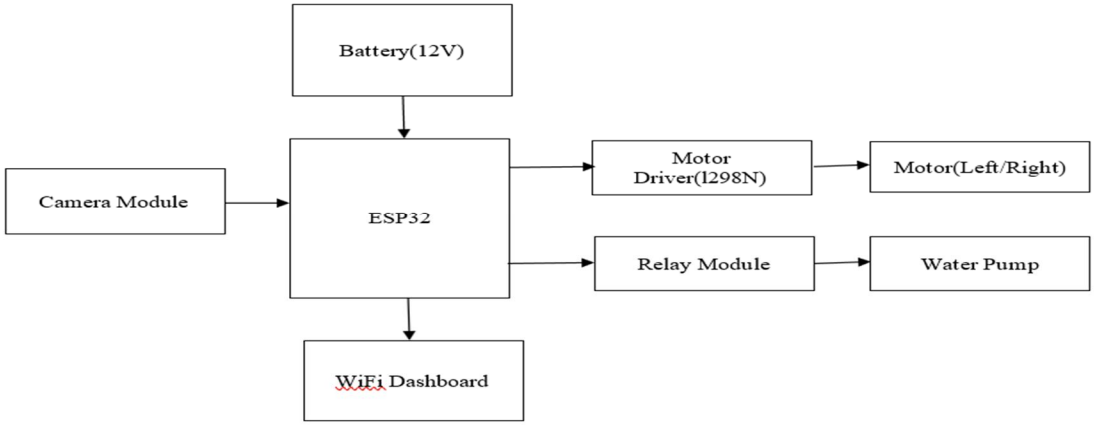


Fig: Block diagram.

A. *Camera Module*

The camera module is mounted at the front of the robot to continuously capture video of the surrounding environment. The captured video is sent to an external processing system, where computer-vision techniques analyze the frames to identify fire based on flame color and intensity. When fire is detected, the processing system sends a detection signal to the ESP32 microcontroller. Using a camera-based approach helps the system identify fire without relying on conventional IR or flame sensors.

B. *ESP32 Microcontroller*

Voltage changes are continuously monitored by a voltage sensor attached to the distribution poles. The sensor transmits data to the Arduino UNO for processing whenever there is a fluctuation. After analyzing these variations, Arduino shows the voltage status or any warnings on the OLED screen. This makes it possible to monitor the power distribution line locally and in real time. The Arduino part does not regulate any loads; it just functions for observation and display.

C. *Battery(12v)*

The 12V battery acts as the primary power source for the robot. It supplies the required electrical energy to operate the motors, water pump, and other components through their respective power connections. Since the ESP32 and other electronic modules require lower operating voltages, a buck converter is used to step down the battery voltage to a suitable level, such as 5V, where supported by the hardware. Proper power distribution helps ensure stable operation of the robot during movement and fire suppression.

D. *Motor Driver (L298N) and BO Motors*

The L298N motor driver receives control signals from the ESP32 and drives the BO motors. These motors enable the robot to move forward, backward, left, and right according to manual commands or autonomous operation.

E. *Relay Module and Water Pump*

The relay module acts as an electronic switch controlled by the ESP32. When fire is detected, the ESP32 activates the relay to turn on the water pump for a fixed duration of 10 seconds. The pump sprays water toward the fire and then switches off automatically.

F. *Wi-Fi Dashboard*

The Wi-Fi dashboard enables users to control the robot remotely and monitor its operation. It provides movement controls, including forward, backward, left, right, and stop, along with options to switch between manual and autonomous modes. The ESP32's built-in Wi-Fi capability enables communication between the robot and the dashboard without requiring an additional Bluetooth module.

VI. IMPLEMENTATION

The implementation of the IoT-enabled Fire Extinguisher Robot involves integrating the camera module, ESP32 microcontroller, L298N motor driver, BO motors, relay module, water pump, and Wi-Fi dashboard. The system begins by capturing video of the surrounding environment through the front-mounted USB camera. The captured video is processed using computer-vision techniques to identify fire based on flame color and intensity. When fire is detected, the processing system sends a signal to the ESP32, which coordinates the robot's movement and activates the water pump. The robot supports both manual and autonomous modes. In manual mode, the user controls the robot through the Wi-Fi dashboard, while in autonomous mode, the robot responds automatically to fire detection. The water pump operates for a fixed duration of 10 seconds and then switches off automatically. The system continuously monitors its operating state, while the Wi-Fi dashboard enables remote operation and control. The 12V battery supplies power to the motors and pump, and buck converters regulate the voltage required by the ESP32 and other low-voltage components. This implementation combines computer vision, IoT, embedded systems, and robotics to provide a portable and cost-effective firefighting solution.

A. *Normal Operating Condition (Before Fire Detection)*

Under normal conditions, the USB camera continuously captures video of the surroundings, and the computer-vision system analyzes the frames for fire. When no fire is detected, the water pump remains switched off, and the robot stays in its normal operating state. In manual mode, the user can control the robot's movement through the Wi-Fi dashboard using forward, backward, left, right, and stop commands. The ESP32 processes these commands and controls the BO motors through the L298N motor driver.

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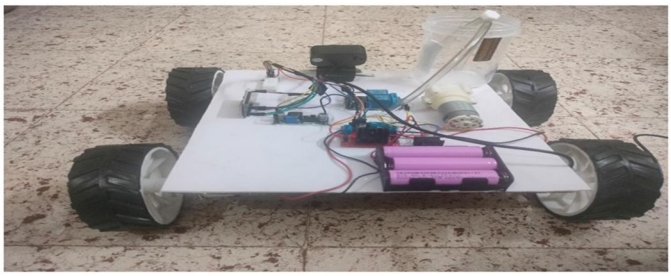


Fig: Movement of Robot

B. Fire Detection and Automatic Response

When fire appears within the camera's field of view, the USB camera captures the video, and the external processing system analyzes the frames using computer-vision techniques. If the system identifies fire based on the programmed detection criteria, it sends a detection signal to the ESP32 microcontroller. The ESP32 then initiates the programmed response by activating the relay module, which switches on the water pump. The pump sprays water toward the fire for a fixed duration of 10 seconds and switches off automatically after the interval. The ESP32 can also coordinate the robot's movement according to the implemented autonomous control logic. This automatic response reduces the need for direct human intervention and helps minimize exposure to hazardous environments.

C. Manual Mode Operation

In manual mode, the robot is controlled remotely through a Wi-Fi-based dashboard connected to the ESP32. The user can issue movement commands such as forward, backward, left, right, and stop. The ESP32 processes these commands and sends the corresponding signals to the L298N motor driver, which controls the BO motors to move the robot in the required direction. The dashboard also allows the user to control the water pump when manual pump operation is enabled. This mode provides flexibility and allows the user to position the robot according to the surrounding conditions without physically approaching the fire. The ESP32's built-in Wi-Fi capability enables communication with the dashboard without requiring a separate Bluetooth module.



Fig: Fire Detection and Extinguishing Process

D. Autonomous Mode Operation

In autonomous mode, the robot monitors its surroundings through the USB camera while the computer-vision system continuously analyzes the captured video. When fire is detected, the processing system sends a signal to the ESP32 to initiate the programmed response. The ESP32 activates the relay module to switch on the water pump for 10 seconds, after which the pump stops automatically. The robot then returns to its programmed normal operating state. Any autonomous movement depends on the movement logic implemented in the system. This mode reduces the need for continuous manual control and demonstrates the use of computer vision and embedded control in automated firefighting.

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VII. RESULTS

The IoT-enabled Fire Extinguisher Robot was successfully designed and implemented to detect and extinguish fire using camera-based detection, embedded control, and wireless communication. The system uses an ESP32 microcontroller as its main control unit and a front-mounted USB camera to continuously monitor the surrounding environment. The captured video is processed using computer-vision techniques to identify fire based on flame color and intensity. When fire is detected, the status is displayed on the Wi-Fi dashboard, enabling the user to monitor the system and its operation. The robot supports two operating modes: manual mode and autonomous mode. In autonomous mode, the robot responds to the fire detection signal by activating the relay module, which switches on the 12V water pump for a fixed duration of 10 seconds before turning it off automatically. In manual mode, the user can control the robot's movement using forward, backward, left, right, and stop commands through the Wi-Fi dashboard. The user can also activate and deactivate the water pump as required. The L298N motor driver controls the BO motors, enabling movement in multiple directions, while the 12V battery supplies power to the motors and pump. Buck converters regulate the voltage required by the ESP32 and other low-voltage components, ensuring suitable power distribution throughout the system. The Wi-Fi dashboard provides a convenient interface for remote operation without requiring an additional Bluetooth module. The project demonstrates the practical integration of the Internet of Things (IoT), computer vision, embedded systems, and robotics for firefighting applications. Overall, the developed system provides a portable and cost-effective approach to fire detection and suppression, helping reduce direct human involvement in hazardous situations. It also establishes a foundation for future improvements, such as obstacle avoidance, improved fire detection accuracy, and advanced autonomous navigation, to enhance the robot's performance in complex environments.

VIII. CONCLUSION

The IoT-enabled Fire Extinguisher Robot successfully demonstrates an efficient and cost-effective approach to fire detection and suppression by integrating computer vision, embedded systems, and IoT technologies. The system uses an ESP32 microcontroller and a USB camera to detect fire in real time through image-processing techniques. It supports both manual and autonomous modes, allowing users to control the robot remotely through a Wi-Fi dashboard or respond automatically to detected fire. The L298N motor driver and BO motors enable movement in multiple directions, while the relay module controls the water pump for fire suppression. The 12V battery and buck converters provide the required power to the system components. Overall, the project aims to reduce human involvement in hazardous firefighting situations, improve response efficiency, and provide a portable solution for fire emergencies. In the future, the system can be enhanced by incorporating advanced fire detection algorithms, obstacle avoidance, improved navigation, and a larger water storage capacity to improve its performance and reliability in real-world environments.

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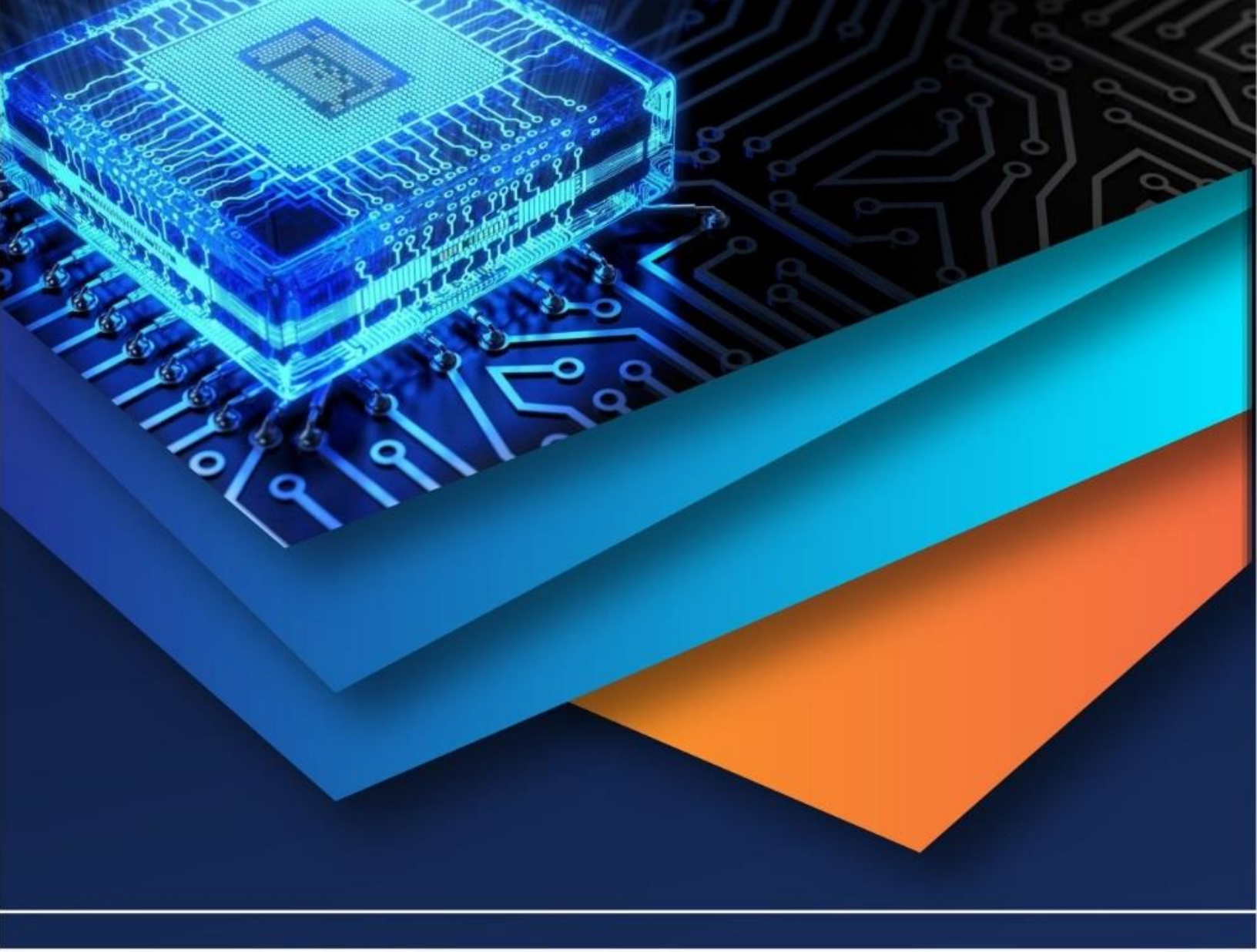
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