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SMART BLAZE BOT: AN INTELLIGENT FIRE FIGHTING ROBOT

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Abstract: Fire hazards pose significant risks to lives and property, necessitating rapid and reliable responses. The "Smart Blaze Bot" is an intelligent fire-fighting robot developed using the ESP32 Wrover microcontroller, designed for real-time hazard detection, autonomous navigation, and IoT-based remote control. It integrates multiple sensors including a flame sensor for detecting fire and an ultrasonic sensor for obstacle avoidance, along with a Wi-Fi camera for 360° remote surveillance. The bot operates in both manual and automatic modes, with alerts triggered via buzzer, email, and mobile notifications. It employs a high-torque servo motor to actuate a foam-based fire extinguisher, ensuring targeted suppression. The robot's operations are powered by rechargeable Li-ion batteries and monitored via an LCD interface. This project offers a scalable, efficient, and autonomous solution for early fire detection and suppression in high-risk zones.

I. INTRODUCTION

Fire incidents in residential, commercial, and industrial environments can cause massive damage to property and pose significant threats to human life. Traditional fire-fighting methods often rely heavily on human intervention, which can lead to delayed response times and increased risk to emergency responders. In response to these challenges, fire-fighting robots have emerged as a promising technological innovation, enabling autonomous hazard detection, fire suppression, and real-time monitoring of dangerous environments. Despite recent advancements in robotics, existing fire-fighting robots are often limited in terms of autonomy, adaptability, and integration with IoT platforms. Many designs fail to incorporate effective obstacle avoidance systems, advanced communication protocols, or real-time data sharing capabilities. Moreover, the lack of multi-channel alerting systems restricts the effectiveness of existing solutions in providing comprehensive situational awareness to operators.

The "Smart Blaze Bot" addresses these shortcomings by integrating embedded systems, real-time IoT connectivity, and intelligent automation. It employs a flame sensor for early fire detection, an ultrasonic sensor for safe navigation, and a Wi-Fi camera for live video feed. Controlled remotely through the Blynk IoT platform, the robot features dual operation modes and sends fire alerts via multiple channels, making it a versatile and reliable solution for fire-prone areas.

II. LITERATURE SURVEY

The need for autonomous fire-fighting systems has encouraged researchers to explore various sensor-based robotic designs. Choudhari et al. [1] introduced a fire-fighting robot capable of identifying and extinguishing flames, emphasizing autonomous operation using basic sensors. Aryan Verma et al. [2] developed an Arduino-based robot that combines flame detection with SMS alert capabilities, ensuring timely notification to users. Surve et al. [3] proposed a surveillance-integrated fire-fighting robot that uses a Wi-Fi camera for real-time monitoring and remote intervention. Kirubakaran et al. [4] designed a robot using ultrasonic and flame sensors for fire detection and obstacle avoidance, with a focus on precise water-based suppression. Teja et al. [6] extended these efforts by integrating IoT-based fire detection with an automatic sprinkler system, enhancing remote management via ESP32 microcontrollers.

Artificial Intelligence (AI) and cloud connectivity are becoming increasingly vital in fire-fighting robotics. Ramasubramanian et al. [7] employed AI for visual fire detection using image recognition techniques, significantly improving hazard identification accuracy. Hossain et al. [8] implemented an IoT-enabled robot for real-time environmental monitoring and automated fire suppression, with data transmitted to a cloud-based dashboard. This facilitates informed decision-making and remote supervision during emergencies. Jayalakshmi et al. [9] focused on sustainable design through the implementation of a solar-powered wireless robot capable of fire surveillance, particularly suited for remote and off-grid locations. Sohani et al. [10] presented a smart robotic system featuring autonomous navigation, IoT-based communication, and LCD-based fire alerts for enhanced usability.

The role of microcontrollers such as ESP32 in intelligent robotics has been further explored by Babiuch and Postulka [11], who designed a smart home fire monitoring system using ESP32 for early detection and suppression. Their work highlights the advantages of using compact, low-power microcontrollers in safety-critical applications. The reviewed literature collectively demonstrates that while earlier fire-fighting robots relied on basic control mechanisms and limited sensing, recent developments incorporate AI, IoT, cloud services, and advanced sensors. These enhancements have improved reliability, efficiency, and scalability, enabling fire-fighting robots to operate effectively in varied and hazardous environments.

III. EXISTING METHODOLOGY

Conventional fire-fighting robots primarily focused on basic flame detection and extinguishing functions with minimal automation. These robots were often designed for specific use cases, either indoor or outdoor, and operated under manual control or pre-programmed paths. Fire detection was commonly handled by infrared or flame sensors, and suppression was achieved using basic relay-activated mechanisms such as water pumps or CO_2 systems.

While some designs integrated IoT components for remote monitoring, these systems generally lacked autonomous decision-making capabilities. They could transmit basic status updates or alerts, but failed to incorporate advanced control features like live navigation, obstacle avoidance, or targeted fire suppression. Additionally, many of these robots had limited mobility and were unable to function effectively in complex environments with narrow passages or unpredictable obstacles.

Cost, bulkiness, and lack of modularity further limited the widespread deployment of these early robotic systems. With fire-prone areas demanding real-time and responsive systems, the need for an intelligent, adaptable, and connected robotic platform became evident — paving the way for developments like the Smart Blaze Bot.

IV PROPOSED METHODOLOGY

The Smart Blaze Bot proposes an integrated solution using the ESP32 Wrover microcontroller, which provides powerful computing and Wi-Fi/Bluetooth capabilities. It combines a flame sensor to detect fire and an ultrasonic sensor to avoid obstacles, enabling autonomous navigation in hazardous environments. The robot uses a high-torque MG996R servo motor to actuate a foam-based extinguisher, ensuring precise suppression of the fire.

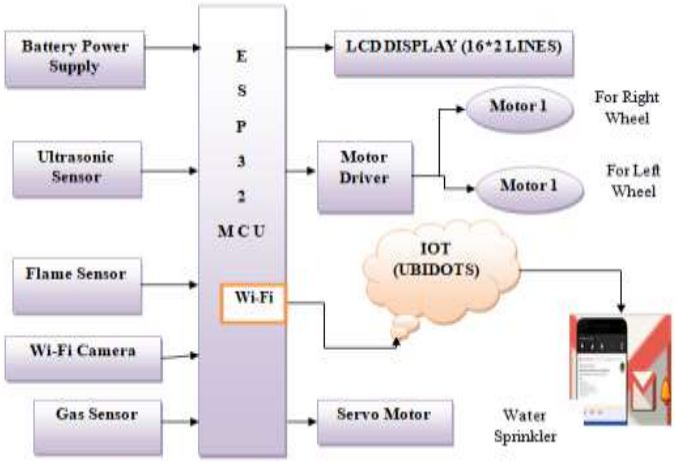
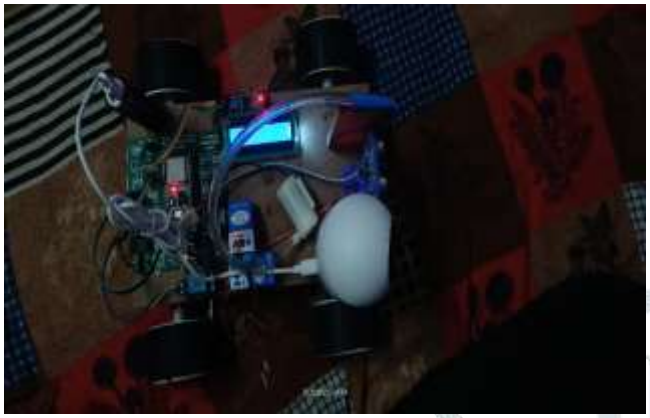


Figure 1: Proposed Architecture

For surveillance and remote operation, the bot is equipped with a Wi-Fi-enabled camera with night vision and 360° rotation, which streams real-time video to the Ezykam+ app. Users can control the robot manually through the Blynk IoT platform if the fire is outside the detection range. The LCD screen displays real-time statuses, including fire alerts, motor directions, and obstacle detection messages, enhancing user awareness and response time.

Powering the bot are three 3.7V Li-ion rechargeable batteries, ensuring extended operation even in challenging scenarios. Alerts are sent via buzzer, email, and mobile notifications when a fire is detected, enabling timely human intervention. The dual-mode functionality — autonomous and manual — allows the robot to adapt to various scenarios, making it ideal for use in industries, homes, offices, and fire-prone public areas.

V. RESULTS & DISCUSSIONS




VII. CONCLUSION

The Smart Blaze Bot provides an intelligent, cost-effective, and autonomous solution to fire hazards through the integration of embedded systems, IoT platforms, and robotics. With its real-time fire detection, obstacle avoidance, live video streaming, and dual operation modes, it enhances fire response effectiveness while minimizing human risk. The combination of multiple sensors, ESP32 microcontroller, and Wi-Fi connectivity makes it a highly adaptable tool for various environments requiring proactive fire safety measures.

VIII. FUTURE SCOPE

Future developments of the Smart Blaze Bot can include AI-based fire detection using computer vision, autonomous path planning for faster navigation, and coordination between multiple bots for large-scale deployments. Additionally, integrating GPS for location tracking, solar-powered batteries for energy efficiency, and enhanced cloud analytics for predictive maintenance and historical data logging can further expand its capabilities in advanced fire safety systems.

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