IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Intelligent Fire Detection and Extinguishing Robot

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Abstract::Fire accidents in industries, commercial buildings, and residential areas can cause significant damage to property and pose serious risks to human life. This project presents a Smart Fire Fighting Robot Using IoT and AI, designed to detect and extinguish fires automatically while minimizing human involvement in hazardous environments. The robot is equipped with flame, smoke, and temperature sensors that continuously monitor the surroundings for signs of fire. When a fire is detected, the system identifies the fire source, navigates toward it, and activates a water pump to extinguish the flames.

The robot is controlled using an ESP32 microcontroller, which enables wireless communication through Wi-Fi for real-time monitoring and emergency alerts. IoT technology allows users to monitor the robot's status remotely using a mobile application or web dashboard. AI-based features, such as camera-assisted fire detection and obstacle avoidance, can further improve the robot's accuracy, navigation, and response time.

This project enhances fire safety by providing rapid fire detection, autonomous operation, and remote monitoring while reducing risks to firefighters. The proposed system is cost-effective, reliable, and suitable for applications in industries, warehouses, hospitals, shopping malls, offices, and residential buildings. It represents an innovative integration of mechanical engineering, electronics, IoT, and artificial intelligence to create a modern fire protection solution.

Keywords: Smart Fire Fighting Robot, AI, IoT, Fire Detection, ESP32, Industrial Safety.

I. INTRODUCTION

Fire accidents are among the leading causes of loss of life and property in residential, commercial, and industrial environments. Traditional firefighting methods often expose firefighters to dangerous conditions, including high temperatures, toxic smoke, and structural collapse. Recent advancements in robotics, the Internet of Things (IoT), and Artificial Intelligence (AI) have created opportunities to develop autonomous systems that can respond quickly and safely to fire emergencies.

The Smart Fire Fighting Robot Using IoT and AI is designed to detect, locate, and extinguish fires with minimal human intervention. The robot uses flame, smoke, and temperature sensors to identify fire hazards and an ESP32 microcontroller to process sensor data and control its movement. Once a fire is detected, the robot automatically navigates toward the fire source and activates a water pump to extinguish the flames. Through IoT connectivity, the system provides real-time monitoring and emergency alerts to users via a mobile application or web dashboard.

The integration of AI can further enhance the robot by enabling intelligent fire detection through camera-based image processing, obstacle avoidance, and optimized path planning. This improves the robot's efficiency, reliability, and response time in complex environments.

The proposed system offers a cost-effective, intelligent, and safe solution for fire protection in industries, warehouses, hospitals, offices, shopping malls, and residential buildings. By combining mechanical design, electronics, IoT, and AI, the project contributes to modern automated fire safety systems and helps reduce the risks faced by human firefighters.

II. Literature Review

Fire safety has become an important area of research due to the increasing number of fire-related accidents in industrial, commercial, and residential environments. Conventional firefighting methods often expose firefighters to dangerous conditions, creating the need for intelligent robotic systems that can detect and suppress fires while minimizing human risk.

Several researchers have developed fire fighting robots using flame, smoke, and temperature sensors with microcontrollers such as Arduino and ESP32. These robots are capable of detecting fire sources and automatically activating water pumps to extinguish flames. Although these systems provide basic fire detection and suppression, many lack intelligent navigation and remote monitoring capabilities.

The integration of the Internet of Things (IoT) has significantly improved robotic firefighting systems by enabling real-time monitoring, wireless communication, and instant emergency notifications. IoT-based platforms allow users to monitor the robot's status and receive alerts from remote locations, improving emergency response.

Recent studies have also explored the use of Artificial Intelligence (AI) and computer vision to enhance fire detection accuracy. AI algorithms can distinguish real fire from false alarms, identify fire intensity, and assist in autonomous navigation and obstacle avoidance. The combination of AI with IoT enables smart decision-making and efficient operation in complex environments.

Despite these advancements, many existing systems remain expensive, have limited mobility, or are designed only for small-scale applications. The proposed Smart Fire Fighting Robot Using IoT and AI addresses these limitations by integrating autonomous fire detection, intelligent navigation, real-time IoT monitoring, and automatic fire suppression into a compact, cost-effective, and reliable robotic platform suitable for industrial and residential applications.

III. Problem Statement

Fire accidents in industries, commercial buildings, warehouses, and residential areas can result in significant loss of life, property, and environmental damage. Conventional firefighting methods often require firefighters to enter hazardous environments, exposing them to extreme heat, toxic smoke, and structural collapse. In many situations, delayed fire detection and response increase the severity of damage.

Existing firefighting robots often have limitations such as limited autonomy, lack of intelligent navigation, absence of real-time remote monitoring, and high implementation costs. Therefore, there is a need for a smart, cost-effective, and autonomous firefighting system that can detect fires quickly, navigate safely to the fire source, extinguish the fire automatically, and provide real-time monitoring through IoT technology.

The proposed Smart Fire Fighting Robot Using IoT and AI addresses these challenges by integrating intelligent fire detection, autonomous navigation, automatic fire suppression, and remote monitoring to improve fire safety while reducing risks to human firefighters...

IV. OBJECTIVES

- To design and develop a Smart Fire Fighting Robot Using IoT and AI.
- To detect fire using flame, smoke, and temperature sensors.
- To automatically navigate toward the fire source.
- To extinguish the fire using an automated water pump system.
- To provide real-time monitoring and alerts through IoT.
- To improve firefighter safety by reducing human intervention in hazardous environments.
- To develop a reliable, cost-effective, and efficient fire safety solution for industrial and residential applications.

V. METHODOLOGY

The proposed Smart Fire Fighting Robot Using IoT and AI is developed using a systematic approach involving hardware integration, software programming, and IoT communication.

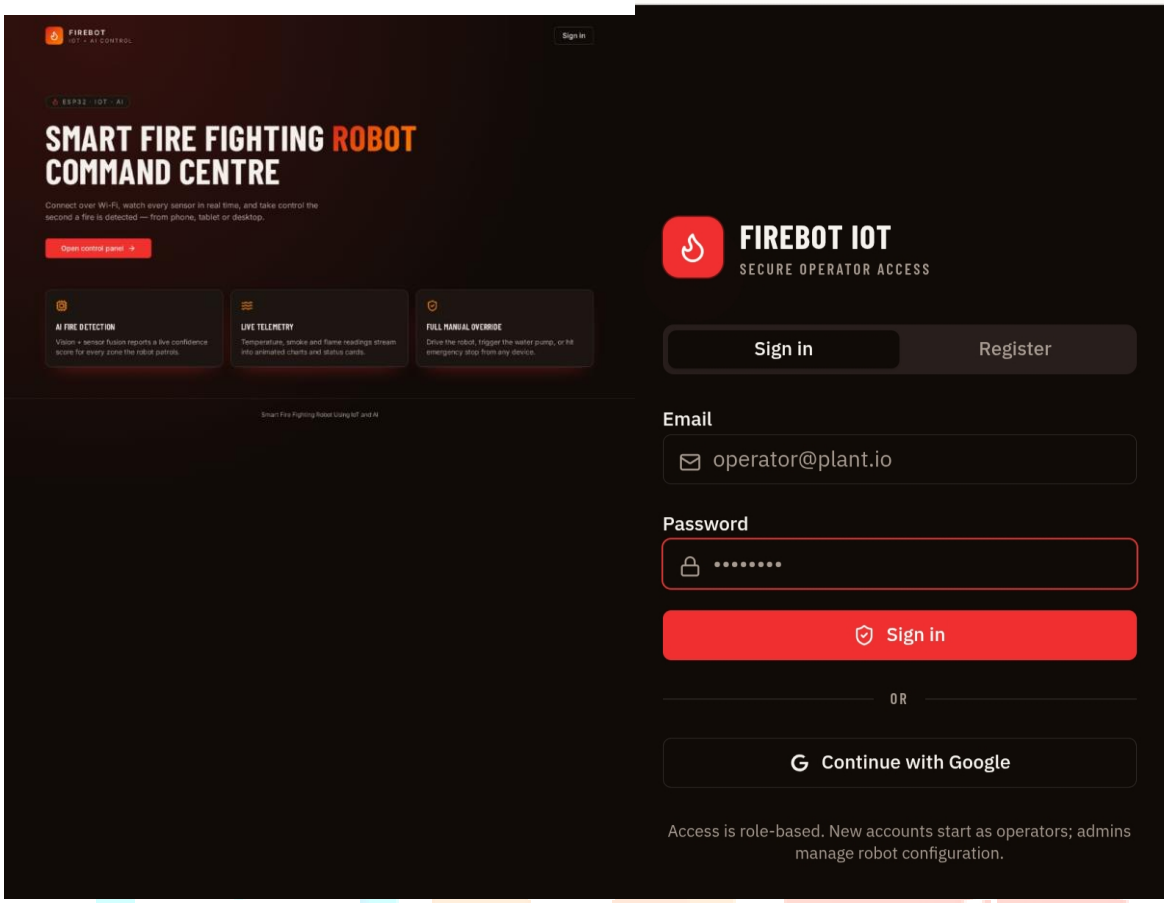
1. System Design: Design the robot chassis and integrate the ESP32 microcontroller, sensors, motors, water pump, and battery.
2. Fire Detection: Flame, smoke, and temperature sensors continuously monitor the environment for fire.
3. Data Processing: The ESP32 processes the sensor data to determine the presence and location of fire.
4. Robot Navigation: The robot automatically moves toward the fire while avoiding obstacles using ultrasonic sensors.
5. Fire Suppression: When the robot reaches the fire source, it activates the water pump and sprays water through the nozzle to extinguish the fire.
6. IoT Monitoring: The system sends real-time alerts and status updates to a mobile application or web dashboard through Wi-Fi.
7. Testing and Validation: The robot is tested under different fire scenarios to evaluate detection accuracy, response time, navigation, and fire extinguishing performance.

VI.RESULT And DISCUSSION

The proposed Smart Fire Fighting Robot Using IoT and AI was successfully designed and tested under different fire scenarios. The flame, smoke, and temperature sensors accurately detected the presence of fire and transmitted the data to the ESP32 microcontroller. Upon detection, the robot automatically navigated toward the fire source and activated the water pump to extinguish the flames.

The IoT platform provided real-time monitoring of sensor readings, robot status, and emergency alerts through a mobile application or web dashboard. The obstacle avoidance mechanism enabled smooth navigation around objects, improving the robot's operational efficiency. The AI-assisted fire detection module reduced false alarms and enhanced the accuracy of fire identification.

Experimental results showed that the robot responded quickly to fire incidents, operated reliably, and effectively suppressed small fires. The system demonstrated low power consumption, stable wireless communication, and consistent performance during repeated testing. Overall, the proposed robot offers a cost-effective, intelligent, and reliable solution for improving fire safety in industrial, commercial, and residential environments while reducing risks to human firefighters.



VII. CONCLUSION

The Smart Fire Fighting Robot Using IoT and AI provides an innovative and effective solution for improving fire safety through automation and intelligent monitoring. The system successfully detects fire using flame, smoke, and temperature sensors, autonomously navigates to the fire source, and extinguishes the fire using an automated water pump. The integration of IoT enables real-time monitoring, remote control, and instant emergency alerts, while AI enhances fire detection accuracy and navigation capabilities.

The proposed robot reduces the risks faced by firefighters, minimizes property damage, and offers a cost-effective solution for industrial, commercial, and residential applications. The project demonstrates the successful integration of mechanical engineering, robotics, electronics, IoT, and artificial intelligence into a reliable fire protection system. Future enhancements may include thermal imaging, GPS-based navigation, robotic rescue capabilities, and advanced AI algorithms for improved performance in complex emergency situations.

VIII. ACKNOWLEDGMENT

The authors express their sincere gratitude to the Principal, Head of the Department, and the faculty members of the Department of Mechanical Engineering for their valuable guidance, encouragement, and continuous support throughout this project.

We extend our heartfelt thanks to our project guide for providing expert advice, constructive suggestions, and constant motivation during every stage of the work. We are also grateful to our institution for providing the necessary facilities and resources required to complete this project successfully.

Finally, we thank our parents, friends, and all those who directly or indirectly contributed to the successful completion of this research work.

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