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Fire Fighter Robot Using IOT and Mobile Application

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Abstract: ***In today's fast-paced world, fire hazards pose significant risks to life, property, and the environment. Traditional fire detection systems often rely on human intervention, leading to delays in response time and exacerbating the damage caused by fire incidents. Our project, the IoT-Based Automatic Fire Detection and Extinguisher Robot, addresses this challenge by utilizing a combination of modern sensor technology, robotics, and IoT to provide an autonomous and real-time solution. The robot is equipped with flame and temperature sensors that allow it to detect fires at an early stage. Once a fire is detected, the robot activates its movement mechanism using DC motors to navigate toward the fire while the integrated servo-controlled water pump precisely sprays water to extinguish the fire.***
In addition to automatic firefighting, the robot features obstacle detection using ultrasonic sensors, ensuring safe navigation in complex environments. The system includes Bluetooth and Wi-Fi communication, allowing for remote control via an Android mobile app. This app provides both manual and automatic control options and sends real-time fire alerts when the robot detects a fire. This autonomous system minimizes human intervention, speeds up response times, and reduces fire damage effectively.
The robot is powered by an ESP32 microcontroller, which processes data from the sensors and controls the motors and water pump. The rescue pod feature allows the robot to perform additional operations like transporting sensitive materials during emergencies. The system's IoT functionality enables real-time alerts and remote monitoring, enhancing its capability as a scalable and cost-effective solution for residential, commercial, and industrial fire safety.

Keywords: Fire Fighter Robot Using IOT and Mobile Application.

1. INTRODUCTION

Fire hazards are one of the leading causes of damage to property and life. Early detection and immediate action are crucial to minimizing the risks associated with fires. Traditional fire

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detection systems often rely on human intervention or static devices such as smoke detectors and sprinklers. However, these systems may face limitations in terms of mobility, coverage, and response time, especially in large or complex environments.

The Automatic Fire Detection and Extinguisher Robot aims to address these limitations by combining the capabilities of fire detection and extinguishing in a single mobile unit. This project focuses on the development of a robot equipped with flame and temperature sensors to detect fire, identify its location, and autonomously extinguish it without requiring human intervention. The robot can navigate its surroundings, detect fire through multiple sensors, and deploy the appropriate extinguishing mechanism. The robot's navigation is enhanced by ultrasonic sensors, which enable it to detect and avoid obstacles while moving toward the fire. The water nozzle is mounted on a servo motor to precisely aim the water spray at the source of the fire. In addition to firefighting, the robot also features a rescue pod, which can be opened remotely to assist in rescue operations or to transport sensitive materials during emergencies. The ESP32 microcontroller serves as the core of the system, handling sensor data, controlling motors, and managing communication with the Bluetooth/Wi-Fi module for remote operation via an Android mobile app. This app allows users to control the robot in manual mode or switch to automatic mode, where the robot detects and extinguishes fires on its own. The system also provides real-time alerts and status updates, ensuring rapid response and constant monitoring.

By providing real-time detection, obstacle avoidance, and immediate response capabilities, the Automatic Fire Detection and Extinguisher Robot offers an innovative approach to modern fire safety management. This robot has the potential to significantly reduce the damage caused by fire incidents in homes, offices, and industrial settings

2. LITERATURE REVIEW

1. Study of Existing System

Recent advances in technology have introduced automatic fire suppression systems, such as sprinklers that are activated by heat. While effective in certain cases, these systems are limited by their fixed positions, which may not cover all areas where fire may occur. Another existing solution includes surveillance-based fire detection using cameras and sensors, but they also rely on manual decision-making to activate extinguishing mechanisms. Autonomous firefighting drones have been developed for large-scale industrial or outdoor applications; however, they are costly and not feasible for small-scale or residential use. Additionally, these systems do not typically integrate IoT functionality, which limits their ability to provide real-time alerts and remote control. The lack of mobility and real-time remote control in most existing fire detection systems creates a gap that our project aims to address with the IoT-based fire detection and extinguisher robot.

2. Findings from Literature Review

Recent research emphasizes the increasing role of IoT in fire detection and suppression systems. IoT-based solutions allow for remote monitoring and control through cloud platforms, enabling real-time notifications and data analysis for fire incidents. These systems can be integrated with mobile applications, offering users the ability to monitor their property

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from anywhere and receive instant alerts when a fire is detected. Additionally, robotic fire suppression systems have been explored in various studies, where autonomous robots equipped with sensors and water-dispensing mechanisms can navigate hazardous environments to fight fires. This approach significantly reduces the risks posed to human firefighters and enhances the efficiency of fire suppression. The integration of artificial intelligence (AI) for decision-making in fire detection systems has also been explored, improving the accuracy of fire detection and response. However, challenges related to cost, power consumption, and scalability remain, indicating the need for further research to develop more affordable and energy-efficient solutions.

3. Problem Statement

Fire outbreaks pose a significant threat to life, property, and the environment, particularly in residential, industrial, and commercial settings. Traditional fire detection systems, which often rely on manual intervention or basic alarms, lack the capability for immediate response, leading to delayed firefighting efforts. This delay results in greater damage and heightened risks to human safety. Additionally, existing fire suppression systems, such as fixed sprinklers and alarms, are limited in their coverage, immobile, and often restricted to specific areas. These systems fail to provide comprehensive protection, especially in complex or large-scale environments where fires can spread quickly.

With the advancement of Internet of Things (IoT) and robotics technologies, there is an increasing demand for an autonomous, mobile solution that can detect fires in real-time, respond immediately by extinguishing the fire, and provide remote monitoring. Current systems do not integrate both fire detection and suppression in a mobile unit that can be controlled and monitored remotely. This lack of a complete, affordable, and scalable solution leaves many environments vulnerable to fire hazards. Therefore, the need arises for a cost-effective, IoT-based automatic fire detection and extinguisher robot capable of early fire detection, autonomous navigation, real-time alerts, and efficient fire suppression, all within a single, versatile system.

4. Project Scope

The IoT-based Automatic Fire Detection and Extinguisher Robot aims to develop an autonomous mobile system that can detect and extinguish fires in real-time while providing remote monitoring and control capabilities through IoT technology. The project focuses on creating a versatile solution suitable for use in residential, commercial, and industrial environments. The robot will be equipped with flame and temperature sensors for early fire detection and ultrasonic sensors for obstacle avoidance, enabling it to safely navigate toward the fire source. The robot's water pump is controlled by a servo motor that allows precise aiming of the water stream, improving the accuracy of fire suppression. Additionally, the robot includes a rescue pod that can be opened or closed via the mobile app, offering a solution for potential evacuation or rescue operations. The system's primary controller is an ESP32, which processes data from the sensors and executes commands to control the motors, water pump, and rescue pod. The robot communicates wirelessly using the Bluetooth and Wi-Fi capabilities of the ESP32, allowing real-time alerts and remote control through an Android app. This feature enables users to monitor the robot’s status and receive notifications when a

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fire is detected, even from remote locations. The scope of the project includes designing, developing, and testing both the hardware and software components of the system to ensure its efficiency and reliability. The robot will be versatile enough to operate in various environments, making it a scalable and affordable solution for improving fire safety in homes, offices, and industrial areas. Future work could include enhancing the **navigation system** and expanding the robot's ability to cover larger or more complex environments.

5. Project Scope

Quick Detection and Response: The primary objective is to ensure early fire detection through flame and temperature sensors. The system will detect the presence of fire in real-time, allowing the robot to act immediately to prevent the fire from spreading. The robot's obstacle detection capability using ultrasonic sensors ensures safe navigation while moving towards the fire, minimizing damage and reducing the risk of fire-related hazards.
Autonomous Fire Extinguishing: The proposed system will autonomously navigate toward the fire source using DC motors and ultrasonic sensors and extinguish the fire with a servo-controlled water pump. This eliminates the need for human intervention, ensuring that the fire is suppressed quickly and safely even in dangerous or hard-to-reach locations.
Remote Monitoring and Control: The integration of IoT technology through the ESP32 enables users to monitor the robot's status and receive real-time alerts via a mobile app. The robot can be controlled manually or switched to autonomous mode, providing flexibility in how it responds to fire incidents.
Rescue Pod Feature: The robot includes a rescue pod that can be opened remotely through the app, allowing it to assist in evacuations or transport materials during fire emergencies.

3. METHODOLOGY

The methodology for the IoT-based Fire Detection and Extinguisher Robot involves the systematic design, development, and testing of hardware and software components to achieve the project's objectives. The following steps outline the methodology:

1. Hardware Design

The robot's hardware components were selected and integrated to achieve autonomous fire detection, navigation, and extinguishing capabilities:

- **ESP32 Microcontroller**: Chosen for its dual Wi-Fi and Bluetooth capabilities, allowing wireless communication between the robot and the Android app.
- **Flame and Temperature Sensors**: Flame sensors were used to detect the presence of fire, and temperature sensors were incorporated to confirm fire by measuring surrounding heat levels.
- **Ultrasonic Sensors**: Installed for obstacle detection and avoidance. The ultrasonic sensors provide real-time distance data to the microcontroller, enabling safe navigation in cluttered or complex environments.

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- **Servo Motor and Water Pump**: The servo motor controls the direction of the water spray, allowing precise targeting of the fire. The water pump is activated when a fire is detected and confirmed by the sensors.
- **DC Motors and Motor Driver**: Four DC motors powered by a motor driver (L298N) were used to control the movement of the robot, allowing it to navigate toward the fire autonomously.
- **Rescue Pod**: A servo motor-operated rescue pod is implemented, which opens upon receiving a command via the mobile app. This feature can be used for emergency evacuations or sensitive material transport during a fire.

2. Software Development

The software development included programming the ESP32 microcontroller and creating the mobile app for user interaction.

- **ESP32 Programming**: The ESP32 microcontroller was programmed using the Arduino IDE. The code was structured to:
  - Continuously monitor the flame and temperature sensors.
  - Trigger an alert when fire is detected, and autonomously direct the robot toward the fire while avoiding obstacles.
  - Control the water pump and servo motor to aim and spray water to extinguish the fire.
  - Manage the rescue pod, opening it remotely via Bluetooth/Wi-Fi commands from the app.
  - Send real-time fire alerts to the mobile app through Bluetooth or Wi-Fi.

- **Obstacle Avoidance Algorithm**: An ultrasonic-based obstacle avoidance algorithm was implemented to prevent collisions while the robot moves toward the fire.
- **Android Application**: The mobile app was developed to provide both manual and automatic modes of operation. It communicates with the robot using Bluetooth (or Wi-Fi for extended range) and allows the user to:
  - Manually control the robot's movement (forward, backward, left, right).
  - Activate the water pump or open the rescue pod.
  - Switch to automatic mode, where the robot autonomously detects and extinguishes the fire.
  - Receive real-time alerts when a fire is detected, including the status of fire suppression efforts.

3. Testing and Iteration

The testing phase involved simulating fire scenarios and navigating the robot in environments with obstacles:

- **Fire Detection Accuracy**: The flame and temperature sensors were tested for their response times and accuracy in detecting various types of fires, such as candle flames and small controlled fires.
- **Obstacle Avoidance**: The obstacle avoidance algorithm was tested using different obstacles to ensure the robot could navigate effectively without collisions.

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- **Water Spray Efficiency**: The water spray system was tested to ensure that the servo motor accurately aimed the water nozzle at the fire, and that the water pump sprayed the appropriate amount of water to extinguish the fire.
- **Mobile App Functionality**: The app was tested for responsiveness and accuracy in controlling the robot in both manual and automatic modes. Real-time alerts and notifications were verified for proper functionality during fire incidents

4. RESULT AND DISCUSSION

The development and testing of the IoT-based Fire Detection and Extinguisher Robot yielded the following results:

- **Fire Detection**: The flame sensors and temperature sensors successfully detected fires with a high degree of accuracy. The robot was able to detect fires within a distance of up to 1.5 meters and respond immediately by navigating toward the fire.
- **Navigation and Obstacle Avoidance**: The obstacle avoidance algorithm based on ultrasonic sensors worked effectively, allowing the robot to detect and avoid obstacles while moving toward the fire source. The robot was able to navigate autonomously in cluttered environments.
- **Fire Extinguishing**: The **servo-controlled water spray system** accurately aimed the water at the fire and extinguished it successfully. Testing showed that the robot could extinguish small to medium-sized fires within seconds.
- **Real-time Alerts and Remote Control**: The Bluetooth/Wi-Fi communication worked seamlessly with the Android app, providing real-time fire alerts and allowing for manual control when necessary. The app allowed users to switch between manual and automatic modes easily, and alerts were received promptly when a fire was detected.
- **Rescue Pod Operation**: The rescue pod feature worked as intended, opening on command from the app. It demonstrated the potential for use in emergency scenarios, such as carrying sensitive materials or rescue operations.

Discussion

The robot performed well in all tested scenarios, demonstrating the potential for autonomous firefighting in residential, commercial, and industrial settings. The successful integration of IoT technology allowed for real-time alerts and remote monitoring, which is a key advantage over traditional fire detection and suppression systems.

However, some limitations were observed during testing:

- **Water Capacity**: The robot's water tank has a limited capacity, which may limit its ability to extinguish larger fires. Future iterations could explore the use of foam-based extinguishing agents or integration with larger water reservoirs.
- **Battery Life**: The battery life was sufficient for short fire-fighting operations, but longer periods of operation or extended fire-fighting sessions may require more efficient power management or larger batteries.

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- **False Positives**: In some instances, the flame sensor detected other sources of light as fire. This can be mitigated by refining the detection algorithm or incorporating additional sensors like smoke or gas sensors.

The results suggest that with further development, the robot can be an effective solution for autonomous fire detection and suppression, especially in areas where human access is restricted or dangerous. Future work should focus on improving fire detection accuracy, extending the robot's battery life, and scaling the system for larger environments. Additionally, integrating machine learning to improve decision-making and navigation in more complex environments could significantly enhance the robot's capabilities.

1. DFD Diagram

Fig.1 Flow Chart of Flow of Fire Fighter Robot

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- **ARCHITECTURE/COMPONENT STURCTURE**

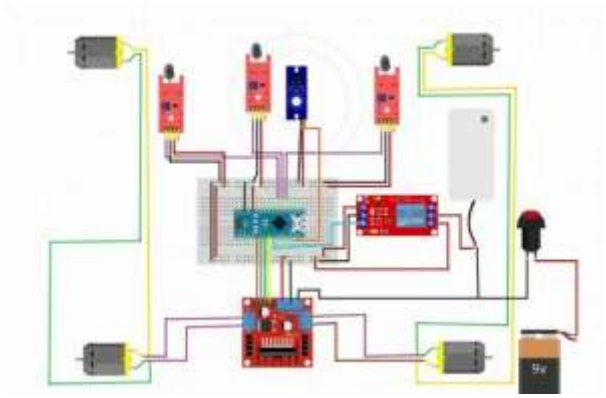

Fig.2 Component Architecture of Fire Fighter Robot

5. CONCLUSIONS

The automatic fire detection and extinguisher robot project represents a significant step forward in enhancing fire safety measures through the integration of IoT technology. By providing early detection and immediate response capabilities, this innovative solution aims to minimize the risk of fire-related incidents, ultimately safeguarding lives and property. The robot's continuous monitoring and data collection functionalities not only enhance its effectiveness but also contribute to a deeper understanding of fire hazards, paving the way for improved safety protocols in various environments.
Despite the many advantages, including increased efficiency and reduced human risk, challenges such as high development costs, technical complexities, and maintenance requirements must be addressed. Nevertheless, the potential impact of this technology on fire safety is substantial, and with the right strategies in place, it can lead to a safer future.

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