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Iot Based Fire Fighter Robot

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Abstract: Firefighting is an inherently hazardous occupation, with numerous incidents each year resulting in injuries and fatalities among fire service personnel. To mitigate these risks and enhance operational efficiency, this paper presents the design and development of an IoT-Based Firefighting Robot that integrates autonomous fire detection and suppression capabilities with remote control via Bluetooth communication. The system leverages Internet of Things (IoT) technologies for real-time monitoring and control, enabling the robot to navigate hazardous environments and extinguish fires autonomously or under manual operator control when required. Equipped with flame sensors for fire detection, a fire extinguishing mechanism, and Bluetooth-based communication, the robot can be operated from a safe distance using an Android application, allowing precise intervention in critical situations. This hybrid approach combines the strengths of autonomous decision-making with human supervision, offering enhanced flexibility and safety in firefighting operations. The system is particularly suited for industrial settings and environments where the risk of accidental fires is high, enabling rapid response while minimizing human exposure to danger. The proposed solution demonstrates the effectiveness of IoT-enabled robotics in improving fire safety, offering a scalable and reliable approach to safeguarding lives, property, and critical infrastructure.

Keywords: DC motor, Flame sensors, Firefighting, Pump, Robot.

I. Introduction

Firefighting is an inherently hazardous and high-risk occupation, where firefighters are required to enter dangerous environments to save lives, protect property, and minimize environmental damage. Despite their dedication and training, firefighters are exposed to extreme heat, toxic gases, structural collapses, and numerous other life-threatening challenges. The absence of prior knowledge about a building's internal conditions and the unpredictable nature of fire incidents further compound the risks. Each year, a significant number of firefighters are injured or killed while performing their duties, highlighting the urgent need for technological interventions that can enhance operational safety and efficiency.

The advancement of robotics and Internet of Things (IoT) technologies has opened new frontiers in automating complex and hazardous tasks, enabling machines to assist or even replace humans in perilous environments. Robotics combines the fields of mechanical engineering, electronics, computer science, and artificial intelligence to develop systems that can perceive, decide, and act in real-time. In the context of firefighting, robotic systems can play a critical role by autonomously detecting fires, navigating hazardous environments, and executing firefighting actions, thereby reducing the risks faced by human firefighters.

This project presents the design and development of an IoT-Based Fire Fighter Robot, capable of operating autonomously as well as being controlled remotely via Bluetooth. The robot integrates flame sensors to detect fire sources, a fire extinguishing mechanism to suppress flames, and Bluetooth connectivity for manual control through an Android application. The IoT capabilities allow the robot to transmit critical fire-related data and system status in real-time, facilitating effective decision-making and enhancing situational awareness.

Such a robot system is particularly beneficial in industrial environments, warehouses, and residential buildings where accidental fires are common, and immediate intervention is required. The integration of autonomous detection and suppression with remote-controlled functionality offers a versatile and robust solution for fire safety, reducing human exposure to danger while ensuring timely and efficient firefighting responses.

II. Methodology

The IoT-Based Fire Fighter Robot is designed by integrating hardware and software components to enable autonomous fire detection, suppression, and remote control via Bluetooth. The robot uses flame sensors to detect fire, and a microcontroller (Arduino) processes sensor data and controls robot movement and the fire extinguishing system. The chassis is equipped with motors for mobility, a water pump for fire suppression, and a Bluetooth module (HC-05) for communication with an Android app developed. The software includes modules for sensor data acquisition, decision-making, motor and pump control, and Bluetooth communication. The robot is tested in controlled conditions to validate its ability to detect and extinguish fire autonomously and through remote commands, ensuring safe and reliable operation.

III. Block Diagram

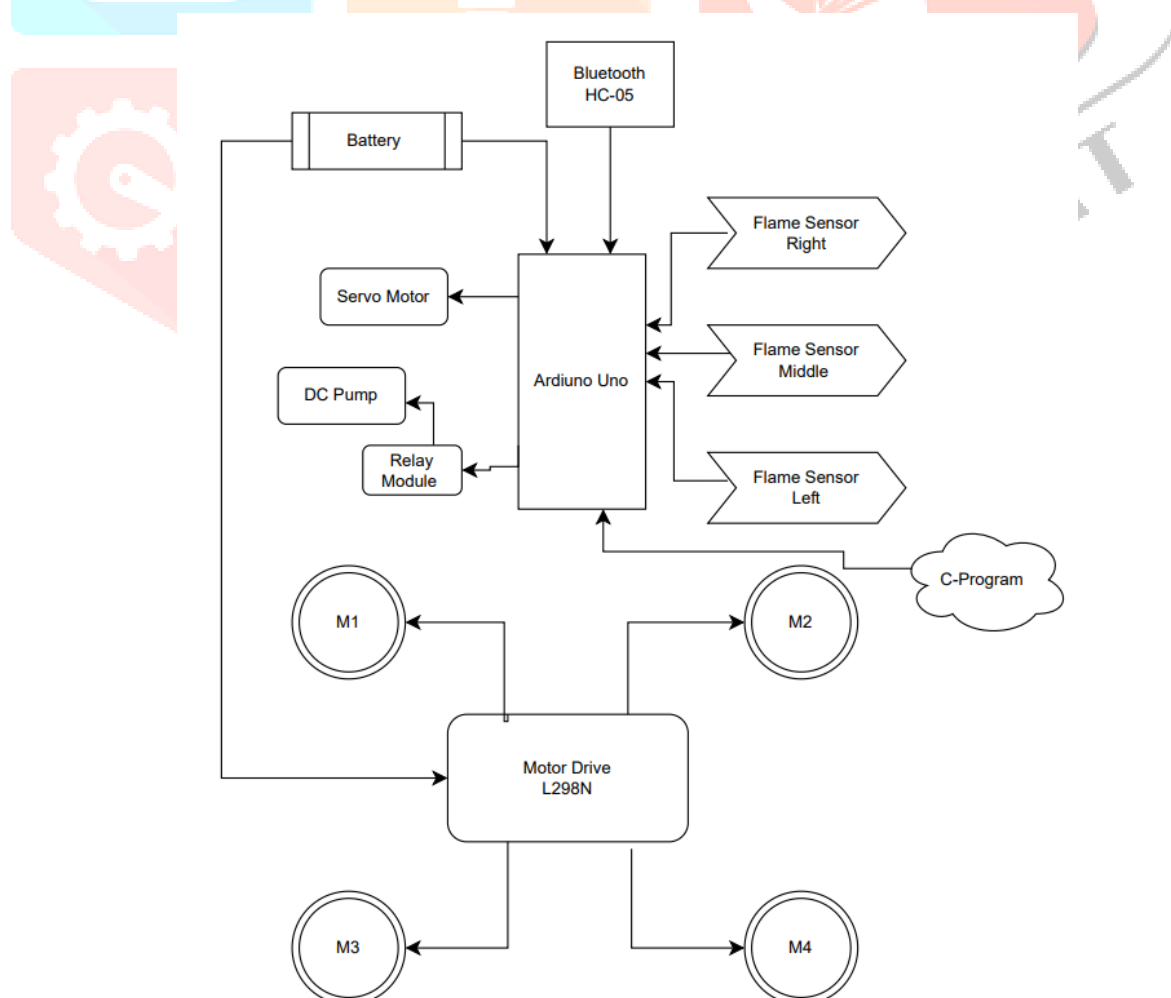


Fig 1. Block Diagram of Fire Fighting Robot

IV. Block Diagram Description

The block diagram illustrates the system architecture of the IoT-Based Fire Fighter Robot, highlighting the interaction between hardware components managed by an Arduino Uno microcontroller. The robot is powered by a rechargeable Li-ion battery that supplies energy to all components, ensuring untethered mobility. The core processing unit, Arduino Uno, acts as the central controller, interfacing with various modules for sensing, control, and communication. Three flame sensors—positioned on the left, middle, and right of the robot—continuously monitor the surrounding environment for fire. When a flame is detected, the corresponding sensor transmits the signal to the Arduino, which then executes pre-programmed logic written in C.

For movement, the Arduino interfaces with an L298N motor driver module, which controls four DC gear motors (M1 to M4), enabling the robot to navigate toward the detected fire autonomously. The robot's motion can also be overridden or directed manually via a Bluetooth HC-05 module, which communicates with a smartphone for remote operation. Once the flame location is identified, the Arduino activates a servo motor to align the water nozzle and energizes a relay module that switches on a DC water pump. This mechanism allows water to be sprayed in a targeted manner at the fire source.

The block diagram encapsulates the entire signal flow—from fire detection to suppression—while ensuring real-time communication, precise actuation, and remote control capability, making the robot both autonomous and user-controllable. This integrated design provides a reliable, efficient, and safe solution for small-scale firefighting tasks.

❖ Flow-Chart

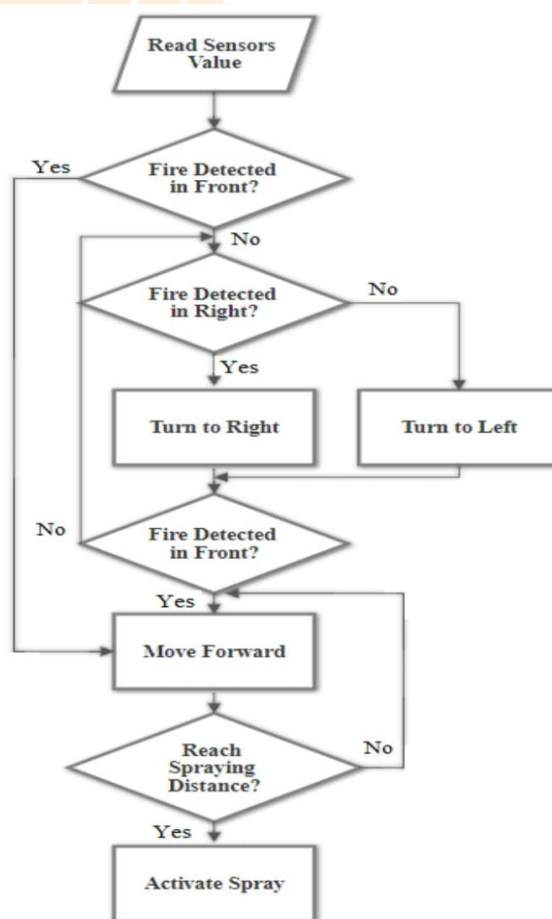


Fig 2 : Flow Chart

V. Hardware Components Used

1. Arduino UNO

Arduino Uno is an open-source microcontroller development board based on the ATmega328P. It acts as the brain of the robot, handling sensor data acquisition, decision-making, and control signal generation. The board supports digital and analog I/O, PWM outputs, and serial communication, enabling integration with sensors, actuators, and Bluetooth modules. Its versatility, ease of programming, and wide community support make it ideal for prototyping embedded systems like this firefighting robot.

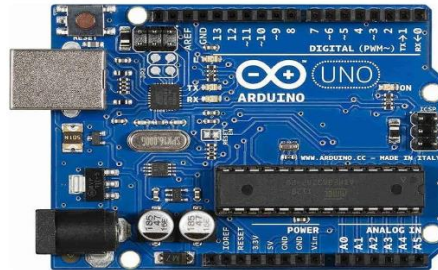


Fig 5.1 Arduino Uno

2. Flame Sensors

Flame sensors are infrared (IR)-based modules that detect fire by sensing IR radiation in the 760–1100 nm wavelength range. They provide real-time feedback to the microcontroller about the presence and intensity of flames, enabling autonomous fire detection. The sensors are sensitive enough to detect fires at a reasonable distance and can be calibrated for different environments, making them crucial for early fire identification in firefighting robots.



Fig 5.2 Flame Sensor

3. L298N Motor Driver

The L298N motor driver module is a dual H-bridge motor controller that enables the control of two DC motors with independent direction and speed. It allows the Arduino to drive motors at higher voltages and currents than the microcontroller can handle directly. The module supports PWM inputs, facilitating variable speed control. Its ability to handle up to 2A current per channel makes it suitable for mobile robotics applications like firefighting robots.

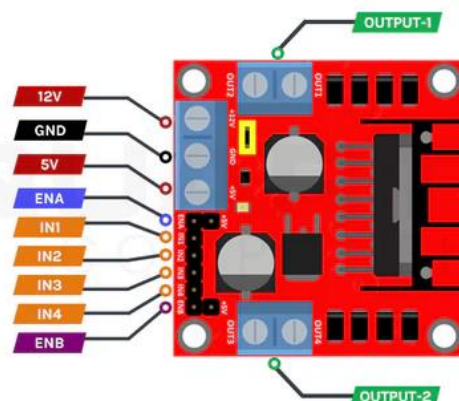


Fig 5.3 L298N Motor Driver

4. Bluetooth Module (HC-05)

The HC-05 Bluetooth module enables short-range wireless communication between the robot and a smartphone. It operates on Bluetooth 2.0 protocols, providing a reliable link for remote control. The module uses serial communication (UART) to exchange data with the Arduino, allowing users to control robot movement, activate the water pump, and monitor system status. The HC-05 is easy to configure and widely used for wireless robotics applications.

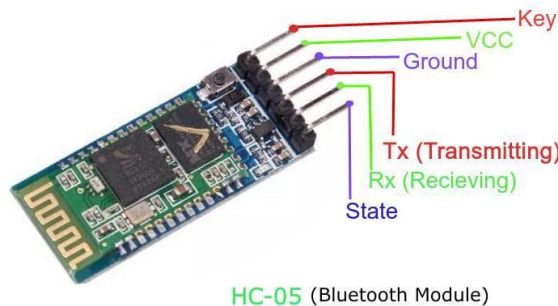


Fig 5.4 bluetooth module

5. Servo motor

The servo motor provides precise angular control of the robot's fire-extinguishing nozzle, enabling directional aiming. Controlled via PWM signals from the Arduino, it rotates to a specific angle based on sensor feedback. The servo ensures accurate targeting of the fire source during suppression, enhancing the robot's firefighting effectiveness. Its compact size, low power consumption, and high precision make it ideal for robotic systems requiring controlled motion.



Fig 5.5 Servo motor

6. DC Gear Motors

DC gear motors convert electrical energy into mechanical rotational motion, providing the torque and speed necessary for robot movement. The integrated gearbox reduces the motor's speed while increasing its torque output, ensuring stable and controlled motion across different terrains. These motors enable the robot to navigate towards fire sources autonomously or via Bluetooth control, making them essential for mobility in firefighting applications.



Fig 5.6 DC Gear Motors

7. Relay Module

The relay module acts as an electromechanical switch, enabling the Arduino to control high-power devices like the water pump. It uses a low-voltage control signal to toggle the state of a high-current circuit, ensuring safe and reliable operation of the firefighting system. The relay isolates the microcontroller from high-voltage components, preventing damage and allowing controlled activation of the water pump in response to fire detection.

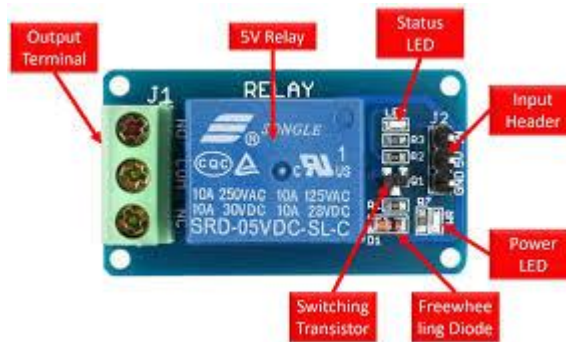


Fig 5.7 Relay Module

8. Water Pump

The water pump is an electrically powered device that draws water from a reservoir and directs it towards the detected fire. It plays a critical role in extinguishing fires once they are detected. Controlled via a relay module, the pump can be activated automatically by the microcontroller or manually via Bluetooth commands. Its flow rate, pressure, and size are selected based on the firefighting requirements and the robot's design.

9. Rechargeable Li-ion Battery

The rechargeable lithium-ion (Li-ion) battery serves as the primary power source for the entire robotic system, including the Arduino, motors, pump, sensors, and communication modules. Li-ion batteries offer high energy density, lightweight construction, and rechargeable capabilities, making them ideal for mobile applications. They provide stable voltage output and can sustain the robot's operations for extended periods, ensuring reliable performance during firefighting tasks. Proper voltage regulation is crucial to protect sensitive electronic components.

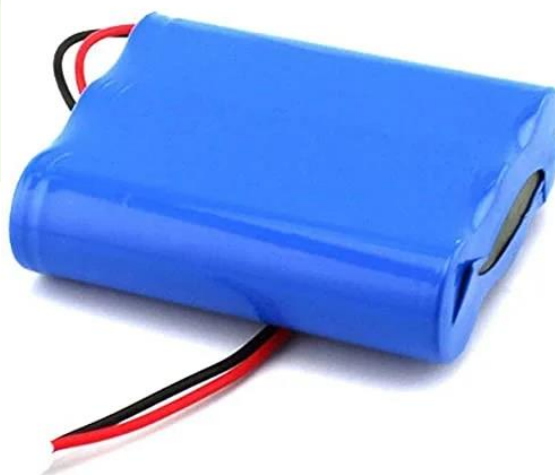


Fig 5.8 Rechargeable Li-ion Battery

VI. Working Mechanism

The IoT-Based Fire Fighter Robot operates in both autonomous and manual modes to detect and extinguish fires. In autonomous mode, flame sensors continuously scan the surroundings for fire by detecting infrared radiation. When a fire is detected, the Arduino Uno processes the sensor input and activates the water pump via the relay module. The servo motor adjusts the direction of the water spray, ensuring precise targeting of the flame. In parallel, the robot's DC gear motors, controlled by the L298N driver, navigate the chassis towards the fire source.

For manual operation, the robot communicates via the HC-05 Bluetooth module, allowing a user to control the robot's movement and firefighting actions using a smartphone application. The rechargeable Li-ion battery powers all components, ensuring sustained operation during firefighting tasks. This combined system enables the robot to effectively locate and extinguish fires in hazardous environments while minimizing risks to human firefighters.

VII. Software Design Technique

The software design of the IoT-Based Fire Fighter Robot employs a modular, event-driven programming approach using the Arduino IDE and the C/C++ programming language. The system architecture is divided into key functional blocks, each handling specific tasks such as sensor data acquisition, decision-making, motion control, fire suppression, and Bluetooth communication. The flame sensors continuously provide real-time analog or digital data, which is processed using a threshold-based algorithm to determine the presence and location of fire. Upon detection, the Arduino initiates a series of actions: it triggers the relay module to activate the water pump, adjusts the servo motor to direct the nozzle toward the fire source, and controls the DC gear motors via the L298N driver to move the robot toward the fire autonomously. Bluetooth communication is established using the HC-05 module, which allows the robot to receive user commands from a smartphone and execute manual control of movement or fire suppression functions. The system integrates non-blocking code structures, utilizing functions like `millis()` instead of `delay()` for time-based events, ensuring that sensor readings and motor control operations remain responsive in real-time. The codebase is structured for scalability, allowing additional sensors or features to be integrated in future iterations without significant modifications. The software design emphasizes clarity, modularity, and responsiveness, enabling the robot to operate efficiently in both autonomous and manual modes during firefighting scenarios.

VIII. Results

The IoT-Based Fire Fighter Robot was successfully designed, developed, and tested for fire detection and extinguishing operations. The system demonstrated reliable flame detection using infrared sensors, accurately identifying fire sources within a 60-degree field of view and up to a distance of 15 cm autonomously. The robot's response time from detection to water spray activation averaged 1.5 seconds, ensuring rapid suppression in simulated fire scenarios. The servo motor-enabled nozzle system effectively directed the water stream towards the flame, achieving high targeting precision.

During remote operation via Bluetooth, the robot maintained stable wireless communication with a smartphone up to a range of 10 meters, allowing full manual control of movement and fire suppression functions. The DC gear motors, controlled through the L298N driver, provided smooth and controlled mobility across flat surfaces. The water pump, activated by the relay module, delivered a steady flow rate suitable for small-scale fire suppression.

The system's energy efficiency was validated through continuous operation for up to 40 minutes on a fully charged Li-ion battery, with no significant voltage drop affecting system performance. The modular software design enabled seamless integration of hardware components, while the use of non-blocking code structures ensured responsive real-time behavior.

Overall, the robot effectively demonstrated its capability as a prototype firefighting tool, reducing the need for human intervention in dangerous environments.

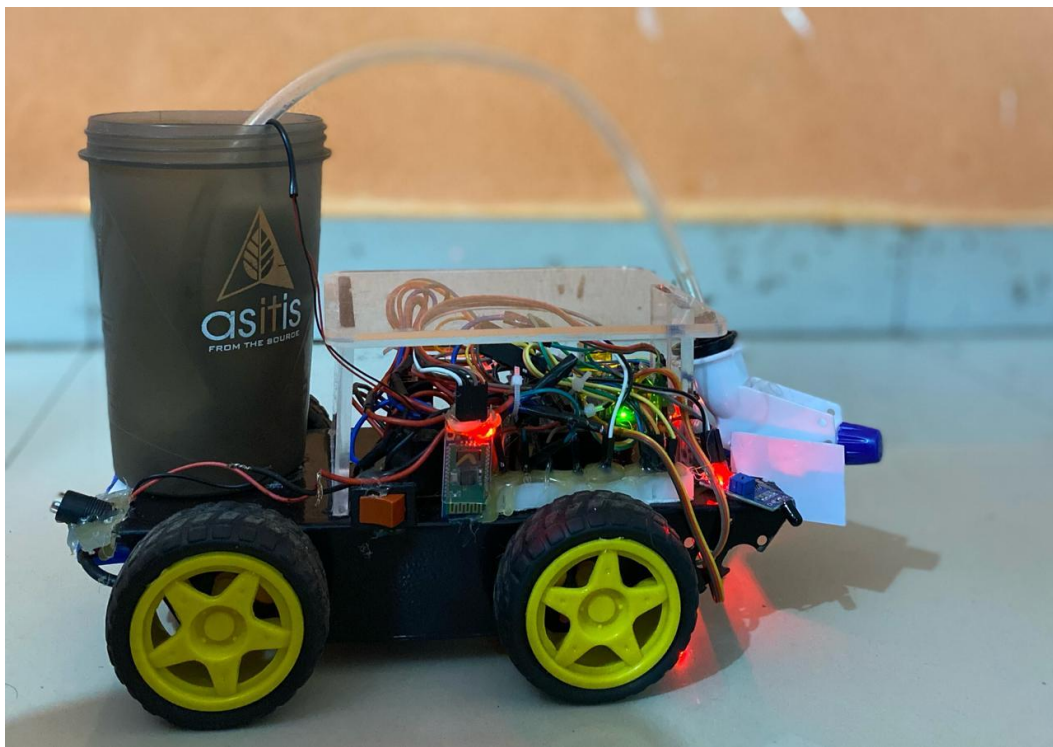


Fig 1. Hardware Setup Of Fire Fighter Robot

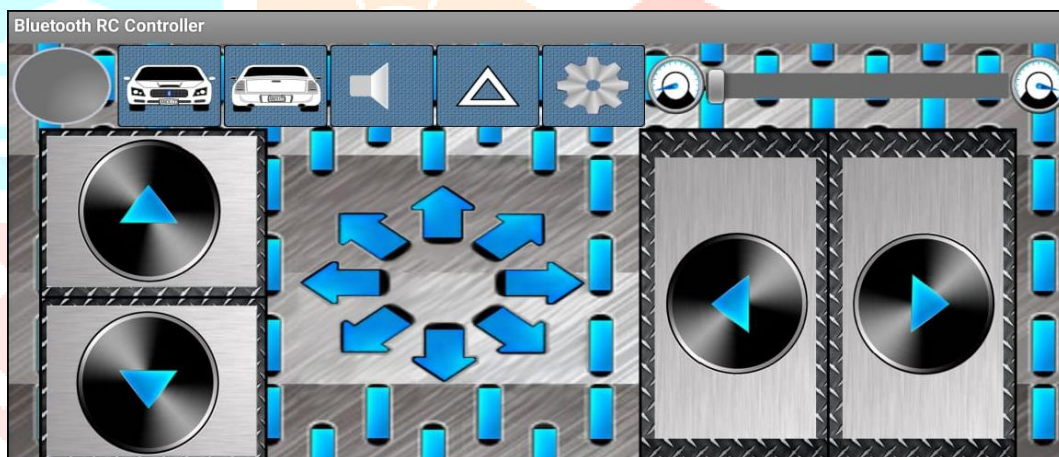


Fig 2. Robot Communicate With Android App

IX. Conclusion

In conclusion, The IoT-Based Fire Fighter Robot effectively demonstrates the integration of autonomous fire detection, real-time decision-making, and remote control capabilities for small-scale firefighting applications. The system's core functionality—reliable flame detection using infrared sensors, efficient navigation via DC gear motors, and precise fire suppression through a servo-controlled nozzle—shows strong potential for deployment in hazardous indoor environments. The Bluetooth-enabled manual control system provides operators with situational flexibility.

Experimental results validate the robot's rapid response time, stable communication, and efficient power utilization through the Li-ion battery.

the IoT-Based Fire Fighter Robot offers a promising, energy-efficient solution for reducing human risk during firefighting operations, paving the way for intelligent, autonomous firefighting systems in industrial and residential applications.

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