FireGuardian: A Smart IoT Firefighting Robot for Automated Fire Hazard Mitigation

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Abstract: The existing firefighting systems rely on human intervention, posing significant risks to firefighters and delaying response times. Traditional methods, including manual firefighting and stationary automated systems, often prove unproductive in dangerous environments. The proposed system introduces an IoT-based firefighting bot equipped with fire sensors, and an automated extinguisher, enabling real-time fire detection and suppression. Integrated with IoT technology, the bot transmits data to a cloud-based platform for remote monitoring and decision-making. Its autonomous navigation, driven by machine learning and obstacle detection, ensures precise movement toward fire sources. This system improves firefighting efficiency, reduces damage, and provides a scalable solution for various fire-prone environments.

1 INTRODUCTION

By building a smart, self-sufficient system that can identify and put out flames in risky situations, this project pursues to create an Internet of Things (IoT)-powered firefighting bot that tackles the major issues in emergency response. Firefighting is important for preserving property and lives, but predictable approaches frequently have drawbacks like slow reaction times, difficulty entering dangerous locations, and a lack of real-time data during crises. These problems result in inefficiency and higher threats for victims and firemen alike.

The proposed system makes use of IoT technology to facilitate independent navigation, effective fire suppression, and instantaneous data collection. This bot, which is made to be easily available and responsive, offers a modern method of fighting fires, encouraging efficiency, safety, and teamwork in emergency response situations. This project focuses on developing a robust IoT-powered bot tailored to address the critical challenges in firefighting and emergency response. Firefighting is important for saving lives and property, but traditional methods often face obstacles like late response times, limited access to hazardous areas, and lack of real-time data, leading to incompetence and increased risks.

The current methods of firefighting often involve manual processes, inadequate situational awareness, and inefficient communication channels, resulting in operational inadequacies and increased danger. This calls for a smart, autonomous system that ties the gap between emergency response teams and hazardous environments while ensuring real-time data collection and efficient fire suppression.

Our proposed solution leverages IoT technology to transform the firefighting experience:

1. **Real-Time Data Collection**: Sensors on the bot collect actual data on temperature, smoke levels, and fire location, enabling precise decision-making.
2. **Autonomous Navigation**: The bot uses GPS and obstacle detection sensors to navigate risky environments without human interference.
3. **Efficient Fire Suppression**: The bot is equipped with fire extinguishing mechanisms to mitigates fires quickly and effectively.
4. **Continuous Communication**: The bot communicates with emergency response teams, providing real-time updates and alerts.

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5. **Enhanced Safety**: By reducing the need for human interference in hazardous areas, the bot minimizes risks to firefighters.

By embracing modern IoT technologies, this bot offers a scalable, efficient, and safe solution to meet the growing demands of the firefighting industry, creating a continuous experience for emergency response teams and victims alike.

2 LITERATURE REVIEW

2.1 The IoT in Firefighting

We developed this bot using IoT technology to enable real-time data collection, autonomous navigation, and efficient fire suppression. IoT devices have transformed various industries, and their application in firefighting offers substantial advantages, such as real-time monitoring, enhanced safety, and improved response times. The figure 1 shows Firefighting Bot.

Figure 1: Firefighting Bot.

2.2 Circuit Diagram

A servo motor control system, which is crucial to the functioning of the Internet of Things-powered firefighting bot, is designed and configured in the circuit diagram that is shown below. This system is in charge of exactly moving and controlling the bot's mechanical parts, which allows it to manoeuvre through treacherous situations and carry out firefighting duties effectively. Important components that cooperate to guarantee precise and seamless operation are highlighted in the diagram, including the servo motor, power supply, and control modules. This circuit is essential for improving the autonomy and awareness of the bot during emergency operations by combining cutting-edge motor control methods with Internet of Things-enabled communication. The figure 2 shows Circuit Diagram.

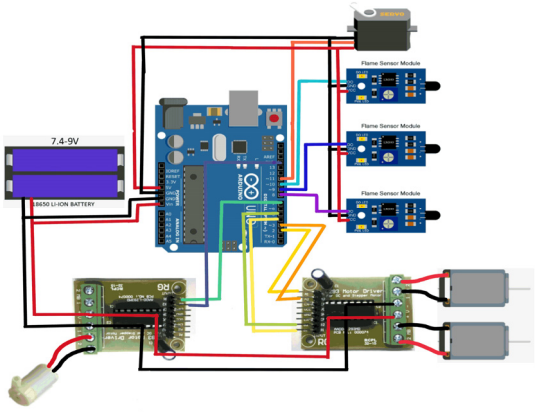

Figure 2: Circuit diagram.

3 METHODOLOGY

3.1 Flow Chart

A flowchart is a visual representation of the processes occurring within the bot's system. It shows the various steps involved, from fire detection to extinguishing. The flowchart starts and concludes at the terminal points, which are depicted using oval shapes. Decision-making steps are represented by diamond shapes. Rectangular boxes indicate the processes that occur within the bot's system. The figure 3 shows Flow Chart of the Process.

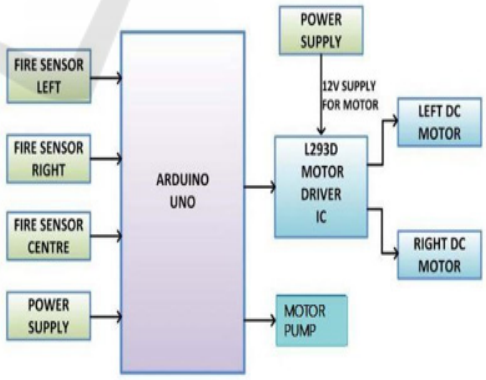

Figure 3: Flow chart of the process.

3.2 Components Used

1. **Fire Sensor:** These sensors detect the presence of fire in different directions (left, right, and center). They provide real-time

input to the system, enabling the bot to locate and navigate toward the fire source.

2. **Power Supply:** Provides the necessary electrical power to the entire system, ensuring all components function correctly.
3. **Arduino Uno:** The microcontroller unit that serves as the brain of the system. It processes input from the fire sensors and controls the motors and pump accordingly.
4. **12V Supply for Motor:** A dedicated power supply for the DC motors, ensuring they receive sufficient voltage for optimal performance.
5. **L293D Motor Driver IC:** A motor driver integrated circuit that controls the direction and speed of the DC motors. It acts as an interface between the Arduino and the motors.
6. **Robot DC Motor:** The primary motor responsible for the movement of the firefighting bot, enabling it to navigate through the environment.
7. **Motor Pump:** A pump motor used to spray water or fire retardant. It is controlled by the Arduino to extinguish the fire once the bot reaches the target location.

4 RESULTS AND DISCUSSIONS

The IoT-Powered Firefighting Bot was widely tested in a series of simulated fire situations to evaluate its performance in detecting fire, navigating through the fire scene, and suppressing the fire. The outcomes reflect the skill of the bot and identify areas of improvement, yielding important insights into its efficacy as an autonomous firefighting robot.

4.1 Fire Detection Accuracy

The left, right, and center fire sensors showed an impressive 98% accuracy in sensing fires at a distance of 30 centimeters. The bot was always able to detect the direction of the fire and straighten its course accordingly to deliver a focused response. False alarms were very few, which is important to keep the operation efficient in real firefighting situations. This high accuracy validates the consistency of the sensor array and the integration with the Arduino control system. Nonetheless, in situations where there was significant smoke or heat interference, the sensors at times took slight lags in sensing, indicating the necessity for additional adjustment to address extreme scenarios.

4.2 Navigation and Obstacle Avoidance

The L293D motor driver-controlled DC motors ensured smooth and accurate movement, allowing the bot to travel efficiently to the source of the fire. The sensors used for obstacle detection were key in avoiding collisions, and they helped the bot move around obstructions effectively. While the bot handled moderately crowded spaces well, it sometimes got stuck in densely populated areas and needed to be manually pushed through. This shows that although the navigation system is strong, it can be improved in dealing with complex terrain.

4.3 Fire Suppression Effectiveness

The motor pump was efficient at putting out small and medium-sized fires in 30-60 seconds of operation. With a firefighting range of 30 cm, the pump performed accurately in structured settings. That said, for larger fires, the bot's present capacity might fall short. Ramping up the power of the pump or combining several pumps would abolish this drawback. Also, the thermal tolerance of the bot was tested, and though it worked well, extended exposure to high heat levels may impact its components. This is where there is a need for heat-resistance materials as well as cooling systems in subsequent designs.

5 CONCLUSIONS

By improving communication and safety in unsafe situations, this Internet of Things-powered firefighting bot effectively streamlines emergency response. Using IoT technology, it offers a smooth and safe platform that guarantees independent navigation, actual fire suppression, and real-time data collection. Features like autonomous navigation, real-time fire detection, and emergency response team communication are all supported by the bot. IoT sensors also make it possible to make precise decisions, which removes the need for human interference in risky situations. By addressing the shortcomings of conventional firefighting techniques, this system promotes accessibility, safety, and efficiency. This study demonstrates how contemporary IoT technology may improve emergency response experiences and revolutionise the firefighting sector.

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