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FI-BOT Smart Fire-Fighting Robot Using Arduino and Sensors

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Abstract
Firefighting is a dangerous profession that exposes firefighters to life-threatening risks, including toxic gases and extreme heat. To improve safety and efficiency, automation and robotics are increasingly being integrated into fire suppression systems. This paper presents the development of an autonomous fire-fighting robot designed to detect and extinguish fires in hazardous environments where human intervention may be difficult or dangerous. The robot operates using an ARDUINO-based control system, fire sensors, and a motorized water spraying mechanism. When a fire is detected, the sensors transmit a signal to the ARDUINO, which activates the motor driver to spray water toward the fire source. This automated approach reduces risks to firefighters, minimizes damage, and enhances fire safety by providing a quick and efficient fire suppression response. The proposed system contributes to advancements in smart firefighting technology and offers a practical solution for fire prevention and emergency response.

1. Introduction

One of the most critical aspects of fire disasters is the loss of human life, especially when firefighters risk their own lives to save others. In certain situations, accessing a fire-affected area becomes impossible due to hazardous conditions such as explosive materials, dense smoke, and extreme heat. A rapid response to fire detection can prevent catastrophic consequences. Based on statistical data, fires can occur both in residential and industrial settings, often resulting from minor sparks that escalate into large-scale fires. Inadequate fire management systems put both industrial workers and residents at risk. However, effective fire control measures can help mitigate these dangers. To address this issue, a fire-fighting robot is proposed. Modern advancements in robotics have led to the development of systems that replace humans in hazardous and life-threatening tasks. The increasing use of robots ensures the safe execution of labor-intensive and high-risk jobs. The proposed Fire Extinguishing Robot operates using IoT technology to autonomously detect and suppress small fires. It is designed to sense fire, navigate toward the affected area, and extinguish it using a built-in suppression mechanism. For fire detection, the robot is equipped with three flame sensors positioned for directional sensing—one for detecting flames on the left, another for the front, and the third for the right. Once a fire is detected, the robot adjusts its movement to reach the source and activates its fire suppression system, which deploys water via a built-in pump. This system enhances fire surveillance, helping prevent large-scale accidents and significantly reducing the risk to human lives [2]

2. Module Design

The fire-fighting robot consists of multiple functional modules that work together to detect and extinguish fires efficiently. Each module is responsible for a specific task, ensuring smooth operation and coordination.

2.1. Fire Detection Module

This module is responsible for identifying the presence of fire using sensors and transmitting the data to the control system. It includes:

IR Flame Sensors – Positioned to detect fire from multiple directions. Figure 1 shows IR Flame Sensor

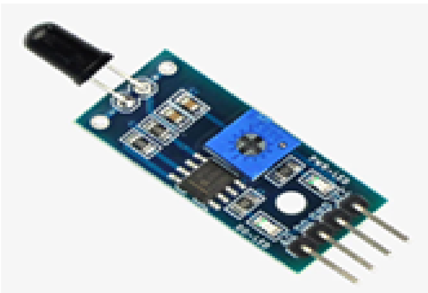

Figure 1 **IR Flame Sensor**

Microcontroller (Arduino) – Processes sensor data and determines the fire's location. Figure 2 shows Microcontroller (Arduino)

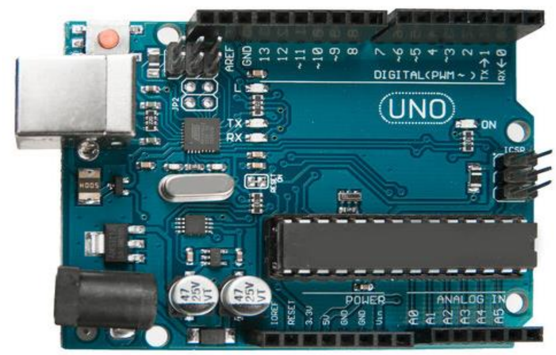

Figure 2 **Microcontroller (Arduino)**

2.2. Navigation and Mobility Module

BO Motors (Battery Operated Motors): DC motors with gear reduction for optimal torque and speed, ensuring efficient control and movement.

Rubber Wheels: Provide grip and stability on various surfaces, preventing slipping and enhancing traction in fire-related environments. Figure 3 shows BO Motor & Rubber Wheels [1]

Figure 3 **BO Motor & Rubber Wheels**

Motor Driver – Controls motor speed and direction. Figure 4 shows BO Motor & Rubber Wheels

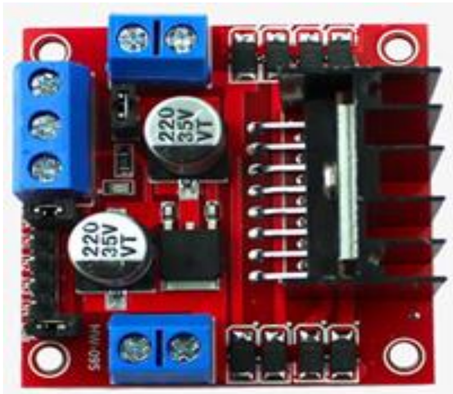

Figure 4 **BO Motor & Rubber Wheels**

Servo Motors – Assist in adjusting the fire-extinguishing nozzle. Figure 5 shows Servo Motor

Figure 5 **Servo Motor**

3. Fire Suppression Module

Once the fire is detected, this module activates the extinguishing mechanism. It includes a

Submersible Water Pump, which sprays water upon fire detection, and a Servo Motor Nozzle Control, which adjusts the direction of the water flow to accurately target the fire source. This ensures efficient and precise fire suppression. Figure 6 shows Motor Model [3]

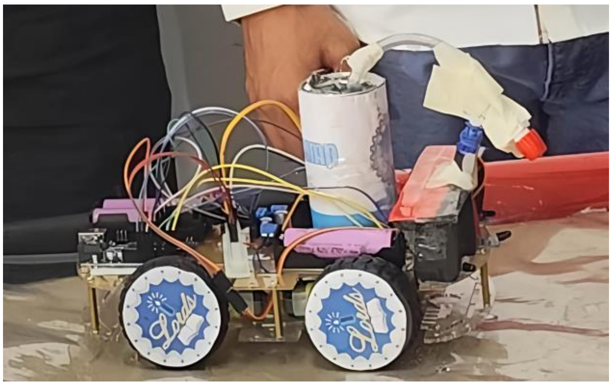

Figure 6 Motor Model

4. Communication and Control Module

This module enables real-time communication between the robot and the Arduino software for seamless operation. It comprises:

- **Microcontroller (Arduino)** – Acts as the central processing unit.
- **Communication Module** – Ensures data exchange and control signals.

Each module plays a critical role in ensuring that the robot can autonomously detect, navigate, and extinguish fires, reducing risks to human firefighters and improving overall fire safety.

4.1. Firefighter Robot: Heat Sensor Placement

The heat sensors in a Firefighter Robot are strategically placed for maximum efficiency. Just like a piezoelectric generator in a shoe is positioned at high-pressure points (heel and toe), the thermal sensors in the Firefighter Robot are placed at critical fire-prone areas. These sensors detect temperature changes quickly, ensuring fast fire detection and response. Fig. 2 illustrates the optimal sensor arrangement in the robot for effective fire monitoring The Firefighter Robot features a network of thermal sensors connected in series for efficient fire detection. The front panel has a linear sensor arrangement for wide coverage, while the rear panel uses a circular arrangement for focused heat detection. The power system captures and stores energy efficiently in a battery unit, ensuring continuous operation. The voltage is monitored in real-time, and once it reaches 5.2V, the system activates, supplying power to essential components like the motor, sensors, and fire suppression system. Figure 7 shows Fast Fire Detection and Response

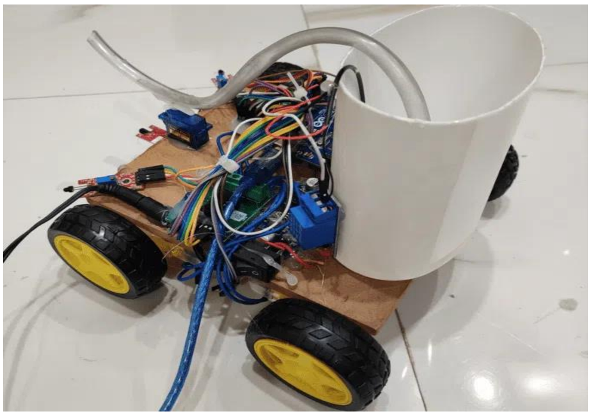

Figure 7 Fast Fire Detection and Response

4.2. Wireless Power Transfer (WPT)

In the early 20th century, Nikola Tesla explored wireless power transmission, but early methods like Tesla coils generated large electric fields. In recent years, the need for autonomous robots has revived interest in wireless power technology. Similar to Wi-Fi eliminating cables, wireless power enhances Firefighter Robot efficiency by using resonant electromagnetic coils for energy transfer. Unlike traditional induction or microwave methods, this system relies on magnetic loop antennas, tuned to the same frequency, ensuring safe and reliable wireless charging in fire-prone areas. The Firefighter Robot can utilize wireless power transfer based on electromagnetic induction for continuous, cable-free charging. Similar to Evanescent Wave Coupling, a primary coil generates a magnetic field, inducing current in a receiver coil inside the robot. Traditional induction has limited range, but resonant coupling improves efficiency by tunneling energy directly to the robot's power unit. This method allows the robot to be wirelessly charged in fire zones, reducing battery constraints, energy loss, and interference while ensuring safe, continuous operation. [4]

5. System Design & Circuit

The schematic design of the power transmission system for the Firefighter Robot is shown in Figure 8 Fig. 3 shows the generation and transmission circuit, where the piezoelectric generator serves as the power source, transmitting energy wirelessly using the wireless power transfer technique.

The receiver and charging circuit are shown in Fig. 4. Here, the receiver (RX) and capacitance bank are connected in parallel, with a rectification circuit converting power into DC form to charge the robot's battery. A regulator can be added between the rectifier and charging circuit for better power control. can utilize wireless power transfer based on electromagnetic induction for continuous, cable-free charging. Similar to Evanescent Wave Coupling, a primary coil generates a magnetic field, inducing current in a receiver coil inside the robot. Traditional induction has limited range, but resonant coupling improves efficiency by tunneling energy directly to the robot's power unit. This method allows the robot to be wirelessly charged in fire zones, reducing battery constraints, energy loss, and interference while ensuring safe, continuous operation. Figure 9 shows Receiver and Charging Circuit, Figure 10 shows Car Model 9 (Figure 11)

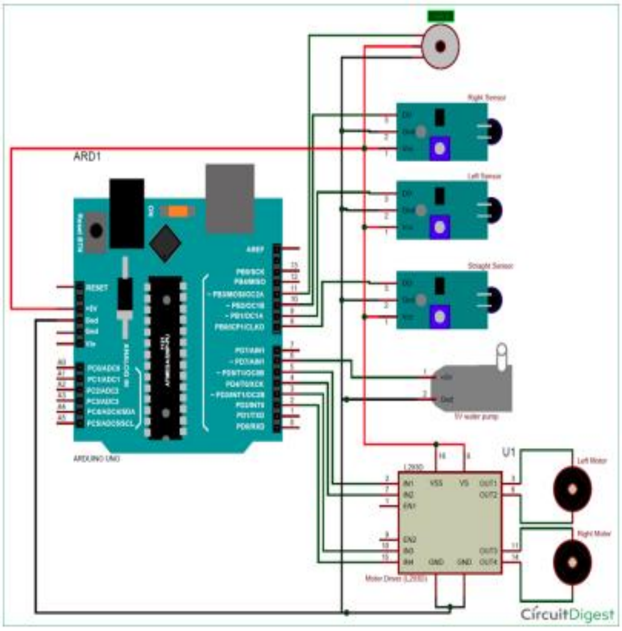

Figure 8 Fire Fighter Robot: Wireless Power Transmission System

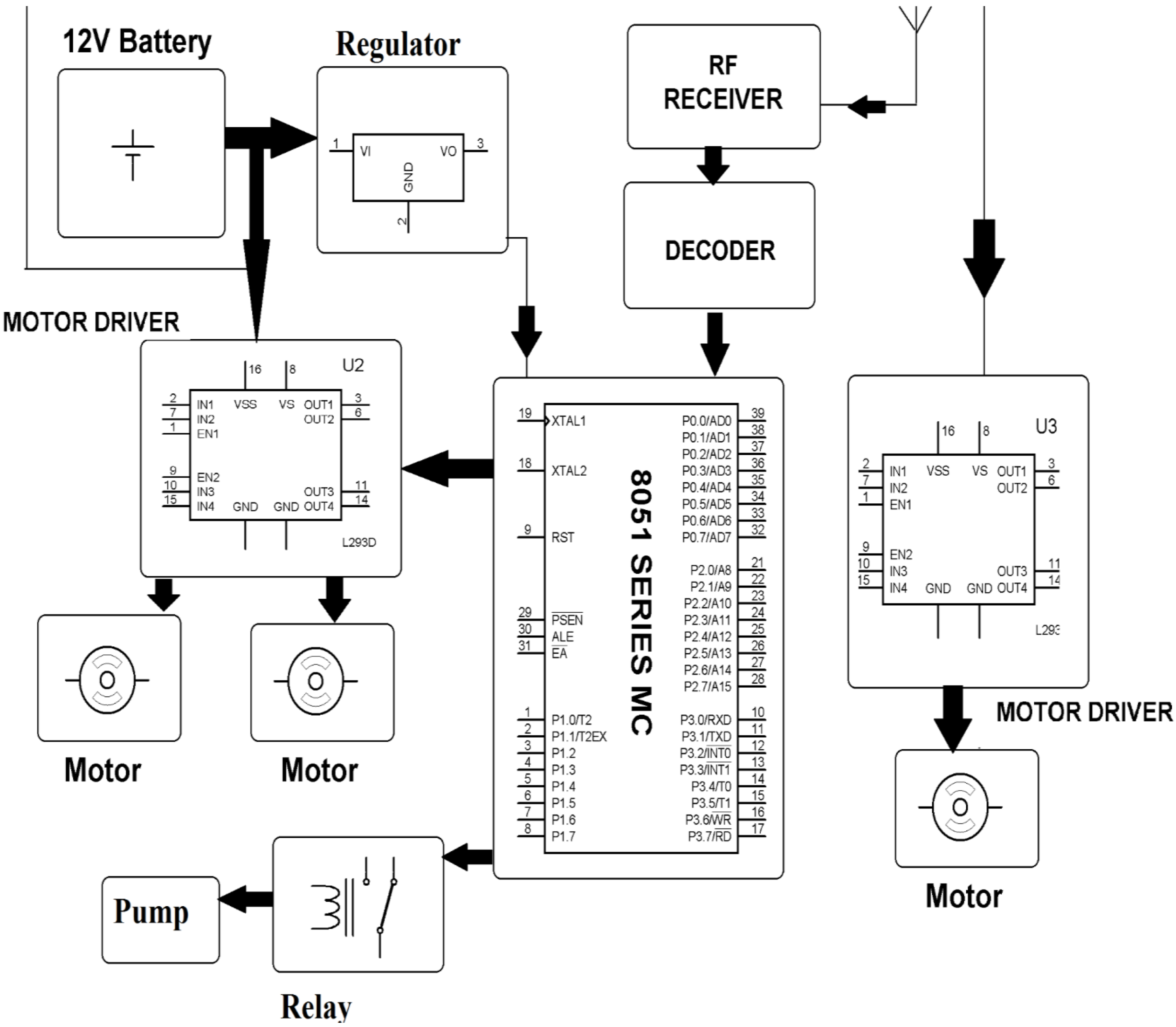

Figure 9 Receiver and Charging Circuit

6. Prototype

Figure 10 Car Model

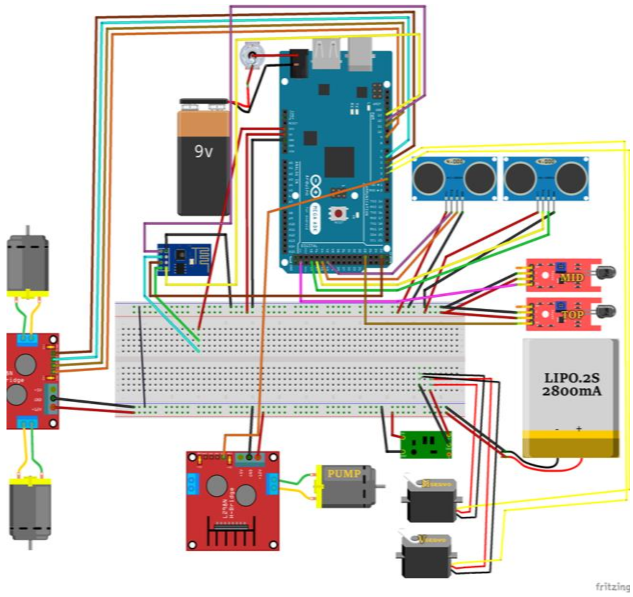

Figure 11 Circuit Wiring

Figure 12 Mobile Connection

Conclusion

In this project, we have developed a wireless power system for the Firefighter Robot, ensuring continuous operation without reliance on traditional charging methods. This innovation enhances autonomous firefighting capabilities, making the robot more effective in emergency situations. The system is versatile, designed for seamless energy transfer to power the robot's functions. As firefighting operations demand uninterrupted performance, this research presents a potential breakthrough in robotic emergency response. Future work will focus on enhancing power efficiency, integrating real-time monitoring, and improving energy security to make the Firefighter Robot even more reliable and self-sufficient in critical situations. [5]

Future Scope

There can be several future enhancements for the firefighter robot, including:

- Advanced Fire Detection Systems – Using AI-powered sensors to detect fires more accurately.
- Enhanced Mobility – Improving movement in rough or collapsed environments.
- Autonomous Navigation – Using LiDAR and machine learning for better pathfinding.
- Integration with Drones – Combining aerial surveillance for better fire assessment.
- Improved Water and Foam Delivery Systems – More efficient fire suppression techniques.
- Heat-Resistant Materials – Enhancing durability in extreme conditions.
- Wireless Power Systems – Using remote charging for continuous operation.
- Communication with Firefighters – Real-time data sharing with human teams.
- Smart City Integration – Connecting with IoT systems for faster fire response.
- Military and Industrial Applications – Adapting robots for hazardous environments.

By focusing on these advancements, the firefighter robot can become a more effective, reliable, and life-saving solution in fire emergencies.

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Bibliography

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