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ARDUINO BASED AUTOMATIC FIREFIGHTING ROBOT

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Abstract: Firefighters play a critical role in detecting and extinguishing fires, but their work often places them in dangerous situations, particularly due to exposure to toxic gases in firefighting environments. To address these challenges, we have developed an autonomous firefighting robot designed to detect and extinguish small fires in hazardous environments, reducing the need for human intervention. Powered by an Arduino microcontroller, this robot integrates various sensors and modules to achieve real-time fire detection, movement control, and extinguishing operations. Equipped with flame sensors, temperature sensors, and an IR module, the robot can effectively identify the presence and intensity of fire. It autonomously navigates toward the fire source using a motorized chassis and a fire detection algorithm. Once the fire is located, the on-board water pump or extinguisher system is activated to suppress the flames. The robot's modular design allows for adaptability in various firefighting scenarios, including indoor and outdoor environments. It utilizes DC motors for movement, a servo motor for precise control of the extinguishing mechanism, and a communication system for remote monitoring. The system is energy-efficient, scalable, and cost-effective, making it suitable for domestic, industrial, and even forest fire prevention applications.

Keywords: **Firefighting Robot, Autonomous Systems, Arduino, Fire Safety, Sensor Integration, Wireless Communication, Flame Detection, Microcontroller, Fire Suppression.**

1. **Introduction:** An autonomous or remote-controlled device intended to support fire detection, suppression, and rescue efforts is known as a firefighting robot. These robots can work in dangerous and difficult situations where human firefighters would be in grave danger since they are outfitted with sensors and water or foam nozzles. Their main function is to help with firefighting duties by identifying flames, entering hazardous locations, and putting them out with little assistance from humans. Rakib et. all worked on autonomous firefighting robots designed to respond quickly and effectively to fires in closed areas where high-value items are stored. These areas are generally unlocked only when needed, so it is crucial to extinguish fires promptly to prevent significant monetary losses [1]. Adilshah et. all focused on the use of these robots in extreme danger zones, such as airplanes, chemical plants, processing factories, and nuclear reactors, where the risk to human firefighters is considerable [2]. The work by Hassanein et al explores the integration of infrared sensors in the robot's design,

which significantly enhances the robot's capability to deal with multiple environmental challenges and conditions. The result is an effective firefighting robot for cluttered or obstructed areas [3]. As it has been stated by Yahaya et a. al, the robots are designed in a compact size to allow them to penetrate into places that are smaller or enclosed. Such a design becomes important in situations where traditional firefighter equipment would be too large to manoeuvre effectively in such areas. [4].

2. Literature Review:

Shuhaimi et. all worked on equipping the robot with high-sensitivity sensors, enabling it to search for, detect, and extinguish fires, thereby fulfilling the primary objectives of fire emergency response in confined spaces [5]. The work of Raju et. all was to develop an Arduino-based algorithm, which formed the main core of the robot's detection and navigation system. With the help of this, the robot could detect fire sources, measure distances to the fire, and move closer to these areas to extinguish them [6]. The entire work done here is from Diwanji et. all: fire detection by robot and suitable distance after which it activates a centrifugal pump for spraying water on the fire. This method is simple yet very effective, as it is an efficient means of extinguishing small to medium fires. Modern firefighting robots now employ a combination of inert gases, such as nitrogen, and water mist to effectively put out fires. Robots become very important when they look for and put out fires in their early stages, before they cause widespread damage. These robots have become more feasible and accessible with a lot of improvement in computing and nanotechnology [7]. Taha et al. further said that fire accidents are the most dangerous types of incidents, resulting in indistinguishable casualties and wide-spread property damage. Fire destroys everything it passes through, even lives [8]. Saturday et. all stated that there are various fire detection methods, and ultraviolet (UV) sensors are the most common. They have a long detection range, and some of them can detect fire through walls; hence, they are very useful in confined or obstructions [9]. Hemashree et. all revealed that studies, in general, indicate that electrical wiring is a frequent cause of fire ignition; thus, there is a need for reliable fire detection and response systems. Further, research by Ball & Fisher highlights the dangers posed by rooftop fires and the difficulties faced by firefighters; hence, they emphasize the necessity of automated fire detection and extinguishing systems [10]. Reddy et. all designed a dynamic robotic system able to cross obstacles by using ultrasonic sensors and fuzzy logic for direction finding. This makes the robot capable of overcoming different barriers and allows moving in complex environments without fixed predetermined path [11].

3. Protype Design

The L298 motor controller has two Pulse Width Modulation (PWM) pins that are used to regulate motor speed. The motor can rotate either clockwise or counterclockwise by altering the polarity of the electrical signal at its input. On the Arduino Uno, pins 5, 6, 9, and 10 can be used for PWM. Here, we have connected pins 5, 6, 7, 8, 9, and 10 from the Arduino to the ENA, IN1, IN2, ENB, IN3, and IN4 inputs of the L298 motor

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controller, respectively. The V_{in} and GND pins of the Arduino are connected to the motor controller's 6–35V and GND pins, respectively. Two left and two right motors are connected to the motor controller outputs A and B, respectively. Additionally, three fire sensors are connected in parallel to the Arduino's 5V and GND pins, with analog pins A1, A2, and A3 each linked to a fire sensor. The Arduino's A4, 5V, and GND pins are connected to a small servo motor. The base of a TIP22 transistor is connected to Arduino pin A5 through a 1kΩ resistor, and its emitter is connected to GND.The water motor is connected to the Vin pin of A5 in parallel with a 102pF capacitor and an IN4148 diode. The battery's GND is connected to the Arduino, and a switch is connected in series with the battery's V_{in} pin.

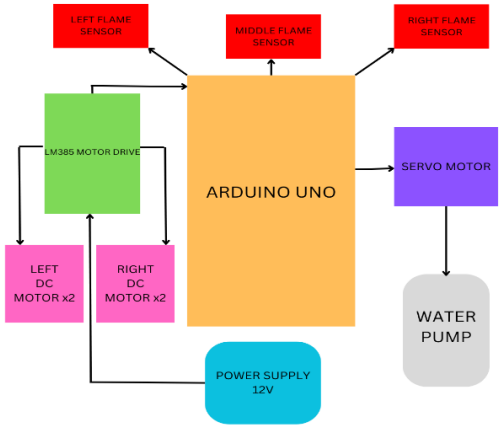

Figure 1: Block diagram of Arduino based automatic firefighting robot.

Table 1: Component list.

SL. No.	Components	Specifications	Quantity
1	Arduino UNO	ATMega328	1
2	Motor Driver	L398N	1
3	Micro Servo	Tower Pro – M990S	1
4	Water Pump	5V	1
5	Lithium-Ion Battery	3.7V	2

Our firefighter's fundamental plan is to use an Arduino UNO to confirm the discovery of the fire once it has been detected by a flame sensor. The Arduino UNO sends this signal to the dc motor, which enables the fire fighting robot to pump water. The water pump receives the pressure from the motor. A 7.4V dc lithium-ion battery power source powers the motor. The battery activates when the Arduino detects a fire. The Arduino sends a signal to the LM96.

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After that, it gives instructions to the four BO motors that attach to the four fire guardian tires. It moves to the area where a fire has been spotted and uses water to put it out.

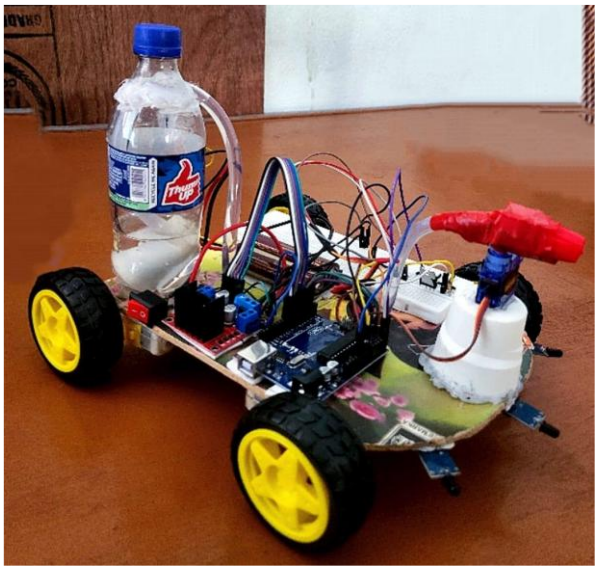

Figure 2: Prototype of firefighting robot.

The Arduino code enables the system to detect fire within 15 cm, using the three flame sensors to digital pins. Controlled by the Arduino, a motor pump activates to extinguish the fire, and a micro servo adjusts its angle to 120 degrees to target the fire effectively.

4. Result and analysis

The system was tested using a lighter as the fire source. It successfully extinguished flames within 15 cm under constant conditions. When the fire intensity doubled, the reaction time reduced by half. However, increasing the lighter's flame to five levels required only three times more extinguishing time. The water pump pressure was highest at 100% water level and halved at 50%, causing the robot's effective range to decrease exponentially. With five flame sensors, the system covered a 180-degree angle, significantly improving reaction speed and accuracy. These results demonstrate the robot's efficiency and scalability in handling varying fire scenarios.

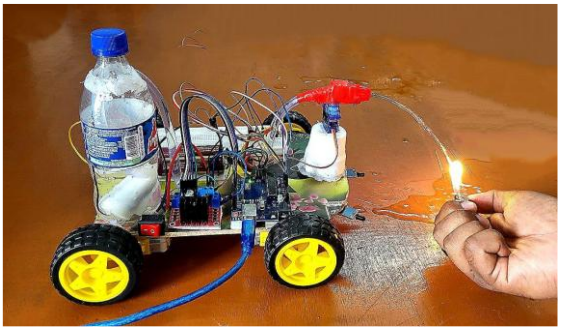

Figure 3: Working module of firefighting robot

5. Conclusion

To sum up, firefighting robots are a revolutionary development in emergency response technology that greatly improves the efficacy, safety, and efficiency of firefighting operations. These robots can put out fires in dangerous situations by combining sophisticated sensors, self-navigating capabilities, and precise extinguishing systems, reducing hazards to human firefighters and enhancing results overall. Firefighting robots will probably become more adaptable and extensively used as technology develops, becoming essential in controlling fire-related emergencies and saving lives. Their creation represents a significant advancement in the continuous endeavour to safeguard individuals and property in difficult and hazardous circumstances.

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