# FIRE FIGHTING ROBOT

## 1. Aim

To design and build an autonomous fire-fighting robot that can detect fire using IR sensors, avoid obstacles, stop at a safe distance, and extinguish fire using a water-spraying mechanism controlled by an Arduino Uno.

This system is intended to work reliably in small indoor environments such as laboratories, classrooms, or small rooms where a fire source like a candle or small flame can be detected and controlled quickly.

The robot is designed as an educational and proof-of-concept project to demonstrate how embedded systems, sensors, and actuators can be integrated to perform an intelligent safety task without human intervention.

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## 2. Components Required

| Component | Quantity |
|---|---|
| Arduino Uno | 1 |
| IR Sensors (Fire detection) | 3 |
| Ultrasonic Sensor (HC-SR04) | 1 |
| L298N Motor Driver | 1 |
| DC Gear Motors + Wheels | 4 |
| Servo Motor (Nozzle control) | 1 |
| Water Pump Motor | 1 |
| Relay Module | 1 |
| Rechargeable Li-ion Batteries (18650 or similar) | 3 |
| Chassis (Robot body) | 1 |
| Jumper Wires | As needed |
| Mini Water Tank + Pipe | 1 |
| Battery Holder/Case | 1 |
| Switch | 1 |
| Breadboard or PCB | 1 |

Each component plays a specific role in the overall functioning of the robot. The Arduino Uno acts as the central controller, the sensors provide environment feedback, the driver modules interface high-current loads, and the mechanical parts such as motors and chassis enable physical movement and water spraying.

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# 3. Objectives

- To build a robot that can detect fire using IR sensors.
- To stop the robot at a safe distance from the fire using an ultrasonic sensor.
- To extinguish the fire by activating a water pump and rotating the nozzle via a servo.
- To avoid obstacles during movement using ultrasonic sensing.
- To run entirely on battery power and function autonomously without manual control.

In addition, the project aims to:

- Demonstrate real-time decision making by the microcontroller based on sensor readings.
- Provide a low-cost platform that can be further upgraded with additional features such as wireless monitoring or data logging in future work.

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# 4. Methodology

The methodology describes how the robot senses its environment, makes decisions, moves, and performs fire-extinguishing actions.

## 4.1 Sensing Fire

IR sensors are used to detect the presence of fire by sensing infrared radiation emitted by the flame.

Multiple IR sensors are placed at the front of the robot to increase the detection area and allow the robot to roughly align itself toward the fire source.

The Arduino continuously reads the digital outputs of these sensors and interprets a high or low state (depending on wiring) as the presence or absence of a flame.

### 4.2 Distance Control & Obstacle Avoidance

An ultrasonic sensor (HC-SR04) is mounted on the front of the robot to measure the distance to any object, including the fire source.

The sensor sends an ultrasonic pulse and measures the time taken for the echo to return; from this time, the distance is calculated in centimeters.

Using this measured distance, the robot is programmed to:

- Move forward while the fire is not detected or is still far away.
- Stop approximately 2 inches before reaching the fire, maintaining a safe distance to avoid direct contact but remain close enough for effective water spraying.
- Detect obstacles such as walls, furniture, or other objects and change direction or stop to prevent collision.

## 4.3 Movement

DC gear motors controlled by the L298N motor driver are used for robot mobility.

The motors are connected in a four-wheel drive configuration to provide sufficient traction and stability for the robot chassis.

The Arduino controls the direction and speed of the motors by sending appropriate logic signals and PWM signals to the L298N driver, enabling forward, backward, left, and right movements as required by the navigation algorithm.

### 4.4 Extinguishing Fire

When fire is detected and the robot is at a safe distance, the Arduino triggers the relay module to turn on the water pump.

The pump draws water from the mini water tank and sends it through a pipe to the nozzle mounted at the front of the robot.

A servo motor is used to rotate the nozzle left and right, spraying water over a wider area to ensure the flame is fully covered and extinguished rather than just hit at a single point.

The water pump and servo remain active for a predefined duration or until the IR sensors no longer detect the fire, indicating that the flame has been extinguished.

### 4.5 Power Supply

The entire system is powered by three lithium-ion rechargeable batteries (18650 or similar).

Power distribution is managed so that the Arduino and logic circuits receive a stable regulated voltage, while the motor driver and pump receive sufficient current for proper operation.

Separately managing power to the Arduino and motor drivers helps minimize noise and voltage drops, thereby improving system reliability and preventing unexpected resets.

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## 5. Procedure

1. Assemble the robot chassis and mount all hardware components (Arduino, sensors, pump, battery pack, etc.). Secure the components firmly using screws, double-sided tape, or brackets to prevent movement during operation.
2. Connect:
    - IR sensors to Arduino digital pins for fire detection.
    - Ultrasonic sensor to specific trigger and echo pins for distance measurement as per the Arduino code design.
    - Motors to the L298N motor driver and then connect the driver inputs to Arduino control pins.
    - Servo motor signal wire to a PWM-capable Arduino pin, and its power to the regulated supply.
    - Water pump to the relay output, and relay input control pin to the Arduino.
3. Verify all power connections, common grounds, and polarity before powering the system to avoid damage to components.
4. Upload the code to the Arduino to:
    - Continuously read IR and ultrasonic sensor data.
    - Move forward until fire is detected within a suitable range.
    - Stop approximately 2 inches before the fire.
    - Activate the water pump and rotate the servo to sweep the water jet over the flame area.
5. Test the robot by placing a small fire source (e.g., a candle) in a safe, controlled environment and observing its detection and extinguishing behavior.

6. Make adjustments to improve accuracy or range if needed, such as:
    - Tuning threshold values for IR sensors.
    - Adjusting ultrasonic distance limits.
    - Changing motor speed or servo sweep angles in the code.
7. Perform repeated trials under slightly different positions and distances of the candle to evaluate the consistency and robustness of the robot behavior.

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## 6. Result and Discussion

The fire-fighting robot responds to the presence of a flame by first detecting it through IR sensors, then approaching it while maintaining obstacle avoidance, and finally stopping at the predefined safe distance before activating the extinguishing mechanism.

During operation, the integration of sensor data and decision logic in the Arduino allows the robot to behave autonomously without manual control, which demonstrates the practical application of embedded systems for safety tasks.

Performance may vary based on ambient light, sensor placement, and battery charge level, so proper calibration and testing are important to achieve reliable results.

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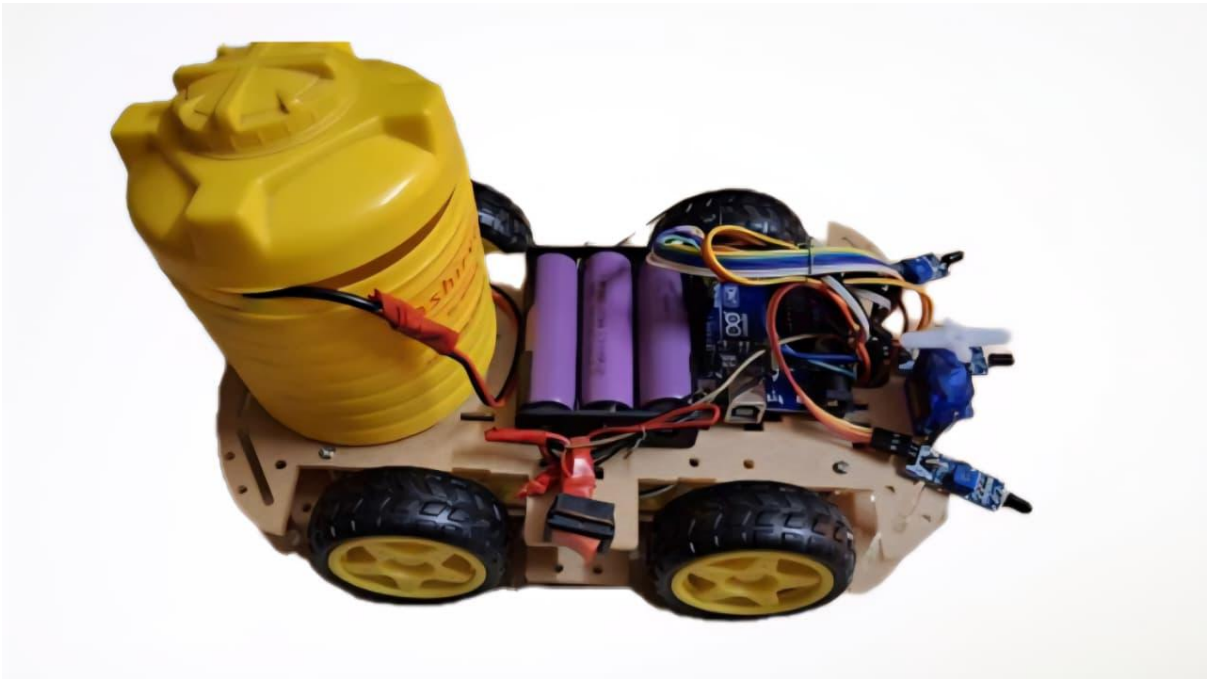
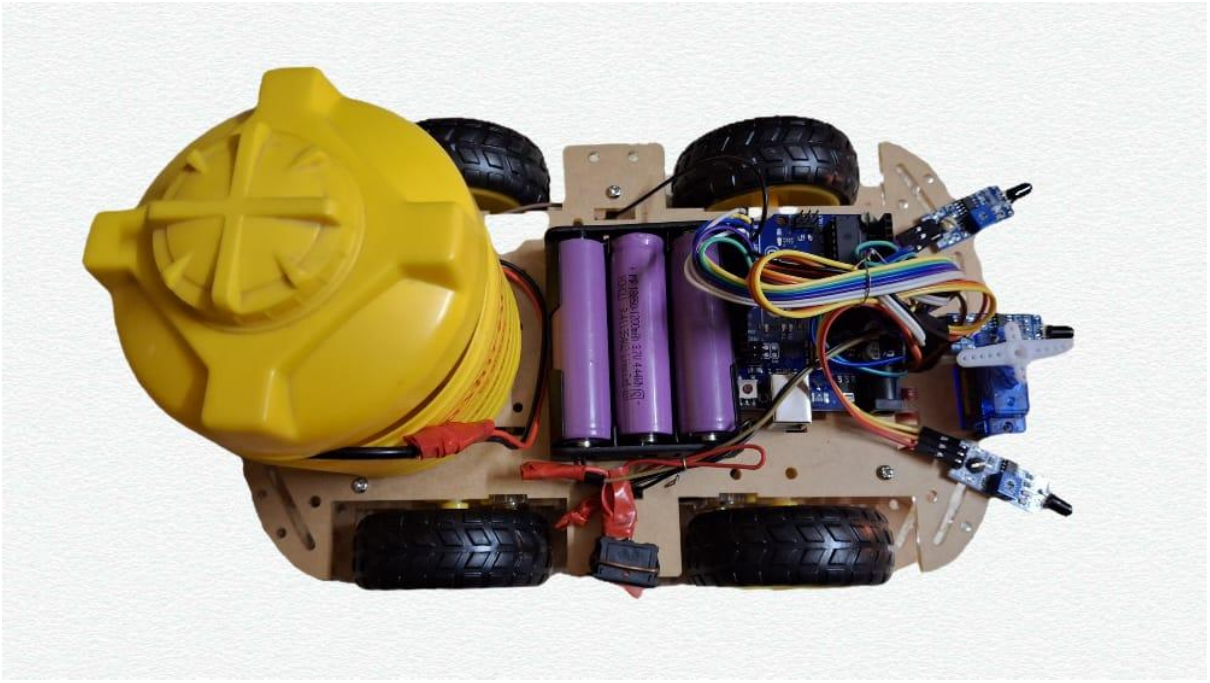
## 7. Assembled Robot Hardware

This section includes photographs or diagrams of the fully assembled robot hardware, showing the placement of the Arduino board, sensors, driver modules, batteries, water tank, and mechanical components on the chassis.



Assembled Robot Hardware-1



Assembled Robot Hardware-2

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## 8. Fire-Fighting Robot Prototype

This section presents the prototype robot in its final form, illustrating the compact arrangement of electronics and mechanical parts and the orientation of the nozzle used for water spraying.

Fire-Fighting Robot Prototype

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# 9. Conclusion

The developed fire-fighting robot successfully detects fire using IR sensors, approaches safely using ultrasonic distance sensing, and extinguishes the flame with a water spray mechanism.

It also avoids obstacles and functions completely autonomously, making it suitable as a small-scale demonstration of intelligent robotic fire safety.

This project demonstrates how embedded systems and automation can be integrated for disaster management applications, especially in fire-prone environments, and provides a foundation for future enhancements such as wireless control, camera-based monitoring, or multi-room navigation.