FIRE FIGHTING ROBOT

A PROJECT REPORT

submitted by

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BONAFIDE CERTIFICATE

Certified that this project report titled "**FIRE FIGHTING ROBOT**" is the bonafide work of **SOORYA M (230701325), SANJAY R (230701291), SAM DAVID S (230701280)**" who carried out the work under my supervision.

Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

Over the past few years, fire accidents have been a serious issue, tending to cause major damage to property, loss to the environment, and danger to human life. This project deals with the design and development of an autonomous fire-fighting robot that can detect and put out small fires in dangerous environments. The robot is provided with flame sensors that scan for the existence of fire in three directions—left, center, and right. On fire detection, the robot moves to the flame with differential motor control and triggers a water-pumping system operated by a relay and servo motor system to put out the fire.The Arduino microcontroller powers the system, which takes sensor data for processing and performs movement, detection, and extinguishing operations. This robot comes in handy where human access is risky or impracticable, for instance, in chemical factories, gas stations, or far-flung buildings. Fire is a great risk to both life and property and can quickly spread if not controlled in a timely manner. The conventional means of extinguishing fires may necessitate human intervention, which can be not always possible or safe, particularly in places like chemical plants, warehouses, or restricted areas where there are toxic gases or volatile materials. To mitigate these risks, this project introduces an autonomous fire-fighting robot that can detect, locate, and extinguish small-scale fires without human involvement.The robot is built around an Arduino microcontroller, which serves as the brain of the system. It uses a combination of three flame sensors positioned on the left, center, and right of the robot to continuously monitor for fire. Depending on the inputs from the sensors, the robot decides the direction of the flame and travels in that direction with a dual motor system. The navigation process is established to enable the robot to head towards the fire from the sensed direction. Once the source of the fire has come into range, the robot powers a water pump via a relay module and utilizes a servo motor to oscillate a nozzle, thus spraying water in a sweeping action in order to douse the flame. The synchronized movement of the servo and pump disperses the water across a greater distance, improving the prospects for successful fire extinguishment.

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CHAPTER 1

INTRODUCTION

Fire accidents are among the most destructive disasters, capable of causing irreversible damage to life, property, and the environment. Quick and effective fire detection and suppression are crucial to minimizing these losses. However, in many cases, especially in confined or hazardous environments, it is not always safe or possible for human firefighters to intervene immediately. This challenge has driven the need for intelligent systems that can operate autonomously to detect and suppress fires before they spread.

The aim of this project is to design and develop an autonomous fire-fighting robot that can detect flames and respond by navigating toward the fire source and extinguishing it using a water-based system. The robot utilizes flame sensors to determine the direction of the fire and employs a motor-driven platform to approach the fire. A water pump, controlled by a relay, and a servo motor-driven nozzle are used to extinguish the flame efficiently.

The core of the system is built around an Arduino microcontroller, which acts as the decision-making unit. It processes the data from multiple flame sensors and accordingly controls the movement of the motors and activation of the fire suppression system. This robot is particularly suitable for areas that are inaccessible or dangerous for humans, such as chemical factories, storage warehouses, or military applications.

This project not only showcases the integration of basic electronics and automation principles but also provides a practical demonstration of how robotics can play a vital role in safety-critical applications

1.1 Motivation

Fire incidents still constitute a significant danger to urban and industrial zones, usually causing the loss of life, property loss, and critical environmental degradation. Although conventional firefighting strategies greatly depend on human action, the methods are normally constrained by the availability, observability, and safety of the environment where the fire is present. In most emergency operations, firemen are exposed to life-threatening danger, particularly in areas such as chemical plants, warehouses containing explosive materials, or disaster areas where human entry is extremely risky or impossible.

The inspiration for this project is driven by the desire to create an intelligent, autonomous system that can identify and put out fires at an early stage—before they get out of control. With the progress in robotics and embedded systems, it is now feasible to create affordable robots that can carry out fire-fighting operations with little human intervention.

This robot project for fire fighting is not only intended to reduce the risk to human life but also serve as a prototype for scalable fire response systems in actual use. It illustrates how robotics and automation can be used to play a pivotal role in designing safer environments, particularly in smart homes, industrial installations, and remote locations. It is also a practical application of embedded systems, sensor integration, and autonomous navigation, thus being a valuable educational and technological achievement.

1.2 Objectives

The general aim of the project is to create and engineer an autonomous robot for fire detection and extinguishment in a designated area. Specific objectives are as follows:

1. Fire Detection:

• Utilizing flame sensors to precisely locate the existence and direction of the fire.

2. Autonomous Navigation:

• Designing a robot that can advance towards the origin of the fire based on inputs from sensors and utilizing motor-based wheels.

3. Fire Suppression Mechanism:

• To engage a water pump through a relay system and atomize water by a servo-operated nozzle for fire extinguishment.

4. Real-Time Decision Making:

• To execute sensor data processing on an Arduino microcontroller for real-time responses like movement and pump operation.

5. Safe Operation:

• To reduce the human presence requirement in dangerous environments through an autonomous reaction to fire detection.

6. Cost-Effective Design:

• To develop an inexpensive and scalable prototype to be improved for industrial or home use.

7. System Integration:

• To combine several hardware elements (sensors, motors, servo, pump, relay) into an operational and dependable robotic system.

CHAPTER 2

LITERATURE REVIEW

With the rising need for automation in safety-critical systems, a number of researchers and engineers have developed robotic solutions for fire detection as well as suppression. The autonomous fire-fighting robots' concept has been researched and used in various guises, from basic sensor-based robots to AI-based robots. This review of literature covers important milestones and current work in the area.

1. Sensor-Based Fire Detection Systems:

Simple fire detection systems typically employ flame, smoke, or gas sensors to detect fire threats. Flame sensors, especially, have been extensively employed in robotics owing to their high response rate and low cost. Most initial-level fire-fighting robots employ analog flame sensors coupled with microcontrollers such as Arduino or Raspberry Pi to sense the direction of the flame and cause the necessary movement.

2. Mobile Fire-Fighting Robots

Studies have confirmed the efficacy of mobile robotic vehicles that can be directed towards the source of fire and put out the fire by spraying water or other extinguishing materials. One study by N. Sharma et al. (2017) proved a low-cost wheeled robot with IR sensors and sprinkler system. The robot could sense a flame, approach it, and douse it by spraying water with a water pump, which exhibited potential in home settings.

3. Servo-Integrated Spraying Systems:

A few designs involve the use of servo motors for steering the nozzle direction to effectively spray water over a broader area. This enhances fire suppression effectiveness and coverage area. Servo-based sweeping systems are preferred in designs analyzed from robotics forum discussions and student research assignments due to their accuracy and reliability.

4. Intelligent Approaches with AI and Image Processing:

Whereas your project relies on detection at the sensor level, certain newer systems apply computer vision and machine learning-based techniques for the detection of fire using color, shape, or thermal imagery. Such systems are more accurate but use more computation power and are more expensive.

5. Limitations of Existing Models:

Most of the basic fire-fighting robots, while effective in controlled environments, face challenges in real-world applications, such as obstacle avoidance, navigation in uneven terrain, and effective targeting of the fire source. Additionally, scalability and robustness remain areas for improvement in many designs.

6. Summary of Gaps and Opportunities:

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2.1 Existing System

Existing fire-fighting systems are manual extinguishers, fixed sprinkler systems, and sophisticated fire-fighting robots. Manual systems need human presence, which is risky in dangerous areas. Fixed systems such as smoke detectors and sprinklers are stationary and may not be focused on the fire. Sophisticated robots employ cameras and AI but are costly and complicated.

Educational and hobby robots are available based on flame sensors and microcontrollers but lack precision, mobility, and reliability. These systems also fail in dynamic or large environments.

There is still a need for a low-cost, autonomous, and mobile system that can effectively detect and suppress fire in small-scale or confined spaces.for mobile or internet connectivity

5.1.1 Drawbacks of the existing system

1. Manual Operation Risk:
Fire-fighting remains heavily reliant on human operation, which risks lives in dangerous conditions.
2. Fixed Suppression Systems:
Conventional systems such as sprinklers are fixed and cannot directly aim at the source of the fire.
3. Limited Detection Accuracy:
Simple flame or smoke detectors are unable to pinpoint the location or direction of the fire.
4. High Cost of Advanced Robots:
Thermal camera and AI-based detection robots are costly and not appropriate for low-budget or small-scale applications.
5. Lack of Mobility in Simple Robots:
Several teaching or homemade robots lack mobility in complex settings or around obstacles.
6. Poor Coverage:
Stationary water outlets or immobile nozzles restrict the range of fire suppression and efficiency.

5.2 Proposed System

The system under consideration is an independent fire-fighting robot that will sense and put out fire in enclosed small spaces without the need for human control. It employs flame sensors to establish the direction of the fire and DC motors for travel towards the source of the flame. When the fire is sensed, a relay-controlled water pump is switched on, and water is sprayed through a servo-controlled nozzle that sweeps over the fire area to enhance extinguishing efficiency.

The robot is driven by an Arduino microcontroller, which interprets sensor inputs and manages motor movement, water spraying, and general decision-making. The system is low-cost, deployable with ease, and acceptable for educational, household, or small-industrial uses.

The robot employs three flame sensors (left, center, right) to identify the occurrence of fire. The sensors are set up to detect large flame signatures and initiate a prompt response. The most important sensor is the center sensor, with the side sensors assisting in guiding the robot to the source of the fire.

5.2.1 Advantages of the proposed system

1. **Autonomous Operation:** Reduces human risk by operating without intervention.
2. **Cost-Effective:** Affordable design suitable for small-scale and educational use.
3. **Efficient Detection & Suppression:** Multiple flame sensors and a servo-controlled nozzle ensure accurate fire detection and suppression.
4. **Mobility & Flexibility:** Can navigate different environments and avoid obstacles.
5. **Real-Time Decision Making:** Quick response based on sensor data processed by the Arduino.
6. **Safety in Hazardous Areas:** Suitable for dangerous or hard-to-reach environments.
7. **Scalability:** Easily upgradable for larger applications.
8. **Educational Value:** Demonstrates practical robotics, sensor integration, and fire-fighting technology.

CHAPTER 3

SYSTEM DESIGN

3.1 Development Environment

3.1.1 Hardware Requirements

1. **Arduino Microcontroller (Uno/Nano):**

   Central unit to process sensor data and control robot functions.

2. **Flame Sensors (3):**

   Detect fire direction and location (left, center, right).

3. **DC Motors (2):**

   Power the robot's movement toward the fire.

4. **Motor Driver (L298N):**

   Controls motor direction and speed.

5. **Relay Module:**

   Switches the water pump on/off.

6. **Water Pump (12V):**

   Pumps water for fire suppression.

7. **Servo Motor (9g/180°):**

   Moves the water nozzle for precise spraying.

8. **Chassis/Frame:**

   Holds all components together.

9. **Battery (7.4V/12V):**

   Powers the robot and all components.

10. **Wires & Connectors:**

    For power and data connections.

11. **Switch:**

To turn the robot on/off.

12. **Mounting Components (Screws, Nuts):**

Secure all parts to the chassis.

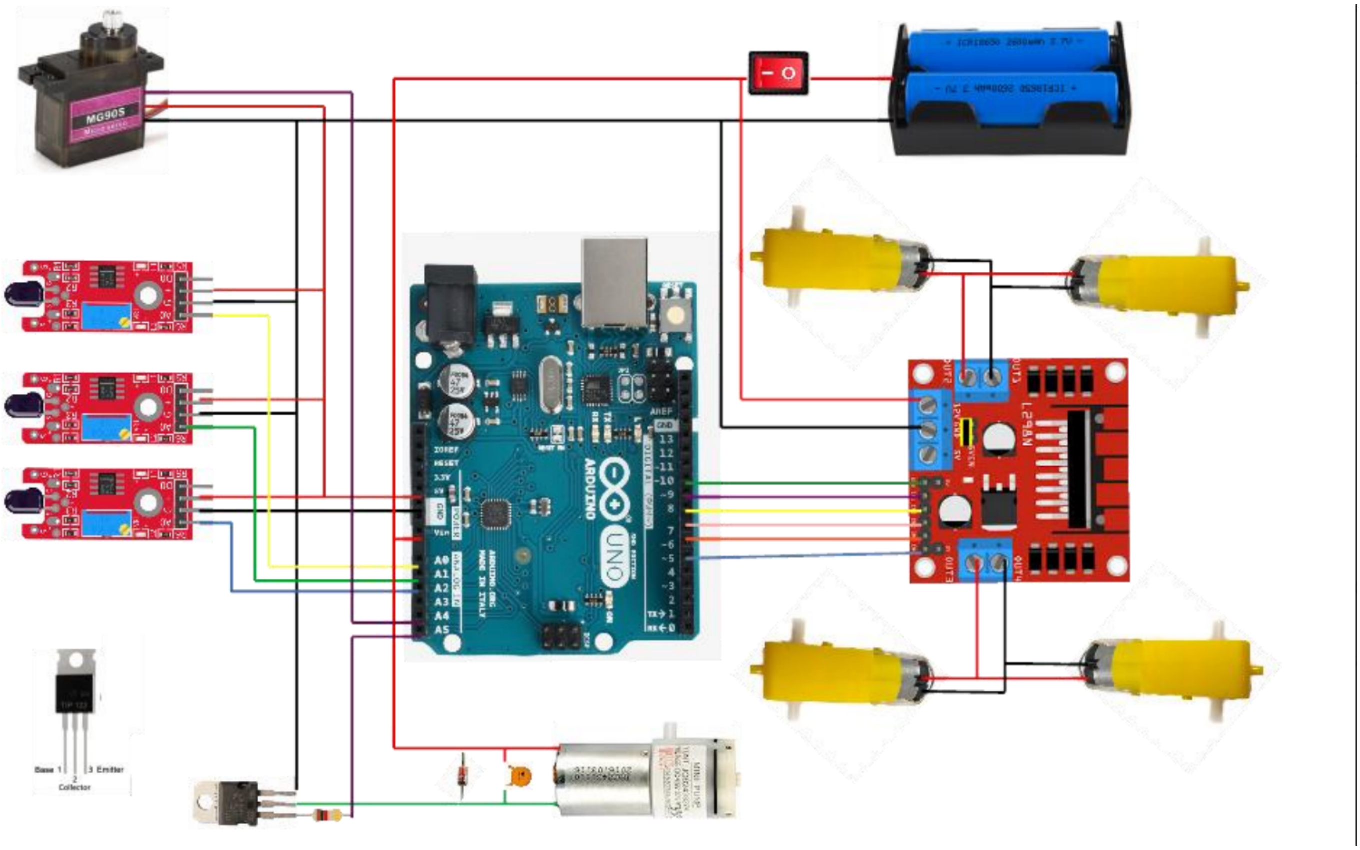
3.1.1 Software Requirements

1. **Arduino IDE**
    - **Role:** Programming environment to write and upload the code to the Arduino microcontroller.
    - **Why:** The Arduino IDE is essential for coding, compiling, and uploading the fire-fighting robot's logic to the microcontroller.
2. **Arduino Libraries:**
    - **Servo Library:**
        - **Role:** Controls the servo motor for nozzle movement.
        - **Why:** Simplifies the programming of servo motors by providing ready-to-use functions.
    - **Standard Arduino Library (if required):**
        - **Role:** Includes basic functions like digitalWrite(), analogRead(), delay(), and Serial.print().
        - **Why:** Fundamental functions for controlling the hardware components and providing serial output.
3. **C/C++ Programming Language**
    - **Role:** The Arduino programming language, based on C/C++, is used to develop the robot's logic.
    - **Why:** Allows the development of custom functions for sensor reading, motor control, and water suppression.
4. **Serial Monitor (optional for debugging):**
    - **Role:** Displays real-time sensor data and status messages for debugging and system monitoring.
    - **Why:** Useful for troubleshooting and verifying the robot's performance during development.
5. **Timer/Delay Functions:**
    - **Role:** Manages timing for actions like servo movements, water pump activation, and motor movements.
    - **Why:** Ensures coordinated and timed actions for smooth robot operations.

CHAPTER 4

PROJECT DESCRIPTION

4.1 ARCHITECTURE DIAGRAM



4.2 METHODOLOGY

1. Planning and Requirements Gathering

- **Objective:** Define the requirements for the fire-fighting robot, including hardware components (flame sensors, motors, water pump, etc.) and software functionalities (robot movement, fire detection, water suppression).
- **Tasks:**
  - Identify the specifications of each hardware component.
  - Determine the control logic required for the robot to detect and extinguish fire autonomously

2. Hardware Setup

- **Objective:** Assemble the physical components of the robot.

- **Tasks:**
    - Connect flame sensors (left, center, right) to the Arduino for fire detection.
    - Set up two DC motors for robot movement and connect them to the motor driver.
    - Install the water pump and connect it to the relay module for water control.
    - Attach the servo motor to the water nozzle for directional control of the water flow.
    - Wire the components to the Arduino microcontroller, ensuring proper power supply from the battery.
    - Mount the components on a robot chassis to create the final structure.

3. Software Development

- **Objective:** Program the robot to function as required.
- **Tasks:**
    - Use the Arduino IDE to write the code that controls the robot's sensors, motors, and water suppression system.
    - Develop functions for reading flame sensor data and interpreting fire presence.
    - Implement motor control logic for the robot to move towards the fire source.
    - Program the servo motor to control the nozzle direction and activate the water pump when fire is detected.
    - Implement real-time feedback through the serial monitor for debugging and status updates.

4. System Integration

- **Objective:** Combine the hardware and software components to form a complete system.
- **Tasks:**
    - Integrate the code with the hardware setup, ensuring that sensor data triggers the appropriate motor and water pump actions.
    - Test the interaction between sensors, motors, and the water pump to ensure correct operation.
    - Optimize the servo movement for effective water spraying.

5. Testing and Calibration

- **Objective:** Ensure the system works correctly under real-world conditions.
- **Tasks:**
    - Test the robot's flame detection accuracy and adjust sensor thresholds for optimal performance.
    - Test the movement system for smooth operation and accurate fire localization.
    - Calibrate the servo to ensure precise water spraying.
    - Test the water pump for reliability in suppressing the fire.

6. Final Evaluation

- **Objective:** Evaluate the performance of the robot in terms of reliability, efficiency, and safety.
- **Tasks:**
    - Conduct final tests in simulated fire scenarios.

    - Evaluate the robot’s response time, accuracy in fire detection, and effectiveness in extinguishing the fire.
    - Identify any improvements or optimizations for future iterations.

CHAPTER 5

CONCLUSION AND FUTURE WORK

Conclusion

The fire-fighting robot successfully demonstrates an efficient and autonomous system capable of detecting and extinguishing fire in real-time. Using flame sensors, DC motors, a relay-controlled water pump, and a servo-controlled nozzle, the robot is designed to autonomously navigate towards the fire and suppress it. The robot’s simplicity, cost-effectiveness, and ability to operate in hazardous environments make it a viable solution for fire prevention in both domestic and industrial settings.

Key achievements of the project include:

- Real-time fire detection using flame sensors.
- Autonomous movement towards fire sources.
- Effective fire suppression with a targeted water spray.
- Cost-effective and scalable design for educational and small-scale applications.

While the current system is functional and provides reliable fire detection and suppression, there are areas for improvement in terms of response time, sensor accuracy, and overall performance.

Future Work

Several enhancements and future work can be explored to improve the fire-fighting robot:

1. **Enhanced Sensors:**
    - Integrating additional sensors such as temperature sensors or smoke detectors could improve the fire detection accuracy and allow the robot to differentiate between different types of fire.
2. **Improved Navigation:**
    - Implementing obstacle avoidance sensors (e.g., ultrasonic sensors) could help the robot navigate more effectively in complex environments and avoid obstacles while heading toward the fire.
3. **Wireless Communication:**
    - Adding wireless communication (such as Bluetooth or Wi-Fi) could enable remote monitoring and control of the robot, allowing users to receive alerts about fire detection and suppression status.
4. **AI Integration:**

   - The inclusion of artificial intelligence (AI) and machine learning could allow the robot to learn and adapt to various fire situations, improving its decision-making and efficiency in fire suppression.
5. **Larger Scale Applications:**
   - The system can be scaled up for use in large industrial or commercial environments. By using larger water tanks, more powerful motors, and better mobility systems, the robot could handle larger areas.
6. **Autonomous Charging:**
   - The robot could be equipped with a docking station to recharge itself after completing a fire suppression task, ensuring continuous operation.

By continuing to build upon the existing system, these improvements can make the fire-fighting robot even more capable and versatile, expanding its applicability in a variety of fire-fighting scenarios.

APPENDIX

SOFTWARE INSTALLATION

Arduino IDE

To run and mount code on the Arduino NANO, we need to first install the Arduino IDE.

After running the code successfully, mount it.

Sample code

```
// Fire Fighting Robot - Arduino Code
// Revised without ENA/ENB connections

// Motor driver pin definitions
#define in1 5      // Motor driver input 1 connected to Arduino pin 5
#define in2 6      // Motor driver input 2 connected to Arduino pin 6
#define in3 9      // Motor driver input 3 connected to Arduino pin 9
#define in4 10     // Motor driver input 4 connected to Arduino pin 10

// Sensor pin definitions
#define flame_center A0    // Center flame sensor connected to A0
#define flame_left A1      // Left flame sensor connected to A1
#define flame_right A2     // Right flame sensor connected to A2

// Servo and pump definitions
#define servo_pin 3        // Servo motor connected to pin 3
#define relay_pin 7        // 5V relay connected to pin 7 for water pump control
```

```
// Constants
#define FLAME_THRESHOLD_CENTER 350  // Threshold value for center flame sensor
#define FLAME_THRESHOLD_SIDES 250   // Threshold value for side flame sensors

// Variables
int center_reading, left_reading, right_reading; // Sensor readings

void setup() {
  // Initialize serial communication for debugging
  Serial.begin(9600);

  // Configure pin modes
  pinMode(flame_center, INPUT);
  pinMode(flame_left, INPUT);
  pinMode(flame_right, INPUT);

  pinMode(in1, OUTPUT);
  pinMode(in2, OUTPUT);
  pinMode(in3, OUTPUT);
  pinMode(in4, OUTPUT);
  pinMode(servo_pin, OUTPUT);
  pinMode(relay_pin, OUTPUT);

  // Initialize water pump to OFF
  digitalWrite(relay_pin, LOW);

  // Initialize servo position (center)
  for (int angle = 90; angle <= 140; angle += 5) {
    servoPulse(servo_pin, angle);
  }
  for (int angle = 140; angle >= 40; angle -= 5) {
    servoPulse(servo_pin, angle);
  }
  for (int angle = 40; angle <= 90; angle += 5) {
    servoPulse(servo_pin, angle);
  }

  // Small delay before starting main operations
  delay(500);
}

void loop() {
  // Read values from flame sensors
  center_reading = analogRead(flame_center);
  left_reading = analogRead(flame_left);
  right_reading = analogRead(flame_right);

  // Print sensor values for debugging
  Serial.print("Right: ");
  Serial.print(right_reading);
  Serial.print("\t Center: ");
  Serial.print(center_reading);
  Serial.print("\t Left: ");
  Serial.println(left_reading);
```

```
// Fire detection and robot control logic
if (right_reading < FLAME_THRESHOLD_SIDES) {
  // Fire detected on right side
  stopRobot();
  activateWaterPump();
  // Scan right side with servo
  for (int angle = 90; angle >= 40; angle -= 3) {
    servoPulse(servo_pin, angle);
  }
  for (int angle = 40; angle <= 90; angle += 3) {
    servoPulse(servo_pin, angle);
  }
}
else if (center_reading < FLAME_THRESHOLD_CENTER) {
  // Fire detected at center
  stopRobot();
  activateWaterPump();
  // Scan full range with servo
  for (int angle = 90; angle <= 140; angle += 3) {
    servoPulse(servo_pin, angle);
  }
  for (int angle = 140; angle >= 40; angle -= 3) {
    servoPulse(servo_pin, angle);
  }
  for (int angle = 40; angle <= 90; angle += 3) {
    servoPulse(servo_pin, angle);
  }
}
else if (left_reading < FLAME_THRESHOLD_SIDES) {
  // Fire detected on left side
  stopRobot();
  activateWaterPump();
  // Scan left side with servo
  for (int angle = 90; angle <= 140; angle += 3) {
    servoPulse(servo_pin, angle);
  }
  for (int angle = 140; angle >= 90; angle -= 3) {
    servoPulse(servo_pin, angle);
  }
}
else if (right_reading >= FLAME_THRESHOLD_SIDES && right_reading <= 700) {
  // Fire is in range but not close enough on right side
  deactivateWaterPump();
  moveBackward();
  delay(100);
  turnRight();
  delay(200);
}
else if (center_reading >= FLAME_THRESHOLD_CENTER && center_reading <= 800) {
  // Fire is in range but not close enough in center
  deactivateWaterPump();
  moveForward();
}
else if (left_reading >= FLAME_THRESHOLD_SIDES && left_reading <= 700) {
```

```
    // Fire is in range but not close enough on left side
    deactivateWaterPump();
    moveBackward();
    delay(100);
    turnLeft();
    delay(200);
  }
  else {
    // No fire detected
    deactivateWaterPump();
    stopRobot();
  }

  delay(10); // Small delay for stability
}

// Function to control servo position
void servoPulse(int pin, int angle) {
  int pwm = (angle * 11) + 500; // Convert angle to microseconds
  digitalWrite(pin, HIGH);
  delayMicroseconds(pwm);
  digitalWrite(pin, LOW);
  delay(50); // Refresh cycle of servo
}

// Robot movement functions
void moveForward() {
  digitalWrite(in1, HIGH); // Motor 1&2 forward
  digitalWrite(in2, LOW);
  digitalWrite(in3, LOW);  // Motor 3&4 forward
  digitalWrite(in4, HIGH);
}

void moveBackward() {
  digitalWrite(in1, LOW);  // Motor 1&2 backward
  digitalWrite(in2, HIGH);
  digitalWrite(in3, HIGH); // Motor 3&4 backward
  digitalWrite(in4, LOW);
}

void turnRight() {
  digitalWrite(in1, LOW);  // Motor 1&2 backward
  digitalWrite(in2, HIGH);
  digitalWrite(in3, LOW);  // Motor 3&4 forward
  digitalWrite(in4, HIGH);
}

void turnLeft() {
  digitalWrite(in1, HIGH); // Motor 1&2 forward
  digitalWrite(in2, LOW);
  digitalWrite(in3, HIGH); // Motor 3&4 backward
  digitalWrite(in4, LOW);
}

void stopRobot() {
```

```
  digitalWrite(in1, LOW);
  digitalWrite(in2, LOW);
  digitalWrite(in3, LOW);
  digitalWrite(in4, LOW);
}

void activateWaterPump() {
  digitalWrite(relay_pin, HIGH); // Turn ON relay to activate water pump
}

void deactivateWaterPump() {
  digitalWrite(relay_pin, LOW);  // Turn OFF relay to deactivate water pump
}
```

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