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Design and Implementation of an Autonomous Arduino-Based Firefighting Robot

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Abstract

This paper presents the design, implementation, and testing of a low-cost, Arduino-based autonomous firefighting robot capable of detecting and extinguishing small-scale fires. The system uses flame sensors to identify infrared radiation from fire sources and an integrated water pump, controlled via a servo motor and relay module, to extinguish detected flames. The robot employs DC motors for mobility, governed by an L298N motor driver, and operates in environments where human intervention may be risky. The prototype demonstrates promising results in fire detection, directional navigation, and water-based fire suppression, making it suitable for industrial, residential, and hazardous settings.

Keywords

Firefighting Robot, Arduino Nano, Flame Sensor, Water Pump, Servo Motor, Autonomous System.

Introduction

Fire accidents in industrial, residential, and natural settings pose a significant threat to life and property. Traditional firefighting methods rely on human involvement, which can be dangerous, slow, and sometimes infeasible. To mitigate these challenges, robotic systems provide a promising alternative for early detection and suppression of fires.

This work aims to develop an autonomous firefighting robot using an Arduino Nano microcontroller, flame sensors, a servo-controlled water pump, and DC motors for movement. The robot autonomously identifies fire, navigates toward it, and activates a suppression system. It can serve as a foundational platform for further enhancements using AI and advanced sensing technologies.

Methodology

A. Hardware Components

- **Arduino Nano**: Serves as the central controller.
- **Flame Sensors**: Detect infrared radiation from fire.
- **DC Motors with L298N Motor Driver**: Enable forward, reverse, and turning movement.
- **Servo Motor**: Aims the water nozzle towards the fire.
- **Water Pump with Relay**: Sprays water upon fire detection.
- **Power Supply**: 12V battery for motors and 5V supply for the microcontroller.

B. Software Logic

The Arduino is programmed to:

1. Continuously monitor flame sensors.
2. Navigate towards the fire source based on sensor readings.

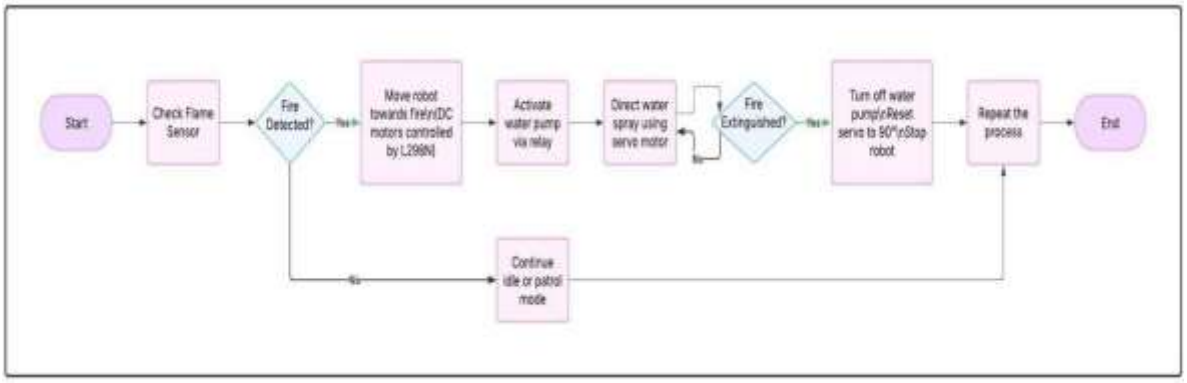
3. Halt movement upon reaching the fire.

4. Activate the water pump and rotate the nozzle using the servo motor.

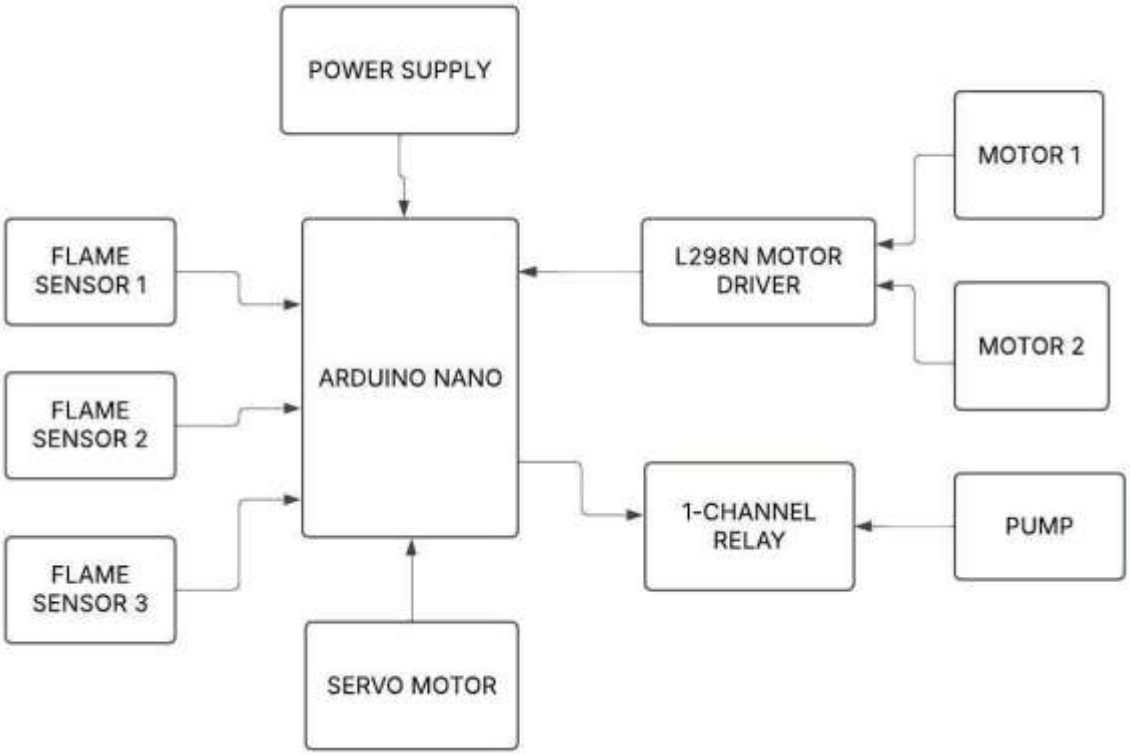
5. Resume idle/patrol mode after extinguishing the fire.

The system relies on simple directional logic and threshold-based fire detection, coded in the Arduino IDE using the Servo library and basic I/O control functions.

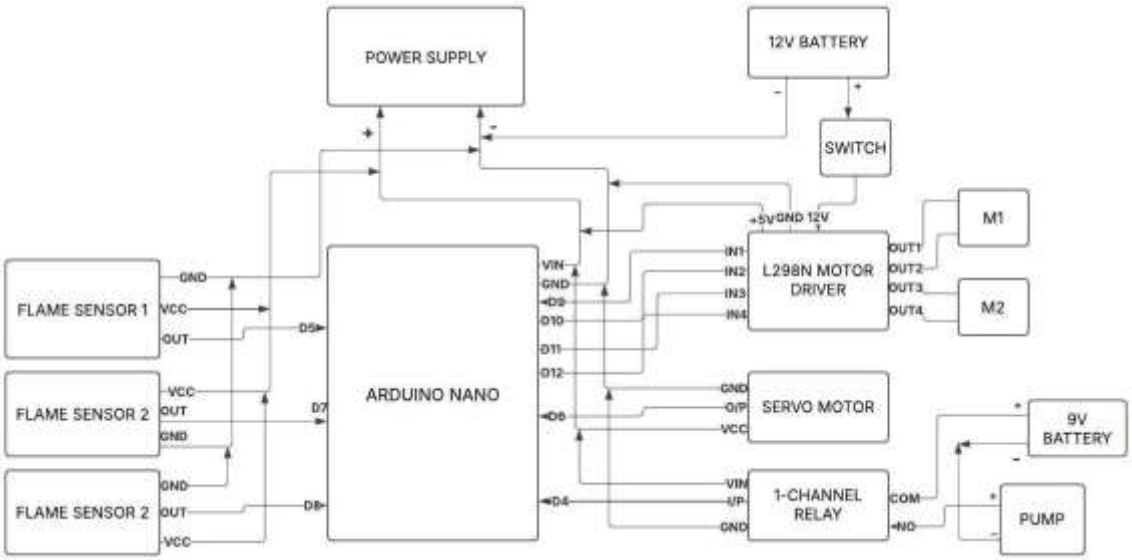
Flow Chart



Block Diagram



Circuit Diagram



Firefighting Robot Arduino Code

```
#include <Servo.h>                    // Include library to control servo motor

// Motor driver pins (connected to L298N) #define LM1 9      //    Left
Motor IN1 #define LM2 10          // Left Motor IN2 #define RM1 11
                                    // Right Motor IN1 #define RM2 12
                                    // Right Motor IN2

// Flame sensor pins
#define Left 5                     // Left flame sensor #define Right 8
                                   // Right flame sensor
#define Forward 7                      // Forward flame sensor

// Relay pin for water pump control
#define pump 4                         // Relay connected to water pump

// Create Servo object Servo myservo;

int pos = 0;                       // Servo position
bool fire = false;                     // Fire detection flag

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

// Set motor pins as output pinMode(LM1,
OUTPUT);
pinMode(LM2,     OUTPUT);     pinMode(RM1,
OUTPUT); pinMode(RM2, OUTPUT);

// Set flame sensor pins as input pinMode(Left, INPUT);
pinMode(Right, INPUT);
```

```
pinMode(Forward, INPUT);

// Set relay pin as output pinMode(pump, OUTPUT);

// Attach servo motor to pin 6 myservo.attach(6);
myservo.write(90);                    // Set servo to neutral position
}

void put_off_fire() {
// Stop movement
digitalWrite(LM1, LOW); digitalWrite(LM2,
LOW);          digitalWrite(RM1,          LOW);
digitalWrite(RM2, LOW);

// Activate water pump
digitalWrite(pump, HIGH);
delay(500);                    // Allow water to start

// Sweep servo to spray water
for (pos = 50; pos <= 130; pos++) { myservo.write(pos);
delay(10);
}

for (pos = 130; pos >= 50; pos--) { myservo.write(pos);
delay(10);
}

// Turn off pump and reset digitalWrite(pump, LOW);
myservo.write(90);                    // Center servo fire = false;
}
void loop() {
// Read flame sensor values
bool leftFire = digitalRead(Left) == LOW;
bool rightFire = digitalRead(Right) == LOW;
bool forwardFire = digitalRead(Forward) == LOW;

// Fire detected logic if (forwardFire) {
// Move forward
digitalWrite(LM1, HIGH); digitalWrite(LM2,
LOW);          digitalWrite(RM1,          HIGH);
digitalWrite(RM2, LOW); fire = true;
}
else if (leftFire) {
// Turn left
digitalWrite(LM1, LOW); digitalWrite(LM2,
HIGH);          digitalWrite(RM1,          HIGH);
digitalWrite(RM2, LOW);
}
```

```
else if (rightFire) {
// Turn right
digitalWrite(LM1, HIGH); digitalWrite(LM2,
LOW); digitalWrite(RM1, LOW);
digitalWrite(RM2, HIGH);
}
else {
// No fire - Stop motors digitalWrite(LM1, LOW);
digitalWrite(LM2, LOW); digitalWrite(RM1, LOW);
digitalWrite(RM2, LOW);
}
delay(300); // Delay for smooth movement

// Trigger firefighting if (fire) {
put_off_fire();
}
}
```

Experimental Results

A. Flame Detection Accuracy

The robot successfully detected candle flame up to 1 meter with high accuracy and minimal false positives. Directional sensors enabled turning toward the fire.

B. Movement and Navigation

The robot accurately navigated towards fire positions. It exhibited stable forward motion and effective left/right turning as per sensor activation.

C. Fire Suppression Performance

Upon detecting fire, the servo adjusted the nozzle from 50° to 130°, covering a wide arc. The water pump reliably activated through a relay switch, spraying sufficient water to extinguish flames within 5 seconds.

D. Limitations

- Limited detection range (~1m).
- Modest water flow suitable only for small-scale fires.
- No obstacle avoidance in the current version.
- The Firefighting Robot demonstrated good performance in detecting fire, controlling movement, and extinguishing fire effectively. Therobot's sensors, motors, and servo worked in harmony to make it a capable firefighting device. Although some limitations were noted, such as the

range of the flame sensors and the pump's flow rate, the system overall achieved its primary goal of detecting and extinguishing small fires. Future improvements could include optimizingsensorrange, enhancingwaterflow, and improving power efficiency for longer operational periods.

Applications:

- Industrial Fire Safety
- Fire Safetyin Warehouses

FUTURE SCOPE AND DISCUSSION

The **Firefighting Robot** represents a significant advancement in fire safety and automation, with its ability to detect and extinguish fires autonomously. However, there is considerable potential for further development and improvement in several areas. Below is a discussion of the **future scope** of the firefighting robot, as well as the challenges and opportunitiesthatlieahead.

Conclusion

The proposed firefighting robot demonstrates an effective and economical solution for fire detection and suppression using open-source hardware. With

successful testing in controlled environments, it validates the feasibility of using such systems in industrial or domestic scenarios. Future developments could

include integration of thermal cameras, obstacle detection, AI-based fire pattern recognition, and swarm robot coordination for broader application coverage.

References

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