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Fire Fighting Robot

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Abstract

Fire-related incidents continue to pose serious risks to human safety and infrastructure, particularly in locations where immediate manual intervention is unsafe or impractical. This paper presents the design and implementation of an autonomous firefighting robot using an Arduino microcontroller. The proposed system is capable of detecting fire and responding without human assistance. Fire detection is achieved using a flame sensor that continuously monitors the surrounding environment. When a fire source is identified, sensor data is processed by the microcontroller to guide the robotic platform toward the affected area using motor-driven locomotion. Upon reaching a predefined safe distance, an integrated water pump is activated to suppress the fire. The system emphasizes simplicity, affordability, and reliability for small-scale fire control. Experimental evaluation demonstrates that the robot can successfully detect and extinguish small flames in controlled indoor environments. This work highlights the potential of embedded robotics in improving fire safety while reducing human exposure to hazardous situations.

Index Terms: Arduino, Fire Detection, Robotics, Sensors, Autonomous Systems

1. Introduction

Fire is one of the most common hazards that can occur unexpectedly and spread rapidly, causing extensive damage to property and posing a serious threat to human life[3]. In environments such as residential buildings, laboratories, warehouses, and industrial units, immediate human intervention during a fire outbreak may be extremely dangerous due to high temperatures, smoke, and toxic gases.

Recent advancements in robotics and embedded systems have enabled the development of automated solutions capable of handling safety- critical situations[8]. Firefighting robots are designed to detect fire at an early stage and take immediate action to control it without direct human involvement[4]. These systems help reduce the risks faced by firefighters and improve response time during emergencies.

This paper presents an Arduino-based firefighting robot that integrates fire sensing, motion control, and an extinguishing mechanism into a single autonomous system[1]. A flame sensor is used to detect fire, while the Arduino microcontroller processes sensor data and controls the robot's movement[10]. Once the robot reaches the fire source, a water pump is activated to extinguish the flame. The main objective of this work is to design a low- cost, reliable, and efficient robotic solution that enhances safety by minimizing human exposure to dangerous fire situations[8].

2. LITERATURE REVIEW

Firefighting robots have been widely studied as an alternative to traditional fire-fighting techniques that rely heavily on human involvement[10]. Early fire safety systems were primarily alarm-based and required manual intervention to extinguish fire, which often resulted in delayed response.

With the introduction of microcontroller-based systems, researchers began developing autonomous firefighting robots using sensors and actuators[12]. Arduino-based platforms have gained popularity due to their simplicity, flexibility, and low cost. Many studies report the successful use of flame sensors for fire detection and motor-driven robotic platforms for navigating toward fire sources[6].

Some research has focused on improving navigation using obstacle detection sensors, while other studies have explored remote monitoring and communication features. Overall, the literature indicates that autonomous firefighting robots are effective for small-scale and controlled environments and can significantly reduce human risk during fire emergencies.

3. SYSTEM DESIGN AND METHODOLOGY

The proposed firefighting robot system is designed using a modular approach that combines sensing, decision-making, and actuation.

Operational Logic

The robot continuously monitors its surroundings using a flame sensor. When a fire is detected, the sensor sends a signal to the Arduino microcontroller. The controller processes this input and activate the motor driver to move the robot toward the fire source. Once the robot reaches a predefined safe extinguishing distance, the water pump is activated to suppress the fire. After the fire is extinguished, the system stops the pump and returns to monitoring mode.

4. HARDWARE IMPLEMENTATION

The hardware implementation includes the robotic chassis, motors, electronic control units, sensors, and the fire extinguishing mechanism.

A. Robot Chassis and Motors

The robot is built on a four-wheel drive chassis to ensure stability and smooth movement. DC motors are mounted on the chassis and connected to a motor driver circuit to control direction and speed. The wheels provide traction and enable the robot to navigate toward the fire source efficiently[4].

Fig. 1. Four-Wheel Robot Chassis Used for the Firefighting Robot

B. Electronic Components

Electronic components such as the motor driver module, relay module, and wiring are securely mounted on the chassis[12]. Proper placement ensures stable operation and reduces the risk of loose connections during movement.

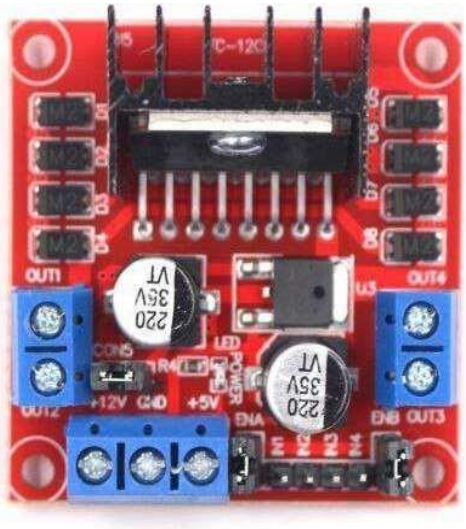

Fig. 2. L298N Motor Driver Module Used for Motor Control

C. Control Unit

The Arduino UNO microcontroller is used as the central control unit of the system. It receives input signals from the flame sensor and generates output signals to control the motors and the water pump. The Arduino is chosen due to its ease of programming, reliability, and compatibility with various sensors and modules[1][2][7].

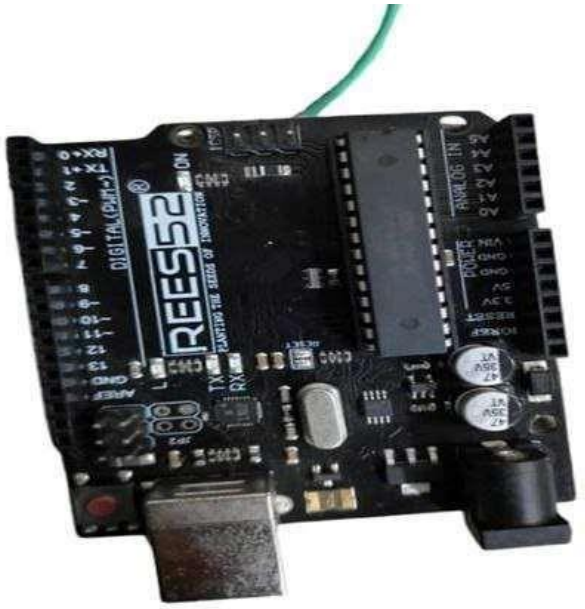

Fig. 3. Arduino UNO Microcontroller Board

D. Fire Detection and Extinguishing Modules

A flame sensor module is used to detect fire by sensing infrared radiation emitted by flames. When fire is detected, the sensor sends a signal to the Arduino[8]. A mini water pump module is used as the fire extinguishing mechanism. The pump is activated through a relay or driver circuit to handle higher current requirements.

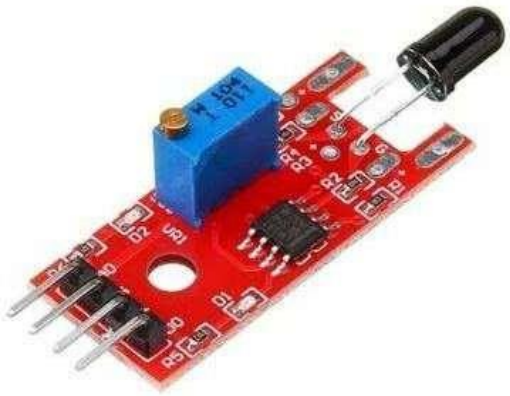

Fig. 4. Flame Sensor Module Used for Fire Detection

5. SOFTWARE IMPLEMENTATION

The software for the firefighting robot is developed using the Arduino Integrated Development Environment. The program continuously reads sensor values and executes control logic based on predefined conditions. Motor control functions manage robot movement, while pump control logic activates and deactivates the water pump when fire is detected.

The program follows a loop-based structure to ensure real-time response. Threshold values are used to determine fire detection and safe extinguishing distance.

```
// Extinguish Fire
void extinguishFire() {
digitalWrite(PUMP_PIN, HIGH);  // Turn pump ON delay(5000);  // Run for 5 seconds
digitalWrite(PUMP_PIN, LOW);       // Turn pump OFF
}
// Move Forward
void moveForward() { motor1.run(FORWARD); motor2.run(FORWARD); motor3.run(FORWARD);
motor4.run(FORWARD); motor1.setSpeed(180); motor2.setSpeed(180); motor3.setSpeed(180);
motor4.setSpeed(180);
}
// Stop Robot
void stopRobot() { motor1.run(RELEASE); motor2.run(RELEASE); motor3.run(RELEASE);
motor4.run(RELEASE);
}
```

Code snippet

```
#include <AFMotor.h> // Motor Shield Library
#include <Servo.h> // For scanning (optional)
Defining Pins
#define FLAME_PIN A0 // Flame sensor analog pin
#define PUMP_PIN 9 // Water pump or fan driver pin
#define SAFE_DISTANCE 20 // cm, distance to stop near fire
Motor Setup
AF_DCMotor motor1(1, MOTOR12_1KHZ);
AF_DCMotor motor2(2, MOTOR12_1KHZ);
AF_DCMotor motor3(3, MOTOR34_1KHZ);
AF_DCMotor motor4(4, MOTOR34_1KHZ);
Variables
int flameValue = 0;
boolean fireDetected = false;
Setup Function
void setup() {
 pinMode(PUMP_PIN, OUTPUT);
 Serial.begin(9600);
 // Initial stop
 motor1.run(RELEASE);
 motor2.run(RELEASE);
 motor3.run(RELEASE);
 motor4.run(RELEASE);
 digitalWrite(PUMP_PIN, LOW); // Pump Off
}
Main Loop
void loop() {
 flameValue = analogRead(FLAME_PIN);
 if (flameValue > 600) { // Fire detected threshold
 fireDetected = true;
 moveForward();
 }
 else {
 fireDetected = false;
 stopRobot();
 }
 if (fireDetected) {
 if (readDistance() <= SAFE_DISTANCE) {
 stopRobot();
 extinguishFire();
 }
 }
}
Supporting Functions
Move Forward
void moveForward() {
 motor1.run(FORWARD);
 motor2.run(FORWARD);
 motor3.run(FORWARD);
 motor4.run(FORWARD);
 motor1.setSpeed(180);
 motor2.setSpeed(180);
 motor3.setSpeed(180);
 motor4.setSpeed(180);
}
Stop Robot
void stopRobot() {
 motor1.run(RELEASE);
 motor2.run(RELEASE);
 motor3.run(RELEASE);
 motor4.run(RELEASE);
}
Extinguish Fire
void extinguishFire() {
 digitalWrite(PUMP_PIN, HIGH);
 delay(5000); // run pump 5 seconds
 digitalWrite(PUMP_PIN, LOW);
}
Distance Reading (If Ultrasonic Used)
int readDistance() {
 // Dummy function or real ultrasonic reading
 return 15;
}
```

6. RESULTS AND DISCUSSION

The developed firefighting robot was tested in controlled indoor environments using small fire sources such as candle flames. The flame sensor successfully detected fire within its effective range, and the robot moved toward the fire source as expected. Once the robot reached a safe distance, the water pump was activated and extinguished the fire within a short duration.

The results indicate that the robot performs reliably for small-scale fire suppression. However, certain limitations were observed. The flame sensor has a limited detection angle and may be affected by strong ambient light. Battery capacity also limits the duration of operation. Despite these constraints, the system achieved its intended objectives effectively.

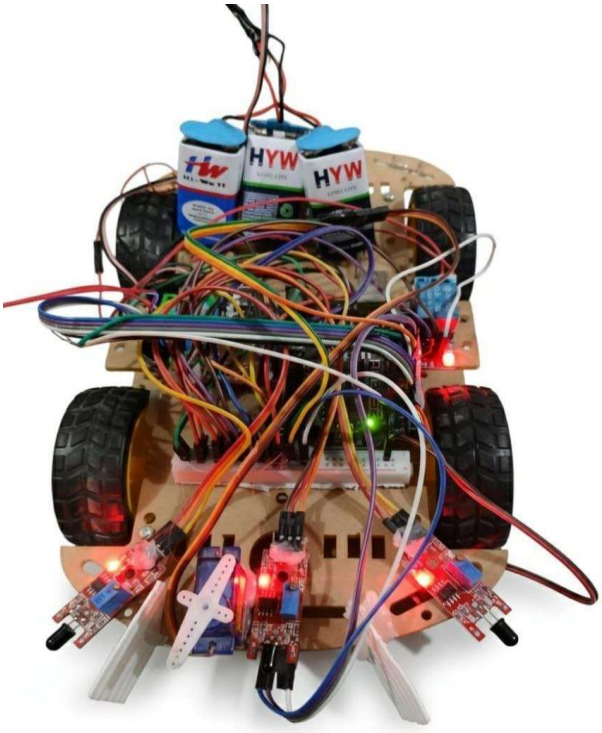

Fig. 5. Final Prototype of the Arduino-Based Firefighting Robot

7. CONCLUSION AND FUTURE SCOPE

This paper presented the design and implementation of an Arduino-based firefighting robot capable of detecting and suppressing fire autonomously. The system integrates flame sensing, robotic movement, and an automated water spraying mechanism to respond to fire incidents in small-scale environments. Experimental testing demonstrated that robots can successfully detect and extinguish small flames in controlled conditions.

The results highlight the potential of embedded robotics systems in enhancing fire safety and minimizing human exposure to hazardous environments. Future improvements may include the integration of temperature and gas sensors for early fire detection, wireless communication modules for remote monitoring, enhanced power management systems, and advanced navigation algorithms. These enhancements could enable the system to operate in more complex environments and support real-world firefighting applications.

8. ACKNOWLEDGEMENTS

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References

1. Arduino, "Arduino UNO Documentation," Arduino Official Website. Available: https://www.arduino.cc
2. STMicroelectronics, "L298N Dual H- Bridge Motor Driver Datasheet," STMicroelectronics, Technical Documentation.
3. Electronics Tutorials, "Flame Sensor Working and Applications." Available: https://www.electronics-tutorials.ws
4. Gupta, "Design and Development of Firefighting Robot," International Journal of Engineering Research and Technology (IJERT), vol. 10, no. 5, pp. 112–118, 2021.
5. P. Sharma and R. Kumar, "Fire Detection and Extinguishing Robot using Arduino," International Journal of Innovative Research in Science and Engineering (IJIRSE), vol. 8, no. 3,
6. pp. 45–50, 2020.
7. S. Rao, "Autonomous Fire Extinguishing Robot: Design and Implementation," International Journal of Robotics and Automation, vol. 7, no. 2, pp. 67–73, 2019.
8. Manufacturer Datasheet, "DC Water Pump Specifications," Product Technical Datasheet.
9. D. Bose, "Sensor-Based Fire Detection Systems for Robotics Applications," Proceedings of the International Conference on Embedded Systems, pp. 123–130, 2020.
10. J. Patel and S. Desai, "Development of Fire Fighting Robot with Automatic Water Sprinkler," International Research Journal of Engineering and Technology (IRJET), vol. 7, no. 6, pp. 2140–2144, 2020.
11. M. Al-Dabbas, "Sensor Integration for Autonomous Firefighting Robots," Journal of Robotics and Mechatronics, vol. 31, no. 5, pp. 814–822, 2019
12. R. K. Sharma, "Design of a Fire Fighting Robot with Flame and Smoke Detection," International Journal of Control and Automation, vol. 13, no. 4, pp. 55–63, 2020.
13. H. R. Joshi and P. D. Mahajan, "Arduino- Based Robot for Fire Detection and Extinguishing," International Journal of Research in Engineering and Technology (IJRET), vol. 9, no. 2, pp. 101–106, 2021.
14. Bharani B. R., Vinay N., Vasu S., Yashas V., "Fire Fighting Robot," *International Journal of Creative Research Thoughts (IJCRT)*, 2022.
15. Ahmad, M. B., Shehu, M. A., Surajo, A., Yanmida, D. Z., Muhammad, A., "Robots for Fighting Fires: A Comparative Analysis," *Global Journal of Research in Engineering & Computer Sciences*, vol. 3, no. 6, pp. 1–8, 2023.
16. Ramakrishnan, K., Priyadarshini, A. S., Abinaya, "Arduino UNO-based Robotic System for Combating Fires," *AIP Conference Proceedings*, vol. 3159, 020041, 2025.