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Design and Development of an Autonomous Multi-Sensor Based Fire Detection, Extinguishing and GSM Alert System using SIM Module

Dr. S. A. Kashid[1], Shraddha A. Kolhapure[2], Muktai P. Limbale[3], Ambika R. Gaudgaon[4]
[1]Assistant Professor, Department of Electronics and Telecommunication Engineering,
N. K. Orchid College of Engineering & Technology, Solapur, Maharashtra, India.
[234]Student, Department of Electronics and Telecommunication Engineering,
N. K. Orchid College of Engineering & Technology, Solapur, Maharashtra, India.

Abstract **-** Fire incidents can expose people and property to hazardous conditions, particularly when direct intervention is required. This paper presents the development of an autonomous firefighting robot based on an Arduino UNO for detecting and responding to controlled fire conditions. Three flame sensors are arranged in different directions to provide information about the approximate direction of a flame, while an MQ-2 sensor is incorporated for smoke and combustible-gas detection. According to the sensor inputs, the Arduino controls four geared DC motors through two L293D motor-driver modules to guide the robot toward the detected fire region. A relay-operated water pump is used for fire suppression, and a servo motor adjusts the direction of the water nozzle. The system also incorporates a SIM800L GSM module that can send emergency SMS notifications and initiate calls to predefined mobile numbers when a fire or significant smoke/gas condition is detected. The developed prototype demonstrates the feasibility of integrating sensing, autonomous movement, water-based suppression, and remote emergency communication within a compact embedded robotic platform.

Keywords - Arduino UNO, Autonomous Firefighting Robot, Flame Sensor, MQ-2 Gas Sensor, L293D Motor Driver, SIM800L GSM

I. INTRODUCTION

Fire accidents can cause serious damage to human life, industrial equipment, and valuable property. In many emergency situations, firefighters are required to work in hazardous environments containing smoke, toxic gases, and high-temperature flames. To reduce human risk and improve safety, autonomous firefighting robotic systems are becoming an important solution in modern fire safety applications.

The proposed robot combines several functions within a single embedded platform. Three flame sensors provide directional information from the left, centre, and right sides of the robot, while the MQ-2 sensor provides additional information about smoke and combustible gases. The Arduino UNO processes these inputs and controls four geared DC motors through two L293D driver modules. When a fire condition is identified, the robot approaches the detected region and activates a relay-controlled water pump. A servo motor assists in positioning the water nozzle, while the SIM800L GSM module provides emergency SMS and call notifications to predefined users.

II. LITERATURE SURVEY

2.1 Arduino-Based Fire Fighting Robot

Divya N. et al. proposed an Arduino-based autonomous fire-fighting robot integrated with flame sensors, smoke sensors, motor driver module, and water spraying mechanism. The robot was capable of detecting fire and automatically navigating toward the fire source for extinguishing operation. The system reduced direct human involvement in hazardous environments and improved fire safety applications. However, the robot performance was limited in obstacle-rich environments and complex fire conditions.

2.2 Fire Fighting Robotic Vehicle

Prof. Shaikh Z. A. R. et al. developed a fire-fighting robotic vehicle using Arduino UNO, flame sensors, ultrasonic sensors, servo motor, and water pump system for fire extinguishing applications. The robot could detect fire and move toward the affected area using motor driver circuitry. The proposed system improved safety during firefighting operations, but it mainly depended on RF communication and had limited sensing capability in large environments.

2.3 Autonomous Fire Detection Robot

S. Warhate et al. designed an autonomous fire-fighting robot capable of detecting fire using flame sensors and extinguishing it through a water pump mechanism controlled by Arduino. The robot automatically scanned the surrounding environment and moved toward the fire source for suppression. The system reduced firefighter risk during dangerous fire situations; however, it had limited decision-making capability and lower automation efficiency under dynamic conditions.

2.4 Fire Fighting Robot using Image Processing

Jay Sathe et al. presented the design and development of a fire-fighting robot using Arduino Mega, flame sensors, smoke sensors, Bluetooth module, OpenCV image pro-cessing, and

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ultrasonic sensors. The proposed system im-proved fire detection accuracy using image processing and wireless monitoring techniques. Although the robot demonstrated effective fire detection performance, the use of camera modules and OpenCV increased the complexity and implementation cost of the system.

2.5 Autonomous Arduino-Based Firefighting Robot

Md. Mohiuddin Maruf et al. proposed an autonomous Arduino-based firefighting robot designed for laboratory environments using multiple infrared flame sensors, servo-controlled water spraying mechanism, and autonomous movement control system. Experimental results showed high flame detection accuracy and efficient extinguishing performance. However, the system was mainly focused on laboratory applications and required controlled environmental conditions for optimum operation.

2.6 Limitations of Existing Systems

The reviewed systems demonstrate different approaches to autonomous fire detection and suppression, but their capabilities vary with respect to sensing, navigation, communication, and system complexity. Some implementations concentrate mainly on flame detection and water spraying, whereas others introduce wireless communication, image processing, or IoT-based monitoring. These additional features can increase hardware requirements and implementation complexity. The proposed prototype focuses on combining multi-directional flame sensing, MQ-2 smoke/gas detection, autonomous motor control, servo-assisted water delivery, and GSM-based emergency notification in one comparatively simple embedded system.

III. PROPOSED SYSTEM

3.1 System Overview

The proposed system is an autonomous mobile robot intended for fire detection and controlled fire-suppression experiments. Arduino UNO is used as the main processing unit. Three flame sensors are positioned to obtain information from the left, centre, and right directions, while an MQ-2 sensor provides an additional indication of smoke and combustible gases. The Arduino processes these sensor signals and controls four geared DC motors through two L293D motor-driver modules. One driver is assigned to the left-side motors and the other to the right-side motors, enabling differential movement. After a fire condition is detected, a relay is used to operate the water pump and a servo motor adjusts the nozzle direction. The SIM800L GSM module provides emergency SMS and call notification to predefined mobile numbers. Thus, sensing, movement, suppression, and remote notification are coordinated through the Arduino-based control system.

3.2 Block Diagram Explanation

Figure 3.1 illustrates the functional arrangement of the proposed firefighting robot. Arduino UNO forms the central control unit and receives information from the flame sensors and MQ-2 sensor. The three flame sensors are placed in different directions so that the controller can estimate whether the fire is located toward the left, centre, or right side. The MQ-2 sensor provides supplementary information related to smoke and combustible gases.

The Arduino controls four geared DC motors through two L293D driver modules. The first driver operates the two motors on the left side, while the second operates the two motors on the right side. This arrangement allows the robot to change its direction according to the detected flame position. When a fire condition is identified, the relay switches the water pump ON. A servo motor changes the orientation of the water nozzle to assist in directing the spray toward the detected region.

The SIM800L GSM module communicates with the Arduino and is configured to send emergency SMS messages and make calls to predefined mobile numbers. The prototype is powered using an 18650 lithium-ion battery arrangement, with an LM2596 buck converter used where regulated low-voltage supply is required.

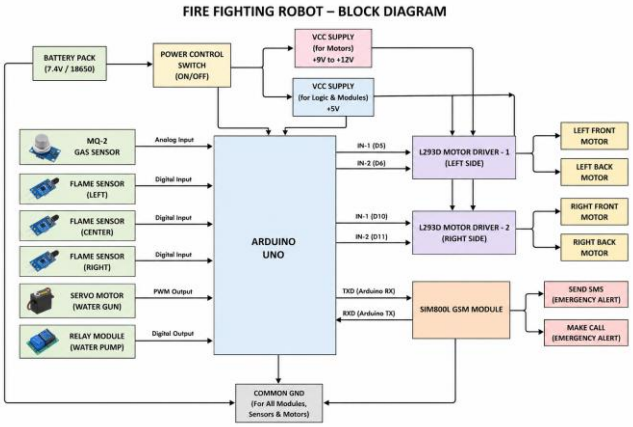

Fig. 3.1 Block Diagram of Proposed Fire Fighting Robot System

Figure 3.2 presents the operating sequence of the firefighting robot. After power-up and system initialization, the Arduino continuously reads the flame and MQ-2 sensors. When no fire or smoke/gas condition is detected, the robot remains in the monitoring state. Once a fire condition is identified, the SIM800L module is used to provide the configured emergency notification. The three flame sensors are then used to estimate the direction of the fire, and the motor drivers control the robot's movement toward that direction.

After the robot reaches the detected fire region, the relay activates the water pump and the servo mechanism adjusts the nozzle position. The sensors continue to be monitored during the suppression process. If the fire condition persists, the suppression sequence continues; otherwise, the pump is switched OFF and the robot returns to a safe state.

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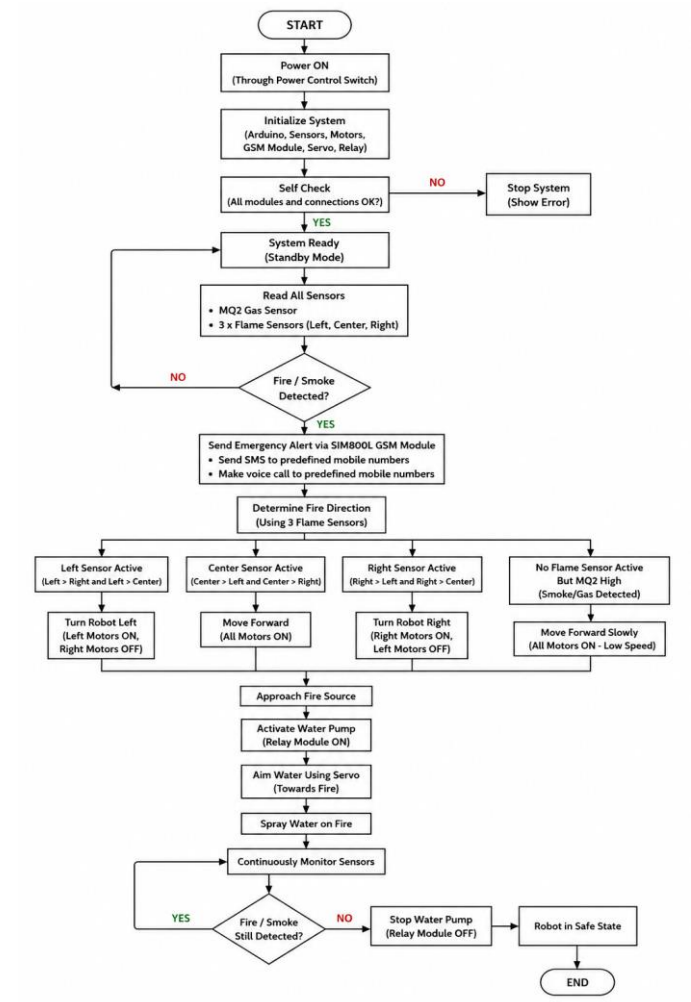


Fig. 3.2 Flowchart of Proposed Fire Fighting Robot System

IV. HARDWARE IMPLEMENTATION

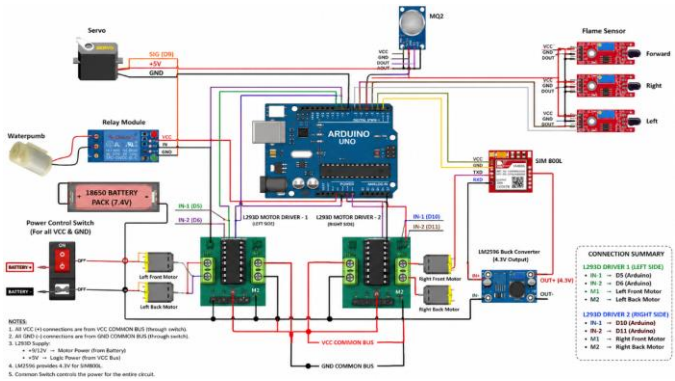


Fig. 4.1 Circuit Diagram of Proposed Fire Fighting Robot System

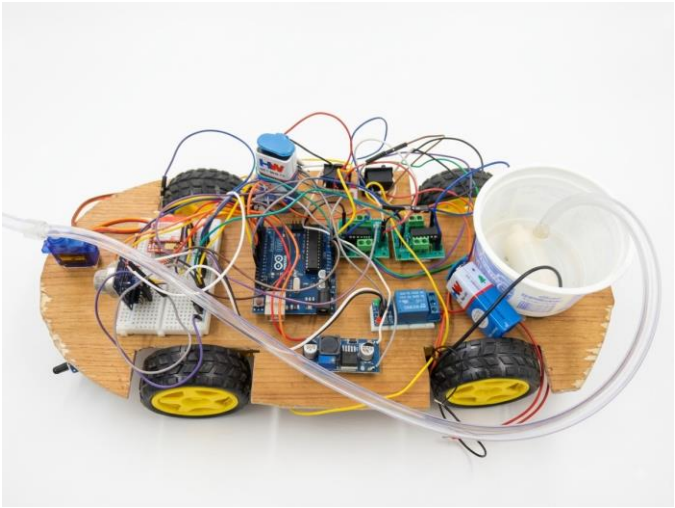
Figure 4.1 presents the hardware arrangement and electrical connections of the developed firefighting robot. Arduino UNO serves as the main controller and interfaces with the flame sensors, MQ-2 sensor, motor-driver modules, relay, servo motor, and SIM800L GSM module.

Three flame sensors are used to obtain directional flame information, while the MQ-2 sensor provides smoke and combustible-gas detection. Two L293D motor-driver modules are employed to control four geared DC motors. One driver controls the two motors on the left side and the second driver controls the two motors on the right side. Independent control of the two motor groups enables forward motion and directional turning.

A relay module is connected to the Arduino to control the water pump. When the required fire condition is detected, the relay switches the pump ON. The servo motor is positioned near the water outlet and is used to adjust the spraying direction. The SIM800L GSM module is connected to the Arduino for transmitting emergency SMS messages and initiating calls to predefined mobile numbers.

The prototype uses an 18650 lithium-ion battery arrangement as its power source. An LM2596 buck converter is used to obtain the regulated supply required by the GSM module. The control electronics and modules share a common ground according to the implemented circuit configuration.

V. RESULTS AND DISCUSSION



The developed prototype was assembled by integrating an Arduino UNO, three IR flame sensors, an MQ-2 gas sensor, two L293D motor-driver modules, four geared DC motors, a servo motor, a relay-controlled water pump, and a SIM800L GSM module. During operation, the three flame sensors provide information from the left, centre, and right directions, allowing the controller to estimate the approximate direction of a detected flame.

The flame-sensor modules used in the prototype are infrared-based devices. Their commonly specified sensing region is approximately 760–1100 nm, and typical modules can detect a small flame at distances of up to about 80 cm under suitable conditions. The actual detection distance can vary with flame size, flame orientation, sensitivity adjustment, and ambient illumination. The MQ-2 sensor provides additional detection of smoke and combustible gases, with a commonly specified flammable-gas sensing range of approximately 300–10,000 ppm. These values represent typical sensor specifications and should not be interpreted as measured accuracy of the developed robot.

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Based on the sensor inputs, the Arduino controls the two L293D motor-driver modules to operate the left and right motor groups. The robot can therefore turn toward the detected flame direction and approach the fire region. After reaching the target area, the relay activates the water pump, while the servo motor assists in directing the water nozzle. The SIM800L module provides remote emergency communication by sending SMS alerts and initiating calls to predefined mobile numbers.

The prototype demonstrates the feasibility of combining multi-directional flame sensing, smoke/gas detection, autonomous movement, water-based suppression, and GSM communication in a single embedded platform. Further controlled experiments are required to quantify detection accuracy, response time, GSM notification time, and extinguishing performance under different operating conditions.

VI. ADVANTAGES

1. The robot combines fire, smoke, and combustible-gas sensing in one platform.
2. Three flame sensors provide approximate directional information for autonomous movement.
3. Two L293D modules enable control of four DC motors through separate left and right motor groups.
4. The relay-controlled pump and servo mechanism provide automatic water delivery and nozzle positioning.
5. The SIM800L module enables emergency SMS and call notification to predefined mobile numbers.
6. The system uses commonly available embedded components, making the prototype relatively simple to implement and modify.

VII. APPLICATIONS

The developed prototype can be used for controlled fire-safety demonstrations in laboratories, workshops, educational institutions, research environments, and small storage areas. The platform can also serve as a foundation for developing more advanced autonomous firefighting robots for hazardous environments.

VIII. FUTURE SCOPE

Future development can focus on improving navigation, sensing, and communication capabilities. Ultrasonic or other obstacle-detection sensors can be incorporated to allow safer movement around obstacles. Camera or thermal sensing can be added for improved fire identification. IoT-based monitoring and autonomous path-planning techniques can further extend the system's capabilities. Improvements in battery management, water-storage capacity, and pump control could also increase operating endurance. Further experimental evaluation under different flame distances, smoke levels, lighting conditions, and floor surfaces would help establish the practical performance of the system.

IX. CONCLUSION

An autonomous firefighting robot integrating multi-directional flame sensing, MQ-2 smoke/gas detection, differential motor control, water-based suppression, and GSM emergency communication was developed using Arduino UNO. The three flame sensors provide approximate information about the direction of a fire, while the MQ-2 provides supplementary smoke and combustible-gas detection. The motor-control system enables the robot to approach the detected fire region, and the relay-operated pump with a servo-adjustable nozzle provides the water-suppression function. The SIM800L module adds remote emergency notification through SMS and phone calls to predefined numbers. The developed prototype demonstrates the feasibility of combining these functions within a compact embedded system. Further quantitative testing is required to evaluate detection accuracy, response time, communication performance, and extinguishing effectiveness under different operating conditions.

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