

Autonomous Fire Suppression Robot Based on Arduino

Ashvini Patil*

Abstract

Fire hazards continue to pose serious risks in homes, workplaces, and industrial facilities, making rapid detection and early suppression crucial for minimizing damage and protecting lives. This paper presents the design and development of an autonomous fire suppression robot built around an Arduino-based control system. The robot is engineered to independently detect, approach, and extinguish small fires with minimal human interaction. It incorporates multiple sensing components, including flame sensors for heat and light detection and an MQ-2 gas sensor for identifying smoke and flammable gases. Sensor data is processed by an Arduino Uno, which coordinates navigation and suppression actions. A servo-driven water nozzle provides accurate targeting, while a motor driver module ensures stable movement across various surfaces. To promote energy efficiency and longer operational time, the robot is powered by a solar-assisted battery system. In addition, a SIM800L communication module delivers real-time alerts, enabling remote supervision. Overall, the system offers a cost-effective, adaptable, and practical solution for improving fire response times and strengthening safety measures in a wide range of environments.

Keywords: Arduino, autonomous robot, embedded systems, fire detection, fire suppression, flame sensor, scalable, SIM800L, water spraying mechanism

INTRODUCTION

Fire safety is a critical concern in both residential and industrial environments, where rapid response and efficient control of fires can significantly reduce the risk of property damage and loss of life. In recent years, the integration of robotics and automation has shown considerable promise in enhancing firefighting efforts, particularly in scenarios that may pose danger to human responders. Firefighting robots equipped with autonomous navigation and fire detection systems are emerging solutions for such high-risk environments.

This paper presents the design and implementation of an Arduino-based firefighting robot that is capable of autonomously detecting and extinguishing fires. The robot utilizes a combination of flame and temperature sensors to detect the presence of fire, whereas a water pump system and motor-driven wheels enable it to navigate towards the fire and suppress it effectively. The Arduino platform was chosen because of its versatility, low cost, and ease of programming, making it ideal for rapid prototyping and educational purposes.

*Author for Correspondence

Ashvini Patil
E-mail: patilashvini65@gmail.com

Assistant Professor, Department of Electronics and Telecommunication, Parvatibai Genba Moze Collage of Engineering, Pune, Maharashtra, India

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The primary objective of this project is to develop a prototype that can autonomously identify fire hazards and execute a fire extinguishing task, thereby demonstrating the potential of robotics in emergency response scenarios. The proposed system aims to enhance safety, reduce human intervention in hazardous environments, and provide a scalable solution that can be adapted to various applications, including industrial plants, warehouses, and search-and-rescue operations [1]. This paper outlines the system design, the selection of components, the algorithm used for fire detection

and navigation, and the experimental results obtained from prototype testing. The outcomes of this project provide valuable insights into the feasibility of Arduino-based firefighting robots and broader implications of autonomous systems in fire safety applications [2].

LITERATURE SURVEY

Autonomous firefighting robots have been extensively studied in the fields of robotics, automation, and fire safety. Various studies have focused on fire detection systems, robot navigation, and fire extinguishing mechanisms [3]. This literature review reviews key studies and technological advancements relevant to the design of a firefighting robot using the Arduino Uno.

Fire detection is a critical component of firefighting robots, and several sensors have been explored for this purpose. In their study, different types of flame sensors were evaluated, highlighting that infrared (IR) and ultraviolet (UV) sensors are commonly used because of their ability to detect flames without being affected by smoke [4]. Furthermore, they demonstrated the use of IR flame sensors in small-scale robotic systems, where the sensor detects light emissions from fire and triggers an appropriate response. This approach has been widely adopted by firefighting robots because of its accuracy and simplicity.

Robotic Navigation and Obstacle Avoidance

Navigation is a key challenge in autonomous robots. The use of ultrasonic sensors for obstacle detection and avoidance in firefighting robots has also been investigated [5]. Their study concluded that ultrasonic sensors provide reliable distance measurements, allowing robots to navigate safely in cluttered environments. This is expanded by implementing a multi-sensor approach that combines ultrasonic and infrared sensors to enhance the ability of the robot to detect both fire sources and obstacles simultaneously. This multi-sensor fusion method ensures that the robot can navigate efficiently while heading towards fire and avoiding obstacles [6].

Microcontroller-Based Control Systems

Several studies have explored the use of microcontrollers such as Arduino in building firefighting robots. Implemented an Arduino Uno-based firefighting robot, emphasizing its simplicity and cost-effectiveness [7]. The study showed that the Arduino Uno can easily interface with sensors, motor drivers, and water-pumping mechanisms, making it ideal for prototyping firefighting robots. Additionally, the use of Arduino's open-source platform allows for flexibility and scalability in developing robotics projects, enabling the addition of new features, such as wireless control and real-time data processing [8].

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Extinguishing Mechanisms

The extinguishing mechanisms vary based on the intended environment of the robot. designed a firefighting robot that used a water pump mechanism to extinguish small fires. Their research demonstrated that water is an effective fire suppressant in controlled environments such as homes and

offices. Other studies have explored the use of CO₂ based extinguishers for large-scale industrial applications [9].

EXISTING SYSTEM

The existing system in our project, an autonomous fire suppression robot based on Arduino, uses a basic flame detection and movement mechanism. It consists of a flame sensor to detect fires, an Arduino Uno microcontroller to process inputs, and a DC motor-driven chassis for movement. Once the flame is detected, the robot moves towards it and activates a mini-water pump or extinguisher to suppress the fire [10]. The system is powered by a battery and operates using a simple decision-making algorithm. It currently functions well in small indoor environments but lacks advanced features, such as obstacle avoidance or thermal imaging. Overall, this design is cost-effective and suitable for autonomous fire control [11].

PROPOSED SYSTEM

The proposed system for an autonomous fire suppression robot aims to enhance the functionality, accuracy, and reliability of fire detection and suppression. It includes multiple flame and temperature sensors for better fire localization and the identification of high-risk zones. An improved algorithm using sensor fusion will allow robots to make smarter decisions in complex environments [12]. The robot will also be equipped with ultrasonic sensors for real-time obstacle detection and avoidance to ensure smoother navigation. A more powerful microcontroller (like Arduino Mega or ESP32) may be used for better processing capabilities. The chassis design was optimized for better maneuverability in narrow spaces. Additionally, the water/suppressant system can be upgraded with precise targeting and controlled spraying. A wireless module (e.g., Bluetooth/Wi-Fi) is added for remote monitoring and control. The system will also feature battery status monitoring for longer and safer operation. Overall, the proposed robot will be more autonomous, intelligent, and suitable for real-world fire safety applications [13].

SYSTEM ARCHITECTURE

The system architecture of the autonomous fire suppression robot was designed with modular components for efficient fire detection, navigation, and suppression. The core is an Arduino microcontroller that processes inputs from various sensors and controls actuators. Flame and temperature sensors were connected to detect the presence and intensity of fire. Ultrasonic sensors provide measurements of distance for obstacle avoidance. The motor driver module (L298N) controls the DC motors for robot movement based on the commands from the Arduino. A mini-water pump or servo-operated extinguisher is activated when a fire is detected. The system was powered by a rechargeable battery pack with a regulated voltage supply. Wireless communication modules (Bluetooth or Wi-Fi) enable remote monitoring and manual overriding, if needed. All components were mounted on a mobile chassis with proper weight distribution. The architecture ensures seamless coordination among sensing, processing, actuation, and communication for autonomous fire suppression.

METHODOLOGY

The methodology of the autonomous fire suppression robot involves a systematic approach for detecting and extinguishing fires. Initially, the robot continuously scanned the environment using the flame and temperature sensors. When a fire is detected, Arduino processes the input signals and determines the location of the fire. The robot then navigated towards the fire using motor control and obstacle detection sensors. Ultrasonic sensors help to avoid collisions with obstacles in the path. Once the robot reaches the fire source, it activates a water pump or extinguisher to suppress the flames. The system operated in a loop and continuously monitored the fire after each cycle. Power was supplied through a rechargeable battery to ensure mobility. All the components were integrated and programmed using an Arduino IDE. Testing and calibration were performed to ensure accurate detection and efficient fire extinguishing performance.

ARDUINO UNO

The Arduino Uno is an open-source microcontroller board based on an ATmega328P chip (Figure 1). It was designed to build electronic projects and prototypes. The board features 14 digital input/output pins, 6 analog inputs, a USB connection for programming, and a power jack for external power sources. It can be programmed using the Arduino IDE, making it accessible to both beginners and experienced engineers. The Arduino Uno is commonly used in robotics, automation, and IoT projects because of its simplicity, versatility, and large community support as shown in Figure 2.

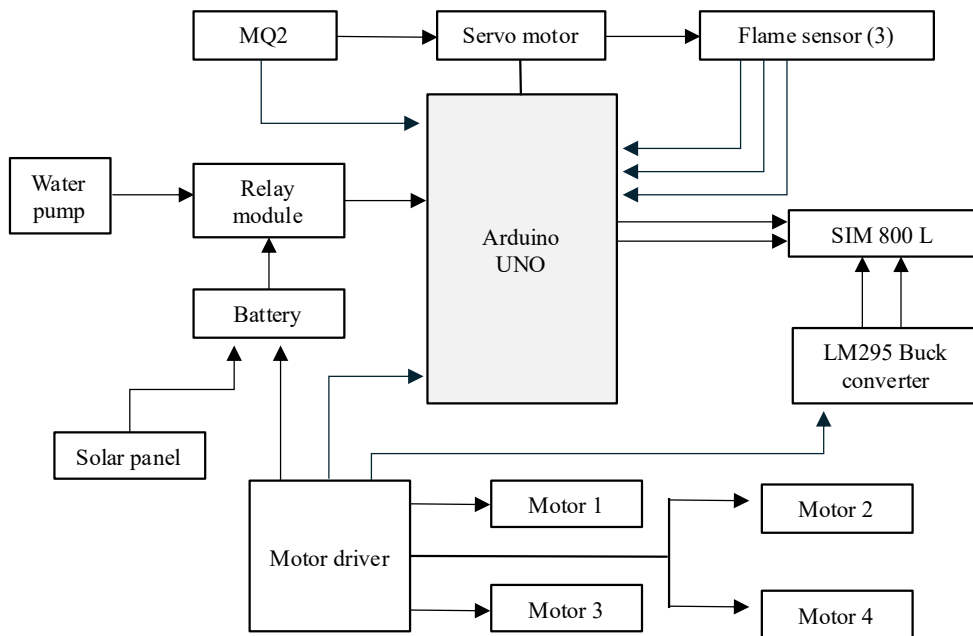


Figure 1. Block diagram.

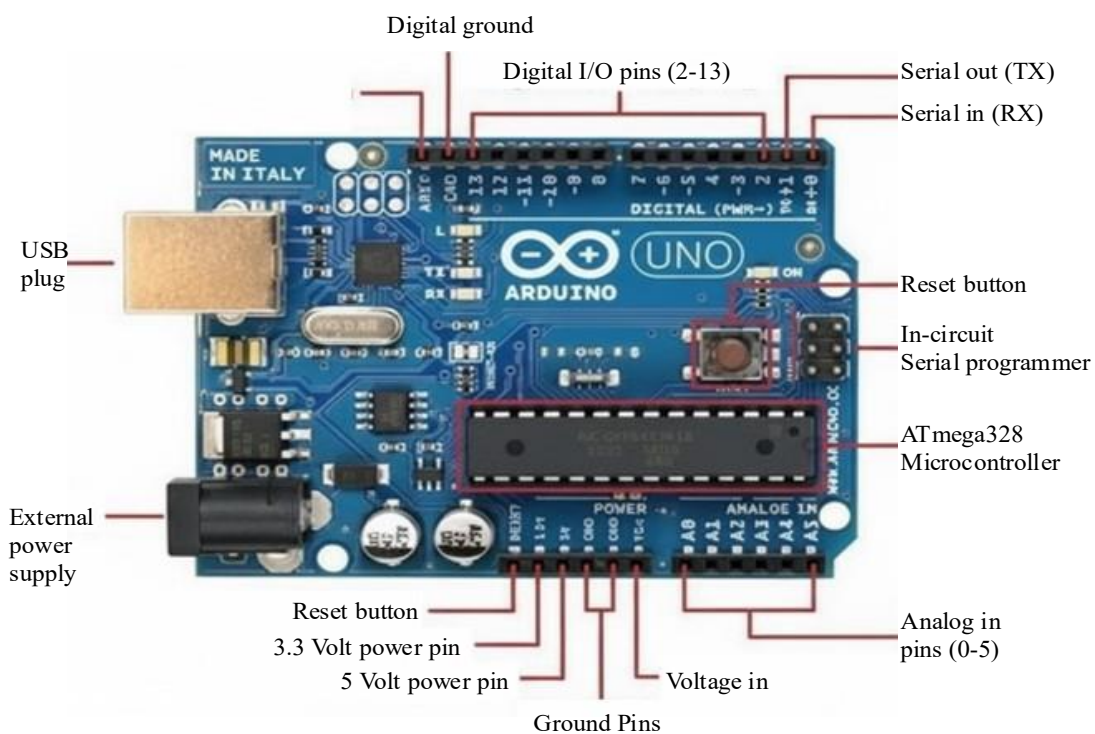


Figure 2. Circuit for Arduino UNO.

FLAME SENSOR

A flame sensor is designed to detect the presence of a flame or fire (Figure 3). It functions by sensing specific light wavelengths emitted by flames, typically in the infrared (IR) or ultraviolet (UV) spectrum. Flame sensors are widely used in safety systems, such as fire alarms, industrial machinery, and gas appliances, to provide early fire detection and automatic shut-off mechanisms during emergencies. Most flame sensors operate within a voltage range of 3.3 V to 5 V, with a typical detection range of 0.8–5 meters, depending on the model.

MQ2 Gas sensor

MQ2 is a versatile gas sensor commonly used for detecting gases, such as LPG, methane, hydrogen, alcohol, propane, and smoke (Figure 4). It is highly sensitive and operates by measuring changes in the resistance of its internal sensing material when exposed to these gases. The sensor has an analog output that varies according to the gas concentration and can also provide a digital output via a comparator. MQ2 operates in a voltage range of 5 V and is commonly used in applications such as gas leak detection systems, fire alarms, and air quality monitoring systems.

SIM800L MODULE

The SIM800L is a compact and affordable GSM/GPRS module that allows devices to communicate over cellular networks (Figure 5). It supports basic functions, such as making and receiving calls, sending and receiving SMS, and accessing the Internet via GPRS. The module operates on 2G networks and is widely used in IoT projects, embedded systems, and remote monitoring applications, owing to its small size and low power consumption. It works on a voltage range of 3.4 V to 4.4 V and communicates with microcontrollers using standard serial communication (UART). SIM800L supports quad-band GSM (850/900/1800/1900 MHz), making it suitable for global use.

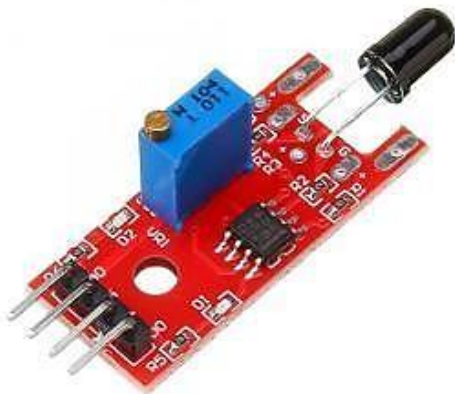


Figure 3. Flame sensor.



Figure 4. MQ2 gas sensor.



Figure 5. SIM800L module.

EXPERIMENTAL RESULT

The experimental results of the autonomous fire suppression robot showed effective real-time performance in fire and gas detection. The robot successfully detected fire using a flame sensor and navigated accurately toward the source. Upon detection, it activated the extinguisher system and simultaneously made an automatic call to a predefined contact using the SIM800L module. When gas was detected using the MQ gas sensor, the robot immediately sent an SMS alert to the user. These communication features worked consistently during the testing. The movement of the robot and obstacle avoidance were smooth and accurate across the different surfaces. Fire extinguishing was completed within seconds of detection in small-scale, controlled fires. The system showed minimal false alarms during repeated tests. The power efficiency was maintained with stable battery performance. Overall, the robot met the expected outcomes and proved to be effective for basic autonomous fire and gas hazard responses.

CONCLUSION

An autonomous fire suppression robot based on Arduino is an efficient and cost-effective solution for early fire detection and suppression. The system integrates multiple sensors, including flame sensors and MQ-2 smoke sensors, to accurately detect fire incidents. Using an Arduino Uno as the central controller, the robot autonomously navigated towards the fire source while avoiding obstacles. The water pump mechanism effectively extinguishes small-scale fires, making it suitable for deployment in homes, offices, and industrial environments. The functionality of the robot is enhanced by a SIM800L module, which provides real-time fire alerts via GSM communication. The solar-powered battery system ensures continuous operation and improves energy efficiency and sustainability. The experimental results confirm the reliability of the robot in detecting and extinguishing fires within a short response time. Future improvements include AI-based fire detection using thermal imaging, wireless remote control, and integration with IoT platforms for enhanced monitoring. This project highlights how autonomous firefighting robots can enhance safety while minimizing the need for human involvement under dangerous conditions.

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