IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 4, April 2026

DOI: 10.17148/IARJSET.2026.13408

DEVELOPMENT OF 360 DEGREES AUTONOMUS AND MANUAL FIRE FIGHTING ROBOT

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Abstract: Fire accidents pose a serious threat to human life, property, and the environment, especially in hazardous or inaccessible areas where manual firefighting becomes difficult and risky. To address this issue, an intelligent fire-fighting robotic system has been developed using an Arduino Mega platform. This project focuses on designing and implementing a multi-functional robot capable of detecting, navigating toward, and extinguishing fire autonomously, while also allowing manual control through Bluetooth communication. The robot is equipped with multiple flame sensors strategically placed around the system to detect fire from different directions. An ultrasonic sensor is integrated to measure distance and avoid obstacles, ensuring safe navigation. Additionally, environmental monitoring is achieved using temperature and smoke sensors, enabling the robot to respond effectively to critical conditions. When fire or abnormal temperature is detected, the system activates a water pump mechanism through a relay and directs a servo-controlled nozzle to spray water over the affected area.

The robot operates in two modes: automatic and manual. In automatic mode, it independently detects fire, navigates toward it, and extinguishes it without human intervention. In manual mode, the robot can be controlled remotely via Bluetooth, allowing the user to maneuver the robot and control the firefighting mechanism. A siren system is also incorporated to provide an audible alert during emergency conditions. The motor driving system is implemented using dual L298N motor drivers, enabling precise movement control such as forward, backward, left, and right navigation. The integration of sensors, actuators, and control logic makes the system efficient, responsive, and reliable in fire detection and suppression tasks. This project demonstrates a cost-effective and efficient solution for fire safety applications, particularly in industrial environments, warehouses, and areas that are dangerous for human intervention. The developed system highlights the potential of robotics and embedded systems in enhancing safety measures and reducing the risks associated with firefighting operations.

Keywords: Fire-fighting robot, Arduino Mega, Autonomous navigation, Flame sensors, Ultrasonic sensor, Water pump system, Servo-controlled nozzle, Bluetooth control, Manual and automatic modes, L298N motor driver.

I. INTRODUCTION

Fire accidents are one of the most dangerous hazards that can cause severe damage to life, property, and the environment. In many critical situations such as industries, laboratories, and confined spaces, manual firefighting becomes risky and challenging. To overcome these difficulties, advanced robotic systems are being developed to assist or replace human fire FIGHTERS.

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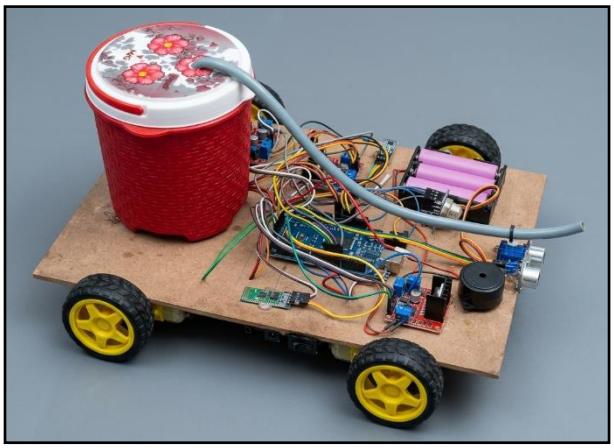

Fig.1

A fire-fighting robot is an intelligent machine designed to detect, approach, and extinguish fire efficiently. This project focuses on the development of a 360-degree autonomous and manual fire-fighting robot, capable of detecting fire from all directions using multiple sensors placed around it. It uses a microcontroller-based system to process sensor data and control its movement and actions. The robot can operate in both autonomous mode and manual mode using Bluetooth control, providing flexibility in different situations. It is equipped with mechanisms such as water spraying, obstacle avoidance, and alert systems to improve safety and efficiency. Overall, this system aims to reduce human risk, provide quick response, and enhance modern firefighting techniques.

II. LITERATURE REVIEW

[1]. S. Patel et al. (2019) DEVELOPED an Arduino-based fire-fighting robot using flame sensors and DC motors. The robot detects fire, moves toward it, and activates a water pump to extinguish the fire.

[2]. R. Kumar & P. Singh (2020) DESIGNED a robot equipped with ultrasonic sensors for obstacle avoidance and flame sensors for fire detection. The system performs automatic navigation to reach the fire source.

[3]. M. Ahmed et al. (2021) PROPOSED a Bluetooth-controlled firefighting robot where the user manually controls movement, and a pump with a nozzle system is used to extinguish fire.

[4]. K. Sharma et al. (2022) Developed a robot integrated with gas, temperature, and flame sensors to detect fire hazards at an early stage. It also sends alerts using an IoT module.

[5]. J. Lee et al. (2022) DESIGNED a tracked firefighting robot with strong mobility for rough terrains. It uses thermal cameras to accurately locate fire sources.

[6]. A. Verma & S. Gupta (2023) Built an autonomous robot using Arduino and ultrasonic sensors. It performs automatic navigation, avoids obstacles, and extinguishes fire using a servo-controlled water spray.

III. METHODOLOGY

In this project “Development of a 360 Degrees Autonomous and Manual Fire Fighting Robot” involves the systematic design and integration of various components to achieve efficient fire detection, navigation, and extinguishing. An Arduino Mega microcontroller is used as the central control unit to process inputs from multiple sensors such as flame, ultrasonic, temperature, and smoke sensors. The robot is capable of 360-degree fire detection using strategically placed flame sensors, enabling it to identify the direction of fire accurately. In autonomous mode, the robot navigates toward the fire while avoiding obstacles using ultrasonic sensing and motor control through L298N drivers. Once it reaches a safe distance, the water pump is activated, and a servo motor controls the nozzle to spray water effectively. In manual mode, the robot can be controlled via Bluetooth commands from a mobile device, providing flexibility in operation. Additionally, a siren alert system is activated during fire detection or emergency situations. Overall, the methodology ensures safe navigation, real-time monitoring, and efficient fire suppression

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IV. COMPONENTS

Fire Detection Mechanism (360° Detection)

This is a flame sensor module commonly used in fire detection systems and robotics projects. It is designed to detect infrared light emitted by flames within a certain range. The module consists of a flame sensing diode, a comparator IC, and an adjustable potentiometer for sensitivity control. It provides both analog and digital output signals, making it easy to interface with microcontrollers like Arduino. This sensor is widely used in fire-fighting robots and safety alarm systems for early fire detection.

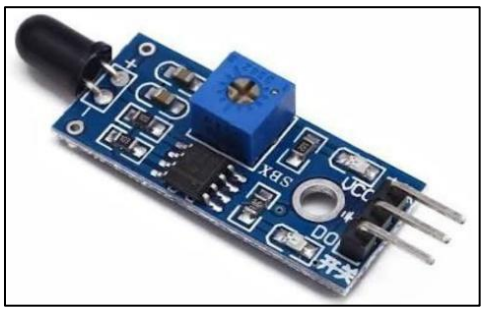

Figure.1: Flame sensor

NAVIGATION AND MOVEMENT

The movement of the robot is controlled using **two L298N motor drivers** connected to four DC motors.

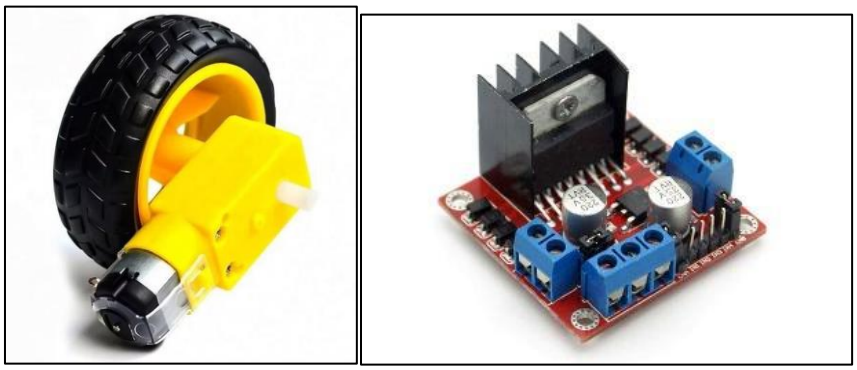

Figure.2: L298n motor driver and motor attached with wheels

OBSTACLE AVOIDANCE

Obstacle avoidance is an essential feature of the robot, implemented using an ultrasonic sensor to detect nearby objects. The sensor works by transmitting ultrasonic waves and receiving the reflected echo from obstacles.

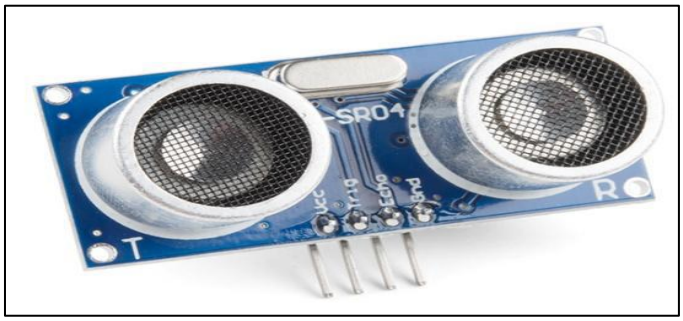

Figure 3: Ultrasonic sensor

The time taken for the echo to return is measured and used to calculate the distance using the formula Distance = Time × 0.0342. Based on this calculated distance, the robot continuously monitors its surroundings while moving. If an obstacle is detected within 15 cm, the robot immediately stops to prevent collision and ensure safe navigation.

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FIRE EXTINGUISHING SYSTEM

The fire extinguishing system consists of a DC water pump controlled by the L298N driver and a servo motor for nozzle movement. When fire is detected within a certain range, the robot immediately stops and activates the water pump. The servo motor rotates the nozzle in a left, right, and center sweeping motion. This movement ensures that water is sprayed over a wider area. As a result, the fire is effectively detected and extinguished in a short time.

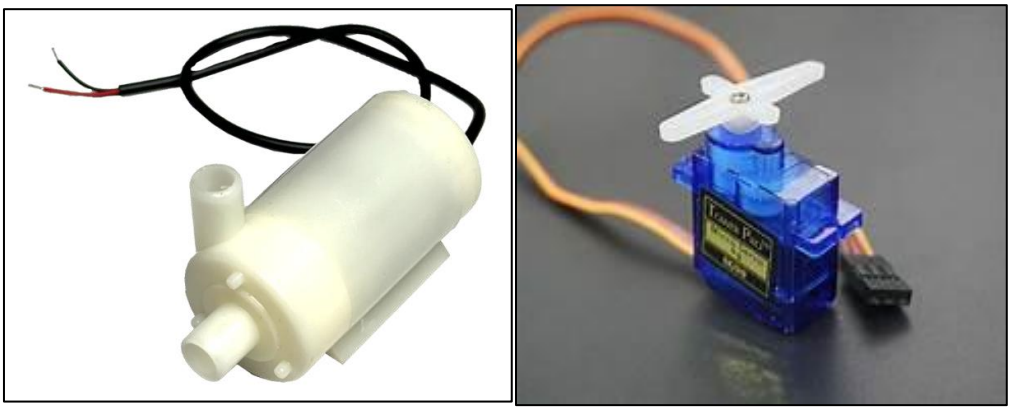

Figure 4: DC water pump & nozzle controller (servo motor)

ENVIRONMENTAL MONITORING

The environmental monitoring system uses a temperature sensor and a smoke sensor to detect hazardous conditions. The temperature sensor reads analog values and converts them into temperature, triggering an alert if it exceeds 55°C. The smoke sensor detects the presence of smoke based on analog signals. When high temperature or smoke is detected, the robot activates the water pump and siren. Additionally, the system sends real-time data via Bluetooth for remote monitoring and control.

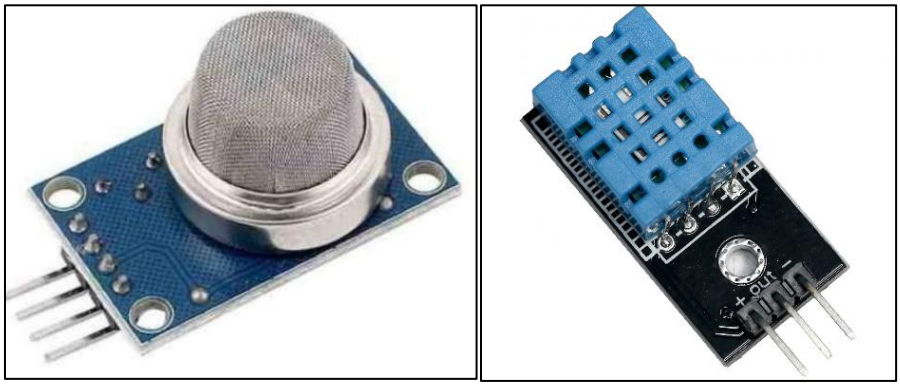

Figure 5: Temperature sensor & Smoke sensor

SIREN ALERT SYSTEM

A speaker is used to generate a fire engine siren sound using frequency variation. The environmental monitoring system also includes a speaker to provide an audible alert during emergencies. The speaker generates a fire engine siren sound using frequency variation. It is automatically activated when fire or hazardous conditions are detected. This alert helps in warning nearby people and improving safety awareness. Along with sensors, it enhances the overall emergency response of the robot.

Figure 6: Siren (Buzzer)

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COMMUNICATION SYSTEM

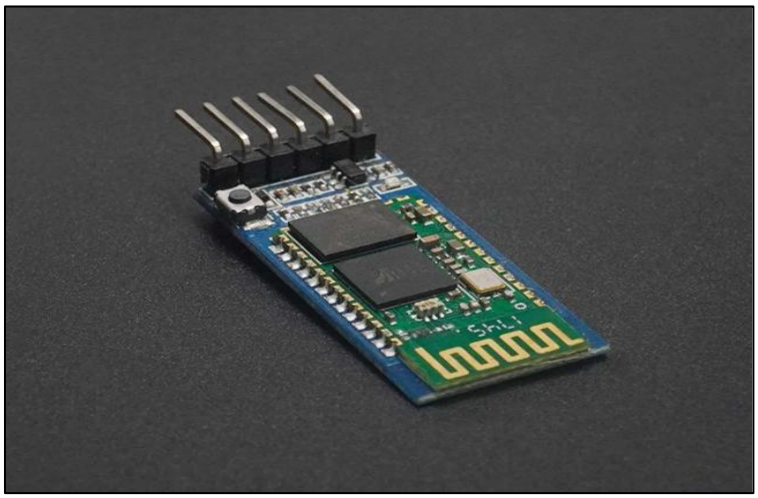

Figure 7: HC-05

The communication system uses the HC-05 Bluetooth module to enable wireless data transfer. It operates through Serial1 communication with the microcontroller. The module receives manual control commands from a mobile device. It also sends sensor data such as temperature and smoke levels. This ensures real-time monitoring and easy control of the robot. The code controls a fire-fighting robot using multiple sensors and actuators to perform both automatic and manual operations. It uses the Servo library to control the movement of the water nozzle, while L298N motor drivers manage the direction and speed of the robot's motors. Eight flame sensors are arranged around the robot to provide 360-degree fire detection, and an ultrasonic sensor is used to measure distance and avoid obstacles. A temperature sensor continuously monitors heat levels, and if the temperature exceeds a set limit, the system activates safety actions. The robot can operate in automatic mode, where it detects fire and moves toward it to extinguish it, or in manual mode, where it is controlled via Bluetooth commands. The water pump is activated to spray water on the fire, and a servo motor sweeps the nozzle to cover a wider area. Additionally, a speaker produces a siren sound to indicate fire detection or emergency conditions, ensuring both functionality and safety.

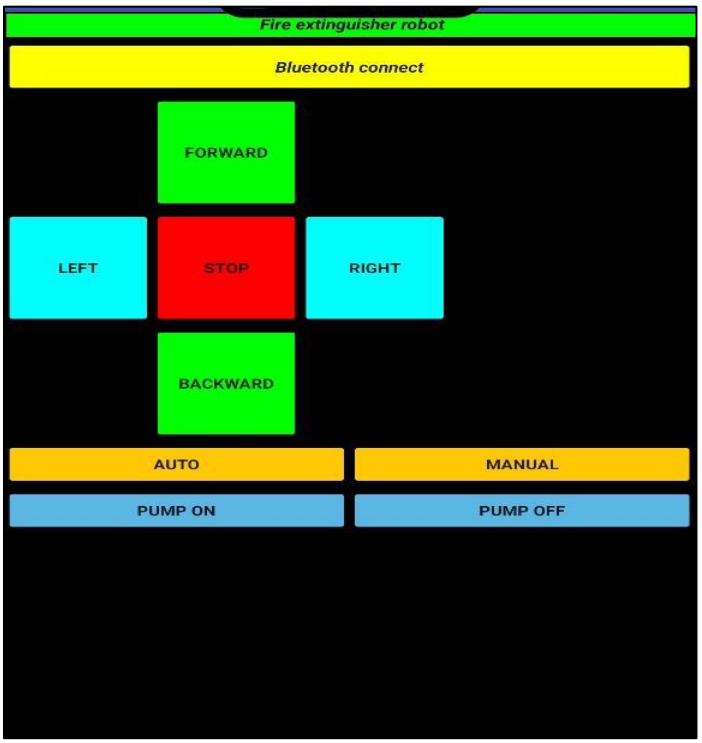

Figure 8: Manual Mode (App)

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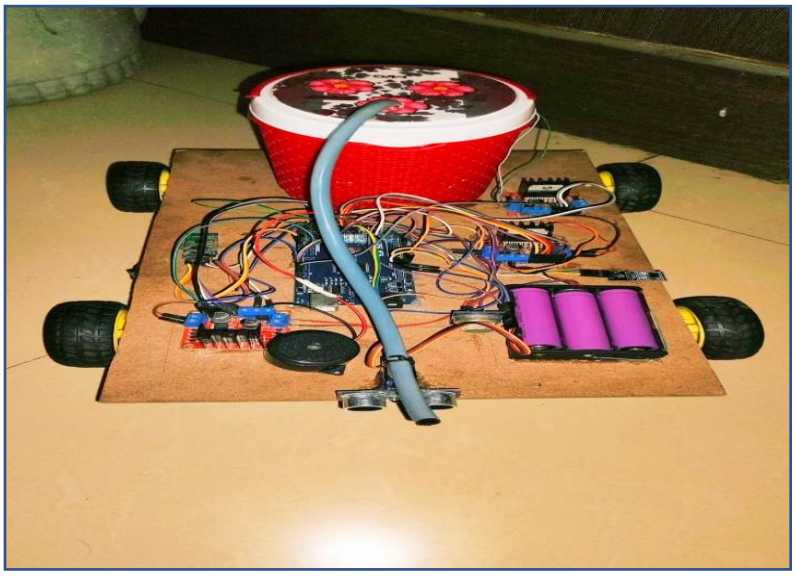
V. RESULTS

The project "Development of a 360 Degrees Autonomous and Manual Fire Fighting Robot" was successfully implemented and tested, demonstrating reliable performance in various conditions. The robot effectively detected fire using multiple flame sensors, providing complete 360-degree coverage with quick response time. In autonomous mode, it successfully navigated toward the fire source by following sensor-based directional logic. The ultrasonic sensor ensured safe movement by detecting obstacles and preventing collisions. The fire extinguishing system, including a water pump and servo-controlled nozzle, efficiently suppressed small fires. In manual mode, the robot responded accurately to Bluetooth commands for movement and control functions.



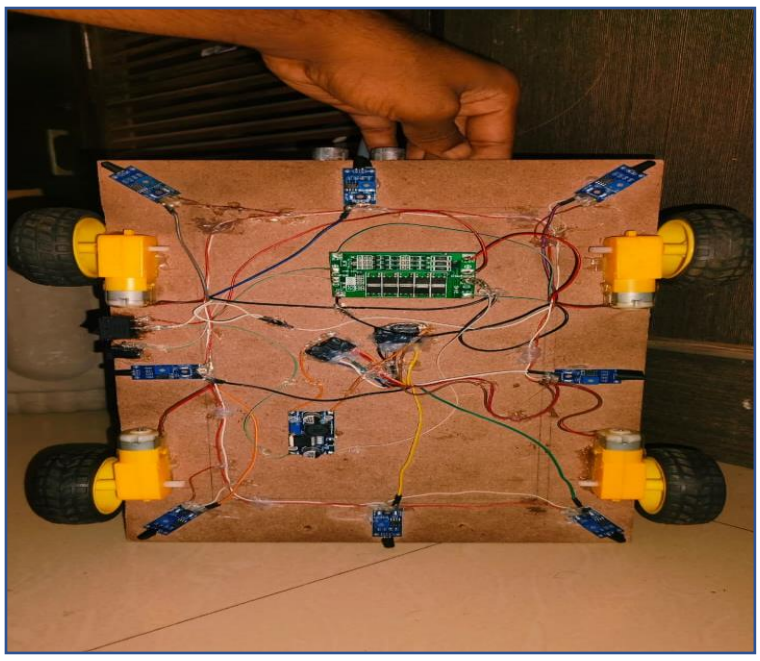


Figure.10

The environmental monitoring system provided real-time temperature and smoke readings, enhancing safety. The siren alert system worked properly, indicating emergency situations with clear sound. The overall system showed stable and continuous performance during repeated tests. Although minor limitations such as sensor sensitivity and battery constraints were observed, the robot successfully achieved all its intended objectives.

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VI. CONCLUSION

The project successfully demonstrates the development of a 360-degree autonomous and manual fire-fighting robot capable of detecting, navigating toward, and extinguishing fire effectively. The integration of multiple sensors ensures accurate fire detection, environmental monitoring, and obstacle avoidance, enabling safe and efficient operation. The robot performs well in autonomous mode by independently reaching the fire source, while the manual Bluetooth control adds flexibility for user intervention. The fire extinguishing mechanism, including the water pump and servo-controlled nozzle, works reliably for small-scale fires, and the siren system enhances safety awareness during emergencies. Although certain limitations such as sensor sensitivity and limited capacity for large fires exist, the overall system performance is stable and satisfactory. Thus, the project highlights the importance of robotics in improving fire safety, reducing human risk, and providing an efficient solution for hazardous environments. The results obtained from the implementation and testing of the **"Development of a 360 Degrees Autonomous and Manual Fire Fighting Robot"** clearly demonstrate that the system performs its intended functions effectively and reliably. The robot was able to successfully detect fire from all directions using multiple flame sensors, ensuring complete 360-degree coverage and quick response to fire incidents.

The autonomous navigation system proved to be efficient, as the robot could accurately move toward the fire source based on sensor inputs without requiring human intervention. The integration of the ultrasonic sensor ensured safe movement by preventing collisions with obstacles, thereby enhancing the overall stability and safety of the system.

The fire extinguishing mechanism, consisting of a water pump and servo-controlled nozzle, worked effectively in suppressing small-scale fires. The sweeping action of the nozzle improved the coverage area, resulting in better extinguishing performance. Additionally, the environmental monitoring system using temperature and smoke sensors enabled the robot to respond to critical conditions even before visible flames were detected.

The manual control feature using Bluetooth communication provided flexibility, allowing the user to operate the robot as needed. The siren alert system also functioned properly, giving an audible warning during emergency situations.

Although certain limitations such as sensor sensitivity and limited range of operation were observed, the overall performance of the robot was stable and satisfactory. The system achieved all the desired objectives, including fire detection, navigation, obstacle avoidance, and fire suppression.

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