Flameseeker: An Autonomous Arduino-Based Fire Suppression Rover

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Abstract- Fire incidents pose significant risks to human life, infrastructure, and industrial assets. Firefighting operations are inherently hazardous, often exposing personnel to life-threatening environments. To minimize human risk and ensure early fire suppression, an automated firefighting system is proposed. This paper presents the design and implementation of a novel Arduino-based firefighting robot capable of detecting and extinguishing fire efficiently.

The system integrates an embedded control unit using Arduino UNO, two flame sensors for fire detection, an ultrasonic sensor for obstacle avoidance, a water pump-based extinguishing mechanism, and a Bluetooth module for wireless control via an Android application. The flame sensors continuously monitor the environment, and upon detecting fire, the system activates the water dispenser to suppress it. The ultrasonic sensor ensures safe navigation by stopping the robot when obstacles are detected and resuming movement once the path is cleared. The robot can be manually controlled in forward, backward, left, and right directions through Bluetooth communication.

The proposed system enhances safety in industrial and hazardous environments by reducing direct human intervention in fire-prone areas. Experimental implementation demonstrates reliable fire detection, obstacle avoidance, and rapid extinguishing capability, making it a cost-effective and efficient solution for early fire response applications.

Keywords: Fire-Fighter, Robot, Extinguishment, Robot, Arduino Uno, Sensors

I. INTRODUCTION

Fire hazards remain one of the most critical threats to human life, industrial infrastructure, and economic stability. Despite significant advancements in fire safety systems, conventional firefighting methods still rely heavily on direct human intervention, often placing firefighters and industrial personnel in life-threatening situations. In hazardous environments such as chemical plants, manufacturing industries, warehouses, and confined spaces, even a minor ignition can rapidly escalate into a catastrophic event. Therefore, the integration of intelligent and automated systems into fire safety mechanisms has become an essential research focus in modern engineering.

The emergence of embedded systems and robotics has opened new possibilities for reducing human exposure to dangerous conditions. Autonomous and semi-autonomous robots are increasingly being deployed in environments that are inaccessible, unstable, or unsafe for human operation. Among these applications, firefighting robots represent a significant innovation aimed at early fire detection, rapid response, and effective suppression without endangering human life. By combining sensing technologies, microcontroller-based control systems, and wireless communication, such robots can operate efficiently in dynamic and high-risk scenarios.

This research presents the design and development of an Arduino-based firefighting robot equipped with dual flame sensors for precise fire detection, an ultrasonic sensor for obstacle avoidance, and a water-based extinguishing mechanism for rapid suppression. The system integrates Bluetooth communication to enable real-time control and monitoring through an Android application. The proposed design emphasizes reliability, cost-effectiveness, and operational safety, making it suitable for industrial and small-scale applications.

Unlike traditional fire alarm systems that merely detect and notify, the proposed robot actively responds to fire incidents by navigating toward the source and initiating extinguishing action. The integration of sensing, navigation, and suppression mechanisms into a compact embedded platform demonstrates a practical approach toward intelligent fire management systems. This work contributes to the advancement of automated safety solutions by presenting a scalable and adaptable firefighting robotic system capable of minimizing human risk while ensuring effective fire control.

II. LITRETURE SURVEY

In recent years, significant research efforts have focused on developing intelligent fire detection and suppression systems to improve safety in hazardous environments. Traditional firefighting approaches rely on human intervention, which is inherently risky and susceptible to delayed responses in complex scenarios. The integration of robotics and embedded systems into fire management has thus emerged as a key area of innovation.

Many researchers have explored the use of sensor-based technologies for early fire detection. Flame sensors, infrared sensors, and gas sensors have been widely implemented due to their capability to detect combustion characteristics such as light intensity, temperature fluctuations, and gas emissions. For instance, in their work on autonomous fire detection systems, authors have shown that multi-sensor fusion significantly enhances the reliability and precision of fire recognition compared to single-sensor approaches. Similarly, studies investigating microcontroller-based control platforms, such as Arduino and Raspberry Pi, have demonstrated that low-cost embedded solutions can achieve real-time sensing and actuation in emergency response systems.

Several research works have also addressed the development of robotic platforms for fire monitoring and suppression. Mobile robots equipped with thermal and optical sensors have been designed to autonomously navigate through environments while identifying fire sources. In one study, researchers deployed an autonomous robotic vehicle with an array of temperature and flame sensors that could locate and approach a fire source, triggering an extinguishing mechanism. Other investigations have integrated ultrasonic sensors into robotic systems to avoid obstacles and ensure safe navigation, particularly in cluttered industrial settings. The use of Bluetooth and wireless communication for remote control and real-time feedback has also been documented, allowing operators to monitor robot behavior and intervene when necessary.

Despite these advances, most existing systems either focus exclusively on detection or lack effective mechanisms for fire suppression. A limited number of studies have combined both detection and extinguishing functions into a single robotic platform. Furthermore, many proposed designs lack user-friendly interfaces or real-time control capabilities, reducing their practical applicability in dynamic environments.

The present research builds upon these findings by integrating flame sensors, ultrasonic obstacle avoidance, wireless control, and an effective water-based extinguishing system into an Arduino-based robotic architecture. This approach not only improves fire detection accuracy but also enables active suppression, autonomous navigation, and remote control through an Android application. The proposed system addresses key limitations in existing literature by offering a cost-effective, reliable, and adaptable solution suitable for industrial and emergency applications.

III. JUSTIFICATION OF THE PROPOSED WORK

The present study addresses these research gaps by developing an Arduino-based firefighting robot that integrates:

Dual Flame Sensors for reliable and accurate fire dete ction.
Ultrasonic Obstacle Avoidance to enable real-time navigation in unpredictable environments.
Water-Based Extinguishing Mechanism to actively suppress detected fires rather than merely detect them.
Bluetooth-Controlled Android Interface to allow real-

time control and feedback, enhancing user interaction and remote operation.
Low-Cost Embedded System Design making the solution affordable, scalable, and suitable for industrial and educational applications.

By addressing these gaps, the proposed system enhances detection accuracy, operational safety, navigation autonomy, and practical usability. This validates its contribution as a cost-effective and reliable solution for early fire response in hazardous and dynamic environments.

IV. NOVEL FIRE FIGHTING ROBOT

The proposed Novel Fire Fighting Robot is designed to minimize human exposure to hazardous fire environments by automating fire detection and suppression. Instead of placing firefighters at direct risk, the robot is deployed to approach and control fire incidents efficiently and safely.

The system is built around the Arduino UNO microcontroller, which serves as the central control unit for sensing, decision-making, and actuation. The hardware architecture consists of flame sensors and temperature sensors for accurate fire detection, a motor driver module to control DC motors for locomotion, a servo motor for directional water spraying, a relay module for pump activation, a water pump, and a mounted water tank for fire suppression.

The power supply unit provides regulated voltage to both the Arduino UNO and the motor driver circuit to ensure stable and reliable operation. When the flame or temperature sensors detect the presence of fire, the Arduino processes the sensor signals and commands the robot to move toward the fire source. Upon reaching an optimal distance, the relay activates the water pump, and the servo motor directs the water flow toward the flame to extinguish it effectively.

This integrated embedded system enables rapid detection, autonomous movement, and active fire suppression, making the robot suitable for industrial, laboratory, and high-risk environments. The proposed design enhances safety, reduces response time, and offers a cost-effective alternative to conventional manual firefighting methods.

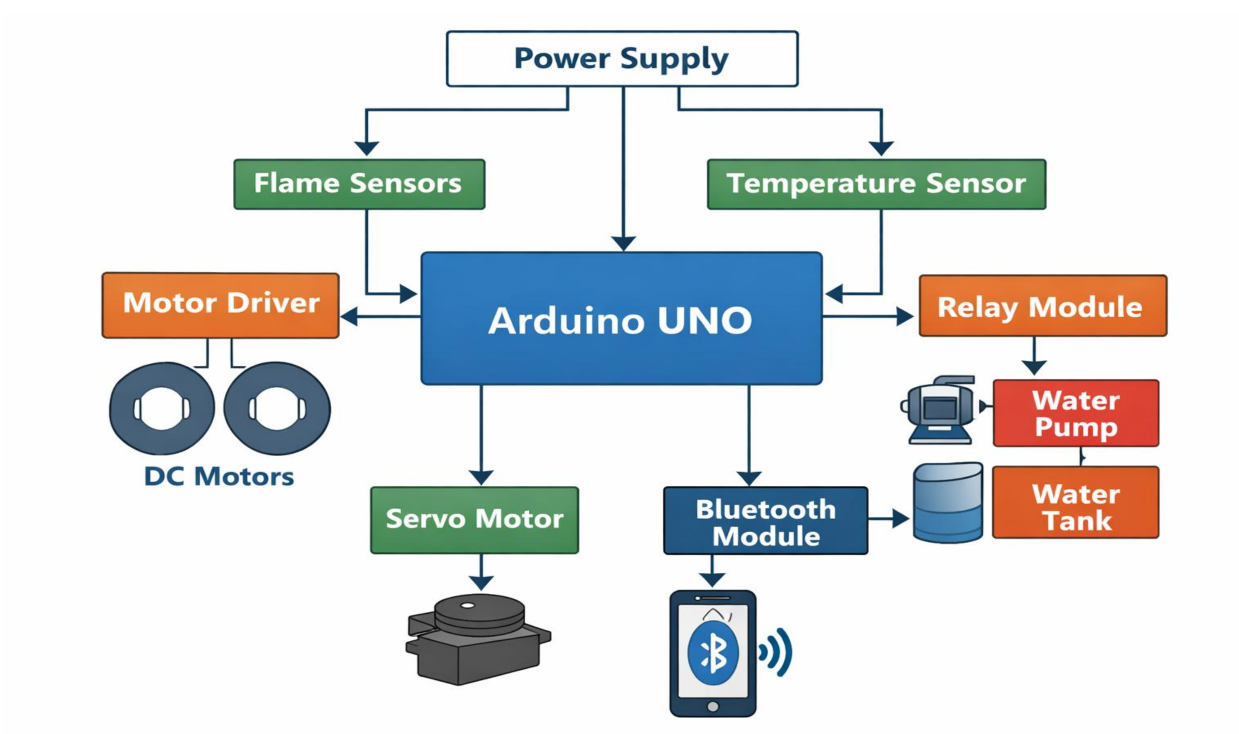

Fig. 1: Block Diagram of Novel Fire Fighting Robot with Arduino

The working of the proposed Arduino-based Fire Fighting Robot is based on an integrated sensing, processing, navigation, and extinguishing mechanism. The power supply unit provides regulated voltage to the Arduino UNO, motor driver module, sensors, relay module, and water pump to ensure stable system operation. The Arduino UNO functions as the central control unit, continuously monitoring input signals received from the flame sensors and temperature sensor.

During operation, the flame sensors detect infrared radiation emitted by fire, while the temperature sensor identifies abnormal temperature rise. These sensor signals are transmitted to the Arduino for processing. Upon detection of fire, the Arduino generates control signals to the motor driver module, which drives the DC motors to move the robot toward the fire source. The robot navigates in the required direction to align itself with the detected flame.

Once the robot reaches a predefined safe distance from the fire, the Arduino activates the relay module, which switches ON the water pump. Water from the onboard water tank is then pumped through a nozzle directed by a servo motor to accurately target the flame. The servo motor ensures proper angular positioning for effective extinguishing. After the fire is suppressed, the system stops the pump and returns to monitoring mode.

Additionally, a Bluetooth module is integrated to enable remote manual control through an Android-based application. This feature allows the operator to control the robot's movement in forward, backward, left, and right directions in hazardous situations. The combined operation of sensing, control, navigation, and suppression modules ensures efficient fire detection and rapid extinguishment while minimizing human risk.

The proposed firefighting robotic system is implemented using the Arduino UNO (ATmega328P microcontroller) as the central processing and control unit. The system architecture is divided into power management, sensing, control, actuation, communication, and display modules to ensure reliable and coordinated operation.

1. Power Management Unit

The power supply section consists of a 220 V AC to 12 V step-down transformer, followed by a bridge rectifier for AC-to-DC conversion. A filtering capacitor is employed to minimize ripple content, and voltage regulators (7805 and 7812) provide regulated 5 V and 12 V outputs. The 5 V supply powers the Arduino UNO, sensors, Bluetooth module, and LCD, while the 12 V supply drives the DC motors and water pump. This dual-voltage architecture ensures electrical isolation and stable operation of low-power logic circuits and high-power actuators.

Fig.1.a. Types of Power Management Unit

2. Sensing Module

The sensing subsystem includes:

- Flame Sensor (IR-based):
  Operates in the wavelength range of 760–1100 nm to detect infrared radiation emitted by flames. The module provides both analog and digital outputs. The detection angle is approximately 60°, with an effective range up to 0.8 m under standard flame intensity. The Arduino continuously samples the digital output to identify fire presence.

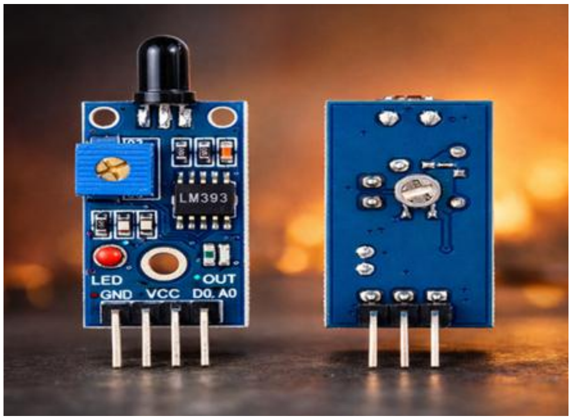

Fig.1.b. IR-Based Flame Sensor Module (KY-026)

- DHT11 Temperature and Humidity Sensor:
  Communicates via a single-wire serial interface. It measures temperature in the range of 0–50°C and relative humidity from 20–90% RH with calibrated digital output. Environmental monitoring enhances fire detection reliability and system awareness.

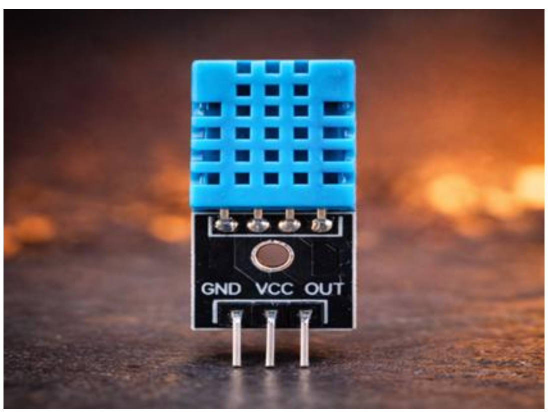

Fig.1.c. DHT11 Temperature and Humidity Sensor:

- HC-SR04 Ultrasonic Sensor:
  Operates at 40 kHz frequency to measure distance using time-of-flight principle. It calculates obstacle distance based on echo return time. This sensor enables real-time obstacle avoidance and collision prevention during navigation.

Fig1.d..HC-SR04 Ultrasonic Sensor:

3. Control and Processing Unit

The Arduino UNO processes sensor inputs using programmed logic. Upon flame detection, the microcontroller executes a predefined control algorithm that:

1. Validates fire detection signal.
2. Enables motor driver for directional movement.
3. Aligns the servo-mounted nozzle toward the fire source.
4. Activates relay module to energize the water pump.

The system supports both autonomous and Bluetooth-controlled manual operation modes.

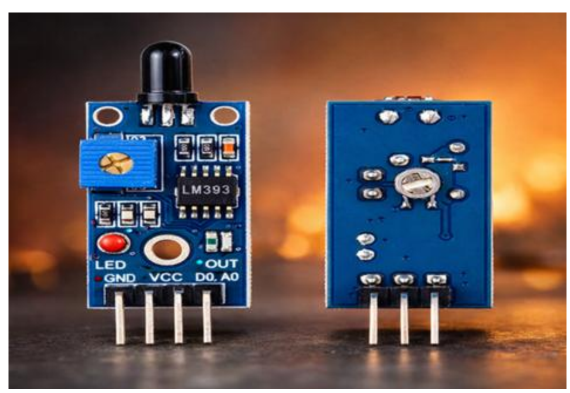

Fig.1.e. Arduino UNO

4. Actuation and Drive Mechanism

- Motor Driver Module (L298N or equivalent): Provides bidirectional control of two DC motors using H-bridge configuration. PWM (Pulse Width Modulation) signals from the Arduino regulate motor speed, while logic signals determine direction of rotation.

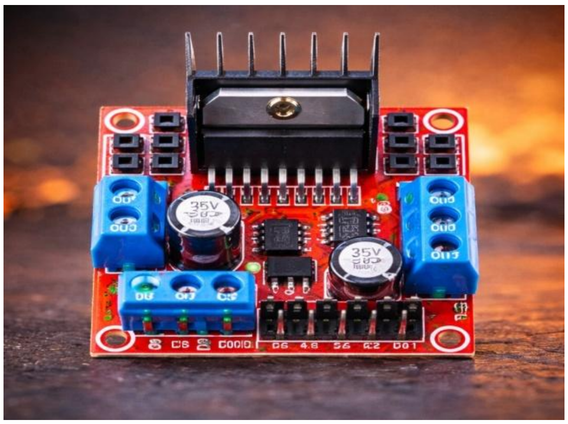

Fig.1.f. Motor Driver Module

- DC Motors: Convert electrical energy into mechanical rotational motion for robot locomotion. Speed control is achieved by varying the applied DC voltage through PWM.

Fig.1.g. DC Driver Module

- Servo Motor: Functions as a rotary actuator with approximately 180° angular displacement (±90°). It is controlled via PWM signals (typically 50 Hz frequency with varying pulse width between 1–2 ms) to achieve precise nozzle positioning.
- Relay Module and Water Pump: The relay acts as an electrically isolated switching device controlled by the Arduino. When triggered, it powers the 12 V DC water pump, which transfers water from the tank to the nozzle for fire suppression.

5. Communication Module

The HC-05 Bluetooth module operates using Serial Port Protocol (SPP) at 2.4 GHz ISM band with Bluetooth V2.0+EDR specification. It provides a wireless communication range of approximately 8–10 meters. The module interfaces with the Arduino via UART (Tx/Rx), enabling command-based control through an Android application for directional movement (forward, backward, left, right) and system activation.

6. Display Module

A 16×2 LCD display is interfaced with the Arduino to provide real-time system information such as temperature readings, humidity levels, fire detection status, and operational mode.

V. OPERATIONAL ALGORITHM

1. System initializes and enters monitoring mode.
2. Sensors continuously scan the environment.
3. If flame intensity exceeds threshold value, Arduino validates detection.
4. Robot navigates toward flame while avoiding obstacles using ultrasonic feedback.
5. Servo motor aligns nozzle toward flame source.
6. Relay energizes water pump to spray water.
7. After flame suppression, pump deactivates and system returns to standby mode.

The proposed architecture ensures coordinated sensing, real-time processing, obstacle-aware navigation, and targeted fire suppression. The integration of embedded control, wireless communication, and electromechanical actuation provides a technically robust, cost-effective, and scalable solution for automated firefighting applications in industrial and hazardous environments.

VI. RESULT ANALYSIS

The proposed Arduino-based Fire Fighting Robot was experimentally tested under controlled indoor conditions to evaluate its fire detection accuracy, navigation performance, obstacle avoidance capability, and extinguishing efficiency.

1. Fire Detection Performance

The flame sensor module was tested using a controlled lighter flame at varying distances. The system successfully detected flame presence within an approximate range of 0.6–0.8 m under normal lighting conditions. The detection angle of nearly 60° enabled effective identification of the flame source within its sensing field. The DHT11 sensor provided supplementary environmental data, confirming a noticeable temperature rise during fire presence. The response time between flame detection and system activation was observed to be within a few milliseconds, demonstrating real-time processing capability of the Arduino UNO.

2. Navigation and Obstacle Avoidance

The HC-SR04 ultrasonic sensor was evaluated for distance measurement and obstacle detection accuracy. The sensor reliably detected obstacles within a range of 2 cm to 400 cm. During experimental trials, when an obstacle was placed in the robot's path, the ultrasonic sensor successfully triggered a directional change without collision. The obstacle avoidance mechanism ensured smooth navigation toward the fire source, validating the effectiveness of the implemented control algorithm.

3. Extinguishing Efficiency

Upon detecting the flame, the Arduino activated the relay module, switching ON the 12 V DC water pump. The servo motor adjusted the nozzle direction toward the flame, enabling targeted water spraying. The average time required to extinguish a small open flame (lighter flame test) was observed to be within a few seconds, depending on flame intensity and distance. The servo-controlled nozzle significantly improved water coverage and extinguishing precision.

4. Wireless Control and Communication

The HC-05 Bluetooth module maintained stable communication with the Android application within a range of 8–10 meters. The robot responded accurately to movement commands (forward, backward, left, and right) without noticeable latency. This feature demonstrated reliable manual control capability in hazardous scenarios.

5. Overall System Performance

The integrated system exhibited stable and coordinated operation among sensing, processing, navigation, and actuation modules. The Arduino UNO effectively handled real-time sensor data processing and actuator control without system failure. The power supply unit maintained consistent voltage levels, ensuring uninterrupted performance during testing.

VII CONCLUSION

In this work, a novel Arduino-based Fire Fighting Robot has been successfully designed and implemented to assist in fire detection and suppression tasks. The proposed system integrates sensing, navigation, control, and extinguishing mechanisms into a compact embedded platform, thereby reducing direct human involvement in hazardous fire environments.

The robot is capable of autonomous as well as Bluetooth-controlled operation. It can move in forward, backward, left, and right directions and stop as required. The integration of flame sensors enables early fire detection, while the ultrasonic sensor ensures effective obstacle avoidance during navigation. Upon detecting fire, the Arduino UNO microcontroller processes the input signals and activates the water pump through a relay mechanism. The servo-mounted nozzle accurately directs water toward the flame, ensuring efficient extinguishing.

The implementation of wireless control using an Android application through the Bluetooth module enhances operational flexibility and safety. The system architecture ensures coordinated functioning of all modules, with the Arduino UNO serving as the central controller for precise and reliable execution of tasks.

Overall, the proposed firefighting robot provides a cost-effective, safe, and efficient solution for fire management in industrial and high-risk environments. It demonstrates the potential of embedded systems and robotics in minimizing human risk, protecting property, and improving emergency response mechanisms. The developed system can serve as a foundational model for future advancements in intelligent and fully autonomous firefighting robotic applications.

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