iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** VI **Month of publication:** June 2025

DOI: https://doi.org/10.22214/ijraset.2025.72413

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

Firefighting Robot Using Arduino: A Fire Detection and Suppression System

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Abstract: Some of the risks that fire incidents present involve destruction of property and sometimes even the loss of human life. Traditional firefighting operations usually require human intervention, which can be unsafe, especially when there are extreme temperature environments or toxic gases around. The design and development of an Arduino-based autonomous firefighting robot that can detect and extinguish fires without human help is presented. The system sends commands to servo motors and waterfalls from a water pump through flame sensors to extinguish the fire as quickly as possible along the direction of the fire. This enhancement shall serve to increase operational efficiency and safety within firefighting activities.
Keywords: Arduino, Firefighting robot, Flame sensor, Water pump, Autonomous navigation, Embedded system.

I. INTRODUCTION

Fire risks refer to possible damages to property, killing life, and destruction of the environment. The traditional methods of firefighting are largely human-centered and place a great amount of human risk in hot or otherwise dangerous conditions. The evolution in robotics and embedded technology makes it possible for an autonomous firefighting robot to provide a safer and more efficient solution.

The Arduino-based autonomous firefighting robot detects and extinguishes small fires. It uses human detection (PIR sensor), water pump for suppression, flame sensors for detection, and wireless control for enhanced performance. It is a more cost-effective option in ensuring a prompt response when fires occur in confined spaces or dangerous places.

II. LITERATURE REVIEW

The potential use of Arduino-based systems in firefighting has been the subject of numerous studies. A flame-tracking robot developed by Sharma et al. [1] uses water pumps and infrared sensors to extinguish small-scale fires.

Therefore, Hosamani et al. [2] suggested a robot that uses a combination of motorised wheels and flame sensors to battle fires on its own. By adding Bluetooth and Wi-Fi camera modules to give real-time input, Murad et al. [3] created a tank-shaped firefighting robot that could navigate through confined locations. Machine learning techniques to forecast fires and optimise the path were presented by Chenchireddy et al. [4], indicating the path towards intelligent robot firefighting systems.

According to these investigations, Arduino-based robots offer a scalable and reasonably priced way to handle fire situations in enclosed or dangerous spaces.

III. SYSTEM DESIGN

Through a synchronised hardware and software interface, the system combines sensors, actuators, and and real-time flame detection.control logic with an Arduino UNO to provide water-based fire suppression, directional movement,

A. Hardware Components

Component	Description
Arduino UNO	Main controller (ATmega328P)
Flame Sensors	Infrared-based, placed at front and sides
Motor Driver (L298N)	Controls two DC motors
DC Motors	Provides movement in all directions
Servo Motor (SG90)	Controls nozzle direction
Water Pump	Sprays water when fire is detected
Bluetooth Module (HC-06)	Enables wireless control
Wi-Fi Camera	Sends real-time footage
PIR Sensor	Detects human presence for rescue operations

B. Sostware Design

The program logic implemented in Arduino IDE includes:

* Continuous sensor monitoring
* Directional flame detection (left, right, center)
* Fire suppression routine
* Servo sweep during water discharge
* Wireless control override (Bluetooth)
* Camera feedback via Wi-Fi

IV. METHODOLOGY

In patrol mode, the robot uses flame sensors to scan the surroundings. It moves forward until it reaches a safe operating distance (30 cm) after detecting a flame and uses signal intensity to estimate the source's direction. It halts, activates the pump, and uses a servo to move the nozzle side to side.

In enhanced versions, the robot includes:

* PIR Sensor Activation – Scans for human life before deploying full suppression.
* Camera Streaming – For remote human verification.
* Bluetooth Override – Allows manual intervention when needed.

V. RESULTS AND DISCUSSION

A. Testing Setup

To minimise false positives, tests were conducted in a 3 x 3 m indoor space with dim ambient lighting. To evaluate detection accuracy and response behaviour, a candle flame was used as the fire source and positioned at various angles and distances. At first, the robot was positioned one metre from the flame.

B. Observations

Observations

Parameter	Result
Detection Range	Up to 80 cm
Response Time	~1.5 seconds (to detect and act)
Suppression Time	6–8 seconds (for a candle flame)
Battery Life	~2 hours of continuous patrol
PIR Detection Accuracy	95% in test scenarios

C. Performance Evaluation

1) Accuracy of Detection: Although detection was less accurate in high ambient lighting circumstances, the fire sensors provided reliable directional information.
2) Mobility: Due to inadequate obstacle avoidance algorithms, the robot performed worse on rough terrain than it did on smooth indoor surfaces.
3) Power Efficiency: Suitable for brief autonomous activities, the device could operate in patrol mode for up to two hours using a standard rechargeable Li-ion battery pack.
4) Human Detection (PIR): To avoid harm, the PIR sensor appropriately identified the presence of a human and started a suppression pause.

D. Limitations

1) Light Interference: Sometimes, glaring natural or artificial light caused false flame detection. Including additional verification (such as gas or temperature sensors) would increase the system's dependability.
2) Limited Adaptability to Terrain: The current design is intended for indoor, level terrain. Modifications to the chassis and suspension would be required for deployment outside.
3) Water Reservoir Limits: The robot's ability to combat larger fires is constrained by the amount of water it can hold.

Despite these drawbacks, the prototype shows a lot of promise as a useful firefighting tool in hazardous or enclosed environments.

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VI. FUTURE SCOPE

The intelligent firefighting technologies that this robot represents are proof-of-concept. Potential improvements include: Enhanced terrain adaptability for outdoor or multi-level firefighting; swarm robots for large-scale firefighting; machine learning for better obstacle avoidance; integration of thermal and gas sensors for early detection; and Internet of Things-based alarm systems for automated dispatch and remote monitoring.

VII. CONCLUSION

A low-cost, Arduino-based autonomous firefighting robot that can identify and extinguish minor flames is shown in this work. More advanced sensors and intelligent algorithms would improve operational deployment in the real world, despite the fact that it is highly effective in a controlled setting. The method has a lot of potential to improve emergency response in hazardous situations.

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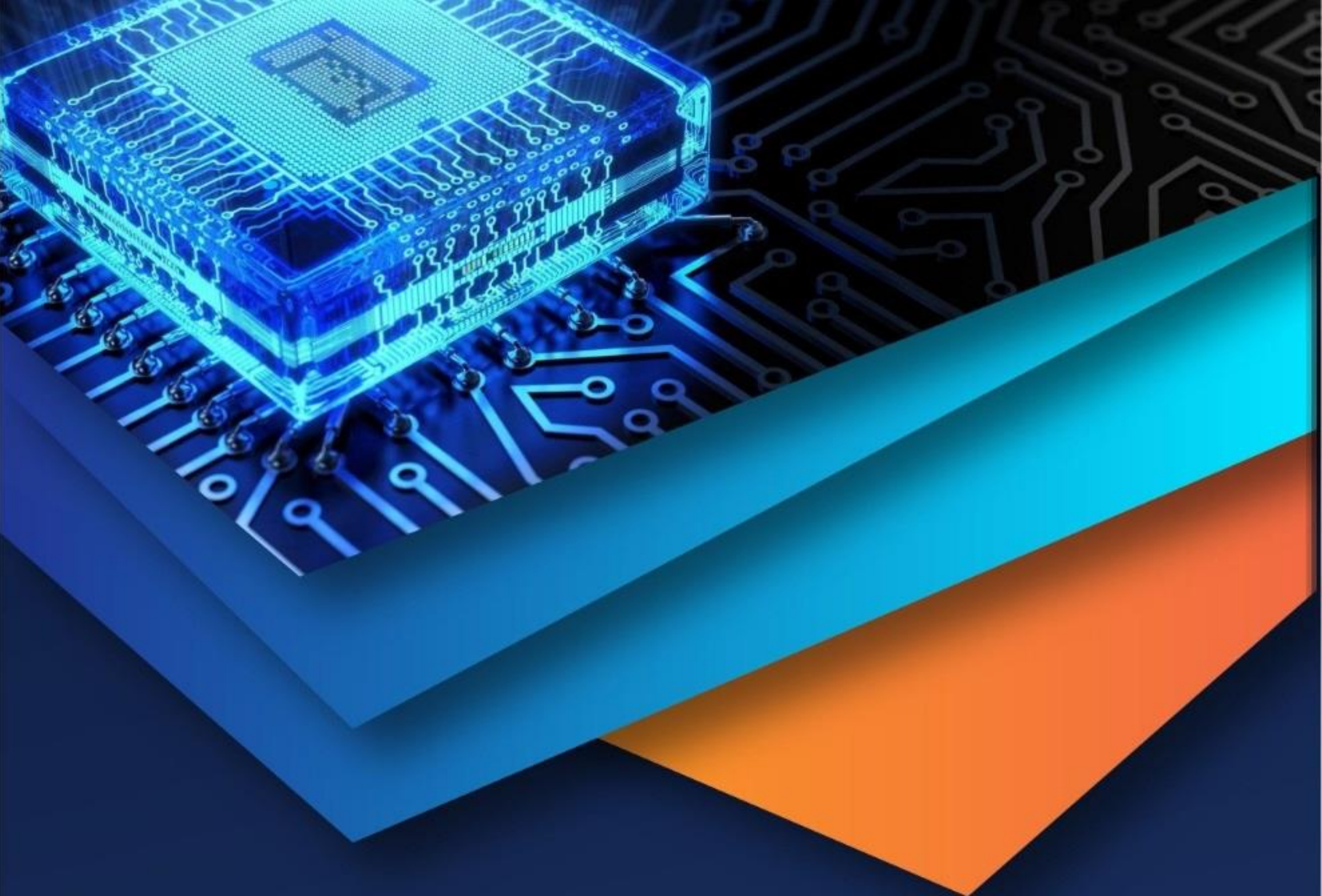

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