E-ISSN: 2349-7017
P-ISSN: 2349-7009
https://www.ijiris.com/archives

Hybrid Fire Fighting Robot

Varsha D, Varun C A, Jaykanth S K, Shreya Sathisha
Department of Computer Science and Engineering
Vemana Institute of Technology, Bengaluru, India
vatrsha.d22032004@gmail.com, varunca08@gmail.com
jaykanthbalaji1999@gmail.com, shreysathisha23@gmail.com
Ms.Sneha Zolgikar
Assistant Professor, Department of Computer Science and Engineering
Vemana Institute of Technology, Bengaluru, India

Publication History:
Manuscript Reference No: IJIRIS/RS/Vol.11/Issue02/APIS10081
Research Article | Open Access | Double-Blind Peer-Reviewed | Article ID: IJIRIS/RS/Vol.11/Issue02/APIS10081
Received: 02,April 2025 Revised: 14, April 2025 Accepted: 25, April 2025 Published Online: 05, May 2025, Volume 2025 Article ID APIS10081 https://www.ijiris.com/volumes/Vol11/iss-02/02.APIS10081.pdf
Article Citation: Varsha,Varun,JaykanthmShreya,Sneha(2025). Hybrid Fire Fighting Robot. International Journal of Innovative Research in Information Security, Volume 11, Issue 01, Pages 70-76
doi:> https://doi.org/10.26562/ijiris.2025.v1102.02
BibTex key: Sneha@2025Hybrid
Copyright: ©2025 This is an open access article distributed under the terms of the Creative Commons Attribution License; which Permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract: Fire accidents pose a significant threat to human life, infrastructure, and the environment, necessitating rapid detection and suppression mechanisms. Traditional firefighting methods rely on human intervention, which can be time-consuming, hazardous, and inefficient in large- scale fires. To address these challenges, the Hybrid Fire Fighting Robot is designed as an autonomous and remotely controlled system that integrates IoT, AI, and automation for real- time fire detection and suppression. The robot is equipped with flame, smoke, and ultrasonic sensors, a high-pressure water pump, and motorized mobility, enabling it to detect fire, navigate obstacles, and extinguish flames effectively. The system supports real-time monitoring and remote control through IoT-based connectivity, making it suitable for industrial, residential, and commercial applications. The project aims to provide a cost- effective, scalable, and reliable fire suppression solution. Future enhancements include AI- driven fire detection, advanced suppression mechanisms, and integration with emergency response networks to improve firefighting efficiency.
Keywords: hybrid, firefighting, robot, Raspberry pi, Bluetooth, Wi-fi, Sensors, Internet of things

Abbreviations

HFFR	-	Hybrid Fire Fighting Robot
Iot	-	Internet of Things
AI	-	Artificial Intelligence
RTM	-	Real Time Monitoring
UVS	-	Ultrasonic sensors
Wi-fi	-	Wireless Fidelity

I. INTRODUCTION

The project addresses fire accidents, which pose a constant threat to safety and cause significant damage. Traditional firefighting methods, which rely on human firefighters, can be hazardous and time-consuming, especially in large-scale fires. Technological advancements in robotics and automation offer innovative solutions for more efficient fire detection and suppression. The Hybrid Fire Fighting Robot is an autonomous and remotely controlled system that combines IoT, sensors, and automation for efficient fire detection and suppression. Equipped with flame, smoke, and ultrasonic sensors, a water pump, and motorized mobility, it can navigate fire-prone areas. The robot operates in both automatic and manual modes, offering flexibility for various emergency situations. Traditional fire fighting involves human intervention, exposing firefighters to dangers such as heat and toxic gases. While modern fire detection has improved response times, automated, AI-driven firefighting systems are needed to reduce human risk. The Hybrid Fire Fighting Robot utilizes AI-based vision processing, IoT, and autonomous mobility to detect and extinguish fires with precision, bridging the gap between traditional and modern fire suppression techniques.

II. LITERATURE SURVEY

In recent years, there has been a notable shift toward the development of autonomous fire-fighting robots using embedded systems, IoT, and AI-based technologies. These innovations aim to minimize human risk, enhance real-time fire detection, and improve suppression efficiency across various environments with easy task replacing the traditional fire extinguishing techniques. Dalvi et al. (2024) introduced an IoT-enabled fire-fighting robot based on the ESP32 microcontroller and integrated sensors for autonomous operation and remote control via the Blynk app. Their system is provided with real-time monitoring, obstacle avoidance, and effective fire extinguishing but faced limitations related to low water capacity and Wi-Fi dependency. Similarly, Mounika et al. (2023) developed an Arduino-based robot utilizing flame, temperature, and ultrasonic sensors for autonomous and Bluetooth-enabled manual control. While the system proved to be low-cost and practical for domestic or industrial use, it suffered from limited range and battery life.

E-ISSN: 2349-7017
P-ISSN: 2349-7009
https://www.ijiris.com/archives

Advancements in fire detection accuracy were highlighted by Sridhar et al. (2023) proposed a hybrid vision and sensor-based fire detection system using a GTCNN deep learning model, achieving 98.23% accuracy with Multiscale Retinex and Gaussian Thresholding. However, its high computational power requirements limit real-time field use causing delay in response, especially in smoke-obstructed environments. Collectively, these studies demonstrate progress in fire-fighting robots using IoT, embedded systems, and AI but highlight ongoing challenges such as water capacity, power efficiency, sensor reliability, and environmental adaptability. This project aims to address these by integrating AI-driven monitoring, enhanced mobility, and suppression capabilities for real-time fire-fighting.

III. EXISTING AND PROPOSED SYSTEM

A. Existing System

Fire incidents are unpredictable and can cause significant damage to life and property. Traditional firefighting relies on human intervention, exposing firefighters to extreme risks like heat, toxic gases, and structural collapse. While semi-autonomous robots assist in firefighting, many still require human input, lack real-time decision-making, and don't offer remote monitoring or IoT connectivity. Existing firefighting robots often need continuous human control, reducing efficiency in large or remote fires. Many can't detect obstacles autonomously and lack IoT connectivity, delaying response times and hindering coordination. They also lack real-time data transmission, which is essential for effective emergency management. To address these gaps, there's a need for a fully autonomous firefighting robot capable of accurate fire detection, autonomous navigation, and remote monitoring. This would enable faster response times and better coordination with emergency teams.

B. Proposed System

The proposed system overcomes the limitations of existing firefighting methods by introducing the Hybrid Fire Fighting Robot, an advanced autonomous and remotely controlled robot that integrates IoT, AI-based fire detection, and automated suppression techniques. This system aims to provide a faster, safer, and more effective response to fire emergencies by enabling both autonomous operation and remote control.

Key components of the system include:

- **IoT-Based Real-Time Monitoring**: Enables cloud connectivity for remote operation and monitoring through a web or mobile app.
- **Advanced Fire Detection System**: Combines multiple sensors with AI-based image processing for precise fire detection.
- **Autonomous Navigation & Obstacle Avoidance**: Uses ultrasonic and infrared sensors to detect and avoid obstacles, ensuring smooth movement in various environments.
- **Effective Fire Suppression Mechanism**: Equipped with a high-pressure water pump and a servo-controlled nozzle, it can also deploy CO□, foam, or other suppression agents.
- **Energy-Efficient & Portable Design**: Powered by rechargeable LiPo batteries for long operational hours and designed for compactness and portability, making it suitable for deployment in hard-to-reach areas.

The feasibility study confirms that the Hybrid Fire Fighting Robot is technically, operationally, and economically viable. It uses affordable components like Raspberry Pi and Arduino, with Python, Flask, and OpenCV for seamless integration and real-time monitoring. The robot is easy to deploy in various environments with a user-friendly interface and operates autonomously, reducing the need for human intervention. It is adaptable to different fire types and offers long-term savings by minimizing fire-related damages and operational costs. Overall, the system provides a practical, scalable, and cost-effective solution for modern fire emergencies.

IV. SYSTEM DESIGN AND IMPLEMENTATION

This section outlines the design and implementation process of the bone fracture detection system, which integrates deep learning and machine learning methodologies. The goal is to develop an efficient system that can accurately identify bone fractures from X-ray images while ensuring scalability and easy deployment on resource-constrained devices. The architecture is modular, with distinct stages covering data preprocessing, model training, and real-time deployment. The following subsections describe the system's architecture, data flow, model design, and user interface, all tailored to provide a robust and user-friendly solution for healthcare professionals.

A. System Architecture

The proposed Hybrid Fire Fighting Robot is structured as a modular architecture designed to optimize efficiency, scalability, and adaptability for real-time fire detection and suppression. The system is composed of interconnected modules, including fire detection, navigation, fire suppression, and remote monitoring. The architecture is designed to handle complex fire emergencies in various environments.

The overall architecture is divided into three primary stages:

1. **Detection & Navigation Stage**: Involves sensor data acquisition, real-time fire detection, autonomous navigation, and obstacle avoidance.
2. **Action & Suppression Stage**: Includes fire suppression mechanisms and autonomous movement, enabling the robot to act based on the detected fire source.
3. **Monitoring & Control Stage**: Focuses on IoT connectivity and remote control via mobile/web applications for real-time monitoring and manual operation.

The Hybrid Fire Fighting Robot's system architecture consists of three primary layers: the Sensor Layer (flame, smoke, temperature, and ultrasonic sensors), the Processing Layer (Raspberry Pi 4 for AI-based fire detection and IoT connectivity), and the Action Layer (motor control and fire suppression via a high-pressure water pump and servo

IJIRIS © 2014-25, AM Publications - All Rights Reserved

E-ISSN: 2349-7017
P-ISSN: 2349-7009
https://www.ijiris.com/archives

nozzle). The Fire Detection Module uses sensors and AI for accurate fire identification, while the Navigation & Obstacle Avoidance Module ensures efficient movement. The Fire Suppression Module activates the fire extinguisher, and the IoT & Remote Control Module enables remote monitoring and control via a mobile/web application. A high-level block diagram of the system architecture is illustrated in Fig. 4.1.

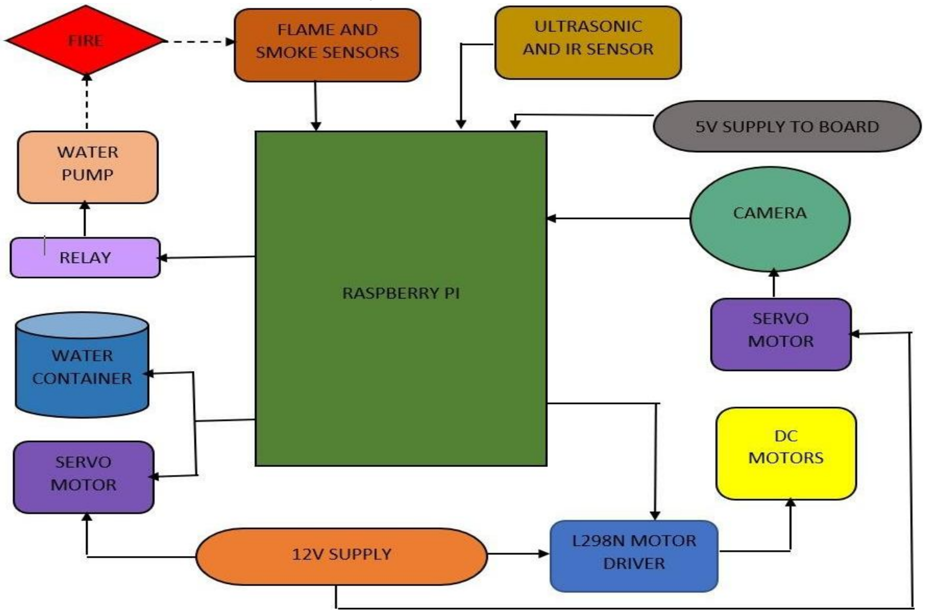

Fig. 4.1. Diagram representing system architecture

B. System Implementation

1. **Raspberry Pi 4 Model B (Main Controller)**: Acts as the central processing unit, processing sensor data and controlling actuators, interfacing with components via GPIO pins and powered by a 5V/3A power bank.
2. **L298N Motor Driver**: Controls six DC motors for bidirectional movement of the robot, regulated by the Raspberry Pi for smooth operation with PWM signals, powered by a 12V battery.
3. **Flame Sensors (Fire Detection)**: Detects fire through infrared radiation, triggering movement toward the fire source and activating the fire-extinguishing system when flames are detected.
4. **Ultrasonic & IR Sensors (Obstacle & Fire Detection)**: Ultrasonic sensor detects obstacles for safe navigation, while the IR sensor detects heat sources, helping identify fire locations.
5. **180° Servo Motor (Camera Rotation)**: Rotates the camera for real-time monitoring and navigation, controlled by the Raspberry Pi and powered by a 12V supply via a step-down converter.
6. **180° Servo Motor (Fire Extinguishing Nozzle)**: Controls the fire-extinguishing nozzle's direction for precise water spraying, powered by 12V and directed by the Raspberry Pi.
7. **6-Wheeled Chassis with DC Motors (Mobility)**: Provides stable movement on various surfaces, powered by six DC motors and controlled by the L298N motor driver, using a 12V battery.

C. Model Design

The circuit diagram illustrates the hardware integration of a fire-fighting robot controlled by a Raspberry Pi 4. This robot is designed to detect fire and smoke automatically using flame and smoke sensors, navigate around obstacles with ultrasonic and IR sensors, and extinguish the fire using a servo-directed nozzle and water pump system. It also includes a manual control mode via a web interface for remote operation. The robot is powered by separate battery systems for different modules to ensure efficient and uninterrupted operation.

- **The sensor system**: It includes multiple modules: flame sensors are used to identify the direction of the fire, a smoke sensor (MQ2) detects the presence of smoke, two ultrasonic sensors (mounted at the front and back) help in obstacle detection and distance measurement, and an IR sensor is used for edge detection or to sense nearby obstacles.
- **The actuator system:** It is composed of two DC motors that enable robot movement and are controlled by an L298N motor driver, a 180° servo motor to rotate the camera for visual surveillance, a 360° servo motor to control the nozzle direction for fire extinguishing, and a one-channel relay module that operates a 12V water pump for spraying water on detected fires.
- **Power supply management:** It is handled through multiple sources: the Raspberry Pi is powered independently, likely using a USB cable or a dedicated battery pack; a 12V battery supplies power to the DC motors and the water pump; and a 9V battery, stepped down through a voltage regulator, provides power to the servo motors. The Raspberry Pi functions as the core controller, collecting input from all sensors and executing programmed logic to control the motors, servos, and relay module, thereby enabling the robot to function effectively in both automatic and manual fire-fighting modes. Figure 4.2 illustrates the circuit diagram of a fire-fighting robot designed to detect and extinguish fires either autonomously or through manual control.

E-ISSN: 2349-7017
P-ISSN: 2349-7009
https://www.ijiris.com/archives

Hybrid Model: Automatic + Remote control

Recognizing that traditional fire-fighting methods often require direct human involvement, putting firefighters at significant risk in hazardous environments. The Hybrid Fire Fighting Robot addresses this challenge by combining automation, IoT, and AI to detect and suppress fires with minimal human intervention. Designed for use in various environments such as industrial plants, warehouses, offices, and homes—it offers a safer, smarter alternative to manual fire-fighting.

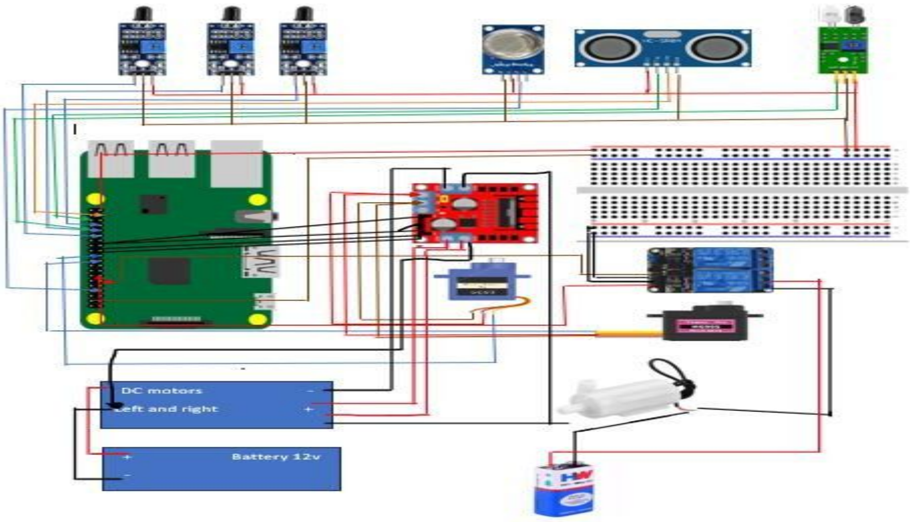

Fig. 4.2. Diagram representing circuit model design

1. **Automatic mode:** In autonomous mode, the robot uses flame, smoke, and thermal sensors to detect fire accurately. Upon detection, it navigates using ultrasonic sensors to avoid obstacles and reach the fire source. A servo-controlled high-pressure water nozzle is then activated to suppress the fire. The system also sends real-time alerts via IoT to a central server or mobile app for monitoring.
2. **Manual mode:** Users can switch to manual control through a Wi-Fi or Bluetooth-enabled web or mobile application. The app displays a live camera feed and offers remote control of the robot's movement and nozzle. This mode is ideal when human judgment is required for navigating complex environments or making tactical decisions.

D. Model Training and Evaluation

The System testing is a crucial part of any project to ensure that it meets the desired requirements and functions correctly. For the Hybrid Fire Fighting Robot, there are several components that need to be tested to ensure their proper functioning.

- **Hardware Testing:** The Hybrid Fire Fighting Robot's hardware components were individually and collectively tested for functionality and reliability. The L298N motor driver successfully controlled the 6-wheeled chassis for smooth directional movement. Flame and smoke sensors accurately detected fire and smoke within effective ranges. Ultrasonic sensors ensured precise obstacle detection, aiding autonomous navigation. The 12V water pump and servo-controlled nozzle effectively targeted and extinguished fires. Servo motors for camera and nozzle rotated accurately through their full range. Power systems provided stable operation, and a manual DPDT switch reliably controlled system power. Final integration testing confirmed that all components worked together seamlessly in both automatic and manual modes.
- **Software Testing:** Software testing verified accurate operation of all code modules and interfaces. Unit tests validated individual scripts for motors, sensors, servos, and the camera. Integration testing ensured smooth communication between all software components. The Flask web interface functioned responsively with stable video streaming. The automatic mode logic correctly prioritized fire detection, avoided obstacles, and activated suppression. Smoke detection triggered alerts as expected. Error handling managed disconnections and invalid inputs gracefully. Stress testing confirmed stable performance during extended use without overheating or system crashes.

E. System Deployment

Thonny and Raspberry Pi are key components in creating and deploying robotics projects, offering an accessible and efficient way to build and control systems that includes:

- **Thonny** is an easy-to-use Python IDE pre-installed on Raspberry Pi, ideal for beginners and debugging code. It provides features like syntax highlighting, variable tracking, and easy interaction with GPIO pins. Thonny is great for writing, testing, and running Python scripts for robotics projects.
- **Raspberry Pi 4** is a small, affordable computer that powers robotics projects. It supports Linux-based OS and provides GPIO pins to interact with sensors, motors, and other peripherals. Raspberry Pi 4 offers enhanced processing power, making it suitable for running complex tasks like controlling a firefighting robot.

F. User Interface and Experience

The user interface is designed to prioritize simplicity and accessibility for user:

- **Mode Toggle & Alerts:** Easily switch between Automatic and Manual modes, with clear fire detection alerts.

- **Camera Feed & Movement Controls**: Display live camera feed and provide joystick/arrow keys for manual movement.
- **Water Pump Control:** Button to activate/deactivate the water pump in Manual Mode.
- **Emergency Stop & Safety:** Include an Emergency Stop button and safety warnings for manual operation.

V. RESULTS

A. Overview

The Hybrid Fire Fighting Robot is an advanced robotic system that autonomously detects and extinguishes fires, while also offering manual control via a web-based interface. Powered by a Raspberry Pi 4, the robot integrates flame sensors, smoke detectors, ultrasonic sensors, a 360-degree servo-mounted nozzle, and a water pump to perform intelligent fire suppression. It operates in two modes: Automatic mode, where it autonomously handles fire detection and suppression, and Manual mode, where users can remotely control the robot through a Flask-based web application. This project combines robotics, IoT, and embedded systems, using Python for sensor input, motor control, live camera streaming, and web interaction. Real-time video streaming allows operators to monitor and intervene when necessary, enhancing situational awareness. The system's hybrid functionality ensures versatility and reliability in various environments, from households to industrial spaces. The robot's multiple sensors enable autonomous fire detection, obstacle avoidance, and smoke sensing. A 360-degree servo motor controls the water nozzle, providing efficient fire suppression from different angles. The combination of Automatic and Manual modes, along with live monitoring, increases flexibility, making it suitable for dynamic and hazardous environments. Overall, the **Hybrid Fire Fighting Robot** presents a scalable and practical solution for improving fire emergency responses. The project demonstrates how smart technology can be utilized to protect lives and property in fire-prone scenarios.

B. User Interface Screenshots

The web-based user interface for controlling the Hybrid Fire Fighting Robot can be structured in a clean and intuitive layout, offering real-time control and monitoring of the robot. Here's an explanation of the key sections:

Control Page

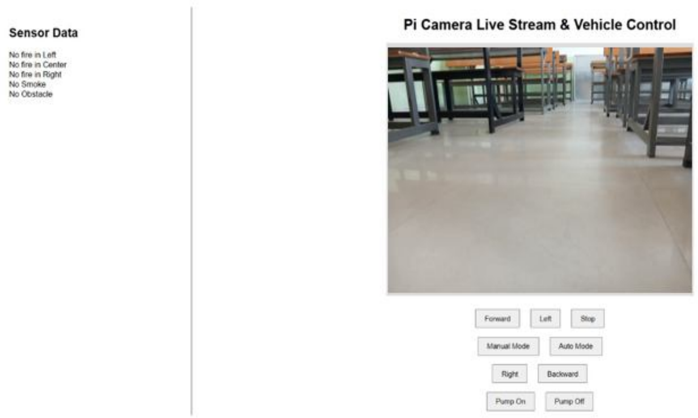

Fig. 5.1 Control page Dashboard to remote control

C. Comparative Analysis

A graphical bar chart comparison was also plotted to visualize model performance across accuracy, precision, recall, and F1-score. The hybrid MobileNet–Random Forest approach showed superior overall performance compared to the other models.

Ref	Technique	Metric	Advantage	Limitation
[1]	OpenCV	Accuracy	Real-time	Maintenance
[2]	Sensor	Mobility	Fast	Power
[3]	GTCNN	Speed	Integration	Complexity
[4]	Flame	Suppression	Storage	Speech
[5]	Servo	Response	Cost	Scalability
[6]	Embedded	Efficiency	Ease	Runtime
[7]	Sensors	Detection	Safety	Wi-Fi
[8]	OpenCV	Obstacle	Remote	Manual
[9]	Fusion	Monitoring	Efficiency	Resources
[10]	Swarm	Mapping	Autonomous	Setup
Proposed system	Thonny	Accuracy	Hybrid	Wi-fi

Table. 5.1. Comparative Analysis of Model Performance

D. Discussion

The **Hybrid Fire Fighting Robot** is an autonomous system designed to efficiently detect and suppress fires, reducing human risk. It integrates IoT-based real-time monitoring, AI-driven fire detection, autonomous navigation, and targeted fire suppression using flame, smoke, and temperature sensors. With dual-mode operation, the robot can function autonomously or be manually controlled via a web or mobile app, offering flexibility for various fire scenarios.

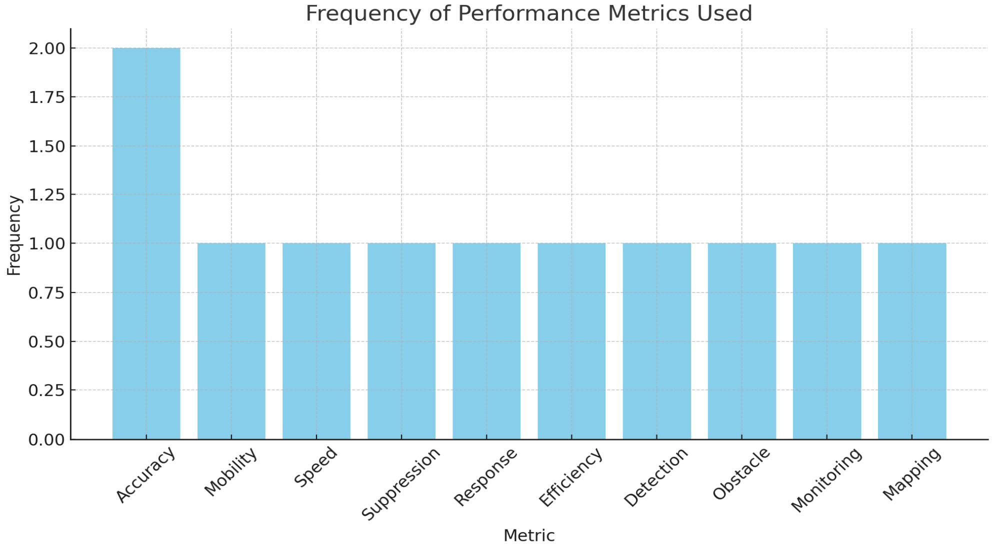

Fig 5.2 Graph displays comparitive analysis

The project is technically, operationally, and economically viable, using cost-effective components and providing a scalable, reliable fire-fighting solution for homes, industries, and commercial buildings, enhancing safety and minimizing damage.

VI. CONCLUSION

In this work, The Hybrid Fire Fighting Robot is an advanced, intelligent, and autonomous robotic system designed to detect and suppress fires efficiently while reducing human risk. Traditional firefighting methods expose firefighters to dangerous environments, making the need for an automated system essential. This project successfully integrates IoT-based real-time monitoring, AI-driven fire detection, autonomous navigation, and effective fire suppression mechanisms to provide a reliable solution for fire emergencies. The system employs flame, smoke, and temperature sensors for accurate fire detection, ultrasonic sensors for obstacle avoidance, and a servo-controlled water pump for targeted fire suppression. With dual-mode operation, it can function autonomously or be manually controlled via a web or mobile application, ensuring flexibility and adaptability in different fire scenarios. The feasibility study confirms that the project is technically, operationally, and economically viable, as it uses cost-effective components, is easily deployable, and provides a long-term fire prevention solution for homes, industries, warehouses, and commercial buildings. By combining modern technology with smart automation, this project offers a reliable, scalable, and efficient fire- fighting system that enhances safety and minimizes fire-related damage.

FUTURE WORK

While the current implementation of the Hybrid Fire Fighting Robot is highly efficient, there are several opportunities for future improvements. Potential enhancements include:

1. **AI-Based Fire Detection and Image Processing**: Implementing computer vision techniques using AI and deep learning to improve fire detection accuracy, along with integrating thermal imaging cameras to better identify fire sources, even in dense smoke.
2. **Advanced Fire Suppression Mechanisms**: Adding CO□ or foam-based suppression systems for handling electrical and chemical fires, and implementing an adjustable pressure water spray system to control the intensity of fire suppression.
3. **Improved Navigation and Terrain Adaptability**: Enhancing obstacle detection using LiDAR technology for real-time mapping, while upgrading wheel mechanisms for better mobility on uneven terrain or staircases, and implementing drone-based firefighting extensions to access high-rise buildings and confined spaces.
4. **IoT and Smart Connectivity Enhancements**: Integrating GPS tracking for real-time location monitoring and emergency response coordination, alongside implementing 5G or LoRa communication for extended remote control in larger areas, and enhancing the cloud-based dashboard to store historical fire incident data for predictive analysis.
5. **Power Efficiency and Battery Life Improvement**: Using solar panels or energy-efficient battery management systems for prolonged operation, while implementing automatic charging stations where the robot can recharge autonomously.
6. **Multi-Robot Collaboration and AI Swarm Intelligence**: Developing multiple firefighting robots that can communicate and coordinate to handle large-scale fires, and implementing AI-based swarm intelligence algorithms to allow multiple robots to collaborate in search-and-rescue missions. By addressing these areas, the system can evolve into a more accurate, reliable, and accessible tool for fire detection, with the potential to revolutionize the way fire accidents can occur, ultimately improving safety and environment.

REFERENCES

1. Dalvi Kaveri, Dhapate Apurva, Adik Rohit, Jadhav Prathmesh, Dr. V.M. Rohokale, “Automatic Fire Fighting Robot using IoT” Volume: 06 / Issue: 01 / January-2024.

2. Sridhar P, Senthil Kumar Thangavel, Latha Parameswaran, and Venkata Ramana Murthy Oruganti, “Fire Sensor and Surveillance Camera-Based GTCNN for Fire Detection System” IEEE Sensors Journal, Vol. 23, No. 7, 1 April 2023.
3. Jeripothula Mounika, CH Ganesh, P Sriman Reddy, B Priyanka, “Fire Fighting Robot Using Arduino” 2023 IJCRT | Volume 11, Issue 5 May 2023 | ISSN: 2320-2882.
4. Vyshnavi M B, Anju Satheesh, Shikha Suresh S, Dr L C Manikandan, “IoT Technology Based Fire-Fighter Robot” Volume 6, Issue 3, May-June-2020.
5. Deore Jagruti, Zalte Priyanka, Waghchaure Dhanashree, Shelke Pratiksha, Guide: Prof. Tathe S.G, “Arduino Based Fire Fighting Robot” Volume 12 Issue 1.
6. Lokesh Venkata Ramana Talabhaktula, Veerraju Daliparthi, Tulasi Ravi Kumar, Dulam Chandra Naga Rakesh, “A Novel Fire Fighting Robot With Arduino” Vol. 10, Iss. 1, Jan 2021.
7. Dr.Amal M R, Abhijith Selvam, Allen Joseph, Aravind A S, Jishnu Suresh, “AI Based Multi Robot Fire Suppression System”, ISSN: 2230-9993.
8. Mohd Aliff, MI Yusof, Nor Samsiah Sani, Azavitra Zainal, “Development of Fire Fighting Robot (QRob)”, Vol. 10, No. 1, 2019.
9. Jay Sathe, Vrushabh Raut, Rahul Parike Peddapelli, Janardhan Waghchaure, Mr. V.W. Bembrekar, “Design And Development of Fire Fighting Robot”, Volume: 10 Issue: 05, May 2023.
10. Dr.N. K. Choudhari, Sai Ponnamanda, Gaurav Deshbhratar, Aashay Gajbhiye, Shivani Chaudhari, Shivani Harde, “Fire Fighting Robot”, Volume 10, Issue 2, March-April-2023.