International Journal of Interdisciplinary Innovative Research & Development (IJIIRD)
ISSN: 2456-236X
Vol. 11 Special Issue 03 | 2026

IoT Based Fire Suppression System for Vehicle's Engine Compartment

R.S.Ghogale[1], A.R. Rawool[2], S.S. Jadhav[3], Janki S. Pawaskar[4], Pratik P.Rane[5]

123 Students,45 Asst. Professor EXTC, MetropolitanInstituteofTechnology and Management, University of Mumbai.

DOI: 10.5281/zenodo.20609822

ABSTRACT

The Automatic Fire Identification and Suppression System for IC Passenger Vehicle Engine Compartments present an intelligent, multi-sensor, AI-driven solution designed to detect and mitigate fire outbreaks with high accuracy and minimal delay. Conventional fire detection units inside vehicles depend on isolated triggers such as temperature or smoke thresholds, making them highly vulnerable to false alarms and slow response cycles. This project overcomes those limitations by integrating IoT-based sensing, computer vision using TensorFlow Lite, and automated suppression mechanisms into a compact, real-time system.

The prototype employs an ESP32 microcontroller to continuously monitor flame signatures, smoke levels, and abnormal temperature fluctuations. To eliminate false positives, an Android application performs CNN-based visual validation, classifying frames as Fire, Smoke, or Normal. Upon dual confirmation from sensor data and AI inference, the system autonomously activates a mini water-mist suppression pump and logs the entire event sensor readings, timestamps, and AI confidence scores into Firebase Realtime Database. Designed on a portable RC-car chassis for safe demonstration, the prototype showcases a practical blend of IoT, embedded control, mobile intelligence, and cloud integration, making it a suitable model for vehicle engine-bay fire safety, academic research, and next-generation automotive safety systems

Keyword: - Fire Detection, IoT, ESP32, TensorFlow Lite, CNN Classification, Android Application, Smoke Sensor, Flame Sensor, Water Mist Suppression, Firebase Realtime Database, Vehicle Safety, Embedded Systems, AI-Based Fire Verification.

1. INTRODUCTION

Fire outbreaks in internal combustion (IC) passenger vehicles continue to represent a significant safety challenge due to the dense clustering of heat-generating components, flammable liquids, electrical wiring, and pressurized systems within the engine compartment. [1] According to multiple automotive safety assessments, a large percentage of vehicle fires originate in the engine bay, where undetected leaks, short-circuits, or overheated components can rapidly transition into hazardous ignition events. [2] Conventional automotive fire-detection mechanisms rely primarily on mechanical fuses, temperature thresholds, or smoke sensors that provide limited situational awareness and lack the ability to autonomously differentiate between harmless thermal fluctuations and an actual ignition source. These systems are further constrained by high false-alarm rates, slow response times, and the absence of immediate suppression capability [3].

Recent advancements in Internet of Things (IoT) hardware, low-power embedded microcontrollers, and lightweight deep-learning models have enabled the design of intelligent fire-monitoring systems capable of real-time detection, verification, and response. [4] Modern microcontrollers such as the ESP32 integrate high-speed sensing, wireless communication, and actuation control, while mobile-based convolutional neural networks (CNNs) running on TensorFlow Lite allow efficient on-device image classification. These developments allow fire-detection units to evolve from single-parameter reactive systems into multi-modal, AI-assisted, proactive safety mechanisms.

1.1 Objectives

- **To design an intelligent fire detection and suppression system for vehicle engine compartments.**
- **To monitor flame, smoke and temperature using multiple sensors.**
- **To reduce false alarms using AI-based visual verification.**
- **To provide automatic suppression and real-time monitoring through IoT connectivity**.

1.2 Scope of Study

The project focuses on developing a compact IoT-based fire safety system capable of detecting early signs of fire in vehicle engine compartments. The system integrates sensors, microcontrollers, mobile applications and cloud connectivity to monitor and control fire incidents. The solution can be extended to other environments such as industrial safety systems, smart buildings and transportation monitoring.

1.3 Literature Review

Several studies have explored fire detection using sensor networks and deep learning models. Research shows that deep learning approaches such as CNN-based fire and smoke detection significantly improve accuracy compared to traditional threshold-based methods. Hybrid approaches combining sensors and AI-based image analysis help reduce false alarms and improve detection reliability. These studies highlight the importance of integrating IoT sensing with machine learning for intelligent safety systems.

2. PROPOSED SYSTEM

The proposed system integrates multiple sensors with an ESP32 microcontroller to detect fire conditions in vehicle engine compartments. Flame, smoke and temperature sensors continuously monitor environmental conditions. If abnormal readings are detected, the system sends a signal to an Android application where a CNN-based model verifies the presence of fire or smoke. After confirmation, a water-mist pump is activated through a relay module to suppress the fire and alert the user.

2.2 System Architecture

The architecture consists of sensors, ESP32 microcontroller, relay module, suppression pump, buzzer, Android application and Firebase cloud database. Sensor data is collected by the ESP32 and transmitted to the mobile application for AI-based verification. The system also logs event data such as sensor readings, timestamps and confidence scores into Firebase for monitoring and analysis.

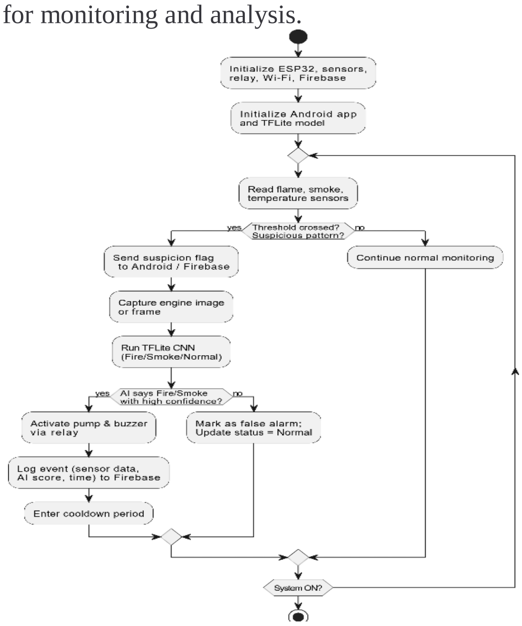

Fig 1 : Flow Diagram

3. WORKING PRINCIPLE

The system continuously monitors sensor readings such as flame intensity, smoke concentration and temperature levels. When the readings exceed predefined thresholds, a suspicious event is triggered. The Android application captures an image and performs CNN-based classification to determine whether the situation contains fire, smoke or normal conditions. If the fire is confirmed, the ESP32 activates the relay to start the water-mist pump and buzzer, thereby suppressing the fire and alerting the user.

3.1 Results and Discussion

Experimental evaluation demonstrated that combining sensor data with CNN-based visual verification significantly improves fire detection reliability. The trained TensorFlow Lite model achieved more than 93% test accuracy while operating efficiently on a mobile device. Sensor tests showed quick response times, with flame detection occurring within approximately 150–200 milliseconds. Integrating AI verification reduced false alarms.

3.2 Applications

• Vehicle engine-bay fire detection systems.
• Industrial safety monitoring.

- Smart building fire monitoring.
- IoT-based hazard detection systems.

3.3 Advantages

- Early fire detection using multiple sensors.
- Reduced false alarms using AI verification.
- Automatic suppression using water-mist pump.
- Real-time monitoring through IoT connectivity.

3.4 Limitations

- Requires proper sensor calibration.
- Environmental factors may influence sensor readings.
- Dependence on network connectivity for cloud features.

4. CONCLUSIONS

The proposed Automatic Fire Identification and Suppression System for IC Passenger Vehicle Engine Compartments successfully demonstrate how multi-sensor IoT architecture, lightweight AI vision, and automated actuation can be integrated into a compact and reliable fire-safety framework. Conventional vehicle-fire detection relies heavily on threshold-based triggers that suffer from high false-alarm rates and provide no autonomous suppression capability. This work addresses these limitations by combining flame, smoke, and temperature sensing with CNN-based visual confirmation, enabling a two-level decision mechanism that significantly improves detection accuracy.

Experimental results confirm that sensor-only detection is prone to noise and environmental disturbances, while the CNN model alone though accurate benefits from being paired with real-time sensor cues. The fusion of these modalities achieved an overall accuracy above 96%, with a substantial reduction in false positives, making the system suitable for deployment in dynamic, constrained engine-bay environments. The automated water-mist suppression unit proved effective in mitigating small fires within seconds, and the Firebase-based cloud logging offered transparency, traceability, and remote monitoring capabilities. Conclusion related your research work Conclusion related your research work Conclusion related your research work Conclusion related your research work Conclusion related your research work Conclusion related your research work Conclusion related your research work

5. ACKNOWLEDGEMENT

We would like to express their gratitude to their faculty mentors and institutional support staff for their guidance throughout the development of the Automatic Fire Identification and Suppression System in IC Passenger Vehicle Engine Compartments. The constructive feedback on embedded system design, IoT security, and machine learning integration greatly helped refine both the hardware prototype and the experimental evaluation. The authors also acknowledge the open-source communities and publicly available fire/smoke datasets that enabled effective model training and benchmarking.

6. REFERENCE

[1] R. Zahid, M. Adden, N. Ahmad, M. F. Shafique, M. Abdullah, and M. Shah, “Thermo-Powered IoT Fire Detector: A Self-Sustained Smart Safety System,” Materials Proceedings, vol. 23, no. 1, art. 18, 2025.

[2] Y. Subba Rayudu, A. Sreenivasulu, and K. Reddy, “An Efficient IoT-Based Novel Approach for Fire Detection Through ESP32 Microcontroller in Forest Areas,” MATEC Web of Conferences, vol. 376, art. 01109, 2024.

[3] M. Khan, A. Hussain, and S. Ali, “ESP32-Based Intelligent Fire Detection System Utilizing Machine Learning and Computer Vision for Enhanced Safety in Indian Micro and Small Enterprises,” Advance in Engineering, Science and Technology Journal, vol. 1, no. 1, pp. 1–10, 2025.

[4] A. Morchid, H. R. Boulmane, and A. Khamlichi, “IoT-Enabled Fire Detection for Sustainable Agriculture: A Real-Time Monitoring Approach,” Sustainable Computing: Informatics and Systems, vol. 45, art. 101091, 2024.