Smart Fire Alarm System

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Abstract—**Fire accidents pose a serious threat to human life and property, especially in residential, commercial, and industrial environments. Conventional fire alarm systems typically rely on a single sensor and are prone to frequent false alarms triggered by cooking smoke, steam, or dust. Additionally, traditional systems lack remote monitoring capabilities, making them ineffective when occupants are away from the premises.**

This paper presents a Smart Fire Alarm System that integrates multiple sensors, Internet of Things (IoT) technology, and rule-based decision logic to provide reliable and early fire detection. The proposed system uses smoke, gas, temperature, and flame sensors connected to an ESP32 microcontroller for real-time data acquisition and processing. A multi-stage alert mechanism classifies conditions into Warning, Alert, and Fire states to reduce false positives. Sensor data and alerts are transmitted to a cloud platform for remote monitoring through a web dashboard. Experimental results demonstrate that the multi-sensor approach significantly enhances detection accuracy and minimizes false alarms compared to conventional systems. The system offers a low-cost, scalable, and reliable solution for modern fire safety applications.

I. INTRODUCTION

Fire safety is a critical requirement for modern infrastructure, as fire-related accidents can cause severe loss of life, property damage, and environmental harm. Traditional fire alarm systems are widely deployed but suffer from several limitations. Most existing systems rely on a single sensor, typically a smoke or heat detector, which often results in false alarms due to non-fire events such as cooking fumes, humidity, or dust. Moreover, conventional systems usually provide only local audible alerts and lack remote notification capabilities. Recent advancements in embedded systems, IoT, and sensor technologies enable the development of intelligent fire detection systems with improved accuracy and reliability. By integrating multiple

sensors and leveraging real-time data processing, smart fire alarm systems can analyze environmental conditions more effectively and distinguish real fire incidents from harmless events. IoT connectivity further enhances safety by enabling remote monitoring, instant alerts, and data logging for future analysis.

This project introduces a Smart Fire Alarm System that utilizes sensor fusion, rule-based logic, and cloud connectivity to overcome the drawbacks of traditional fire detection mechanisms. The system is designed to deliver accurate, real-time alerts with reduced false alarms while offering remote access and historical data analysis for improved fire safety management.

II. MATERIALS AND METHODS

A. System Architecture

The Smart Fire Alarm System is composed of several integrated modules working together to ensure reliable fire detection:

- Sensor Module – Includes smoke (MQ-2), gas, temperature (DHT22), and flame sensors for environmental monitoring.
- Processing Module – An ESP32 microcontroller processes sensor data and executes rule-based decision logic.
- Alert Module – Buzzer and LED indicators provide local alerts based on fire severity.
- Cloud Module – Stores sensor data and alert status for remote access.
- User Interface Module – A web dashboard displays real-time sensor readings and alert notifications.

B. Tools and Technologies

- ESP32 Microcontroller – Central processing unit with built-in Wi-Fi capability

- MQ-2 Gas and Smoke Sensor – Detects combustible gases and smoke
- DHT22 Sensor – Measures temperature and humidity
- IR Flame Sensor – Detects flame presence
- Arduino IDE – Used for programming and firmware development
- Firebase Cloud Platform – Used for data storage and real-time monitoring
- Web Technologies – HTML, CSS, and JavaScript for dashboard development

C. Detection Logic and Algorithm

A rule-based logic approach is used to classify fire conditions:

- If one sensor exceeds its threshold → Warning
- If multiple sensors exceed thresholds → Alert
- If smoke, temperature, and flame sensors all indicate danger → Fire Condition

This multi-stage logic reduces false alarms and ensures reliable decision-making.

III. RESULTS AND DISCUSSION

The Smart Fire Alarm System was tested in controlled environments to evaluate its performance. The system successfully detected smoke, gas leaks, temperature rise, and flame presence in real time. The cloud-based dashboard displayed live sensor values and updated alert conditions instantly.

Performance Analysis

- Detection Accuracy: High accuracy due to multi-sensor fusion
- False Alarm Reduction: Significantly fewer false positives compared to single-sensor systems
- Response Time: Real-time alerts with minimal delay
- Remote Monitoring: Effective cloud-based notifications accessible from any device

Observed Limitations

- Sensor calibration is required for different environments
- Flame sensors may require proper placement to avoid obstruction
- Internet connectivity is necessary for cloud features

Overall, the experimental evaluation confirms that the proposed system is reliable, cost-effective, and suitable for practical deployment in homes and small industrial setups.

IV. HELPFUL HINTS

- Ensure correct sensor placement: Mount smoke sensors on ceilings (center of rooms) and flame / IR sensors with clear line-of-sight to high-risk areas (kitchens, heaters).
- Calibrate sensors for the environment: Set thresholds after collecting baseline readings in the intended deployment area — kitchens and factories will need different thresholds.
- Use multi-sensor fusion: Combine smoke, gas, temperature, and flame inputs in decision logic to reduce false positives from cooking, steam, or dust.
- Periodic self-test & maintenance reminders: Schedule automatic sensor self-checks and push maintenance reminders (monthly/quarterly).
- Adjustable debounce / cool-down: Add a cool-down period (e.g., 30–60 s) for repeated identical alerts to avoid alarm storms from a single transient event.
- Log data for forensics: Save raw sensor values and event snapshots with timestamps to cloud or local storage for post-incident analysis.
- Access control for dashboard: Enforce role-based authentication on the dashboard (admin, viewer) to prevent unauthorized access.
- Test in realistic scenarios: Validate the system against cooking smoke, incense, steam, and small controlled flames to tune sensitivity and reduce false alarms.
- Watchdog & fail-safe modes: Implement a watchdog timer on the ESP32 and a fail-safe behavior (e.g., enter Alert mode if the controller becomes unresponsive).
- Optimize network behavior: Use local buffering and retry logic for cloud uploads to handle intermittent connectivity; avoid blocking the main detection loop.
- Data compression & retention policy: Store snapshots at reduced resolution (e.g., 480p) and define retention windows to save storage while keeping evidence.
- User acknowledgement & escalation: Let users acknowledge warnings remotely; if

unacknowledged within a timeout, escalate alerts to emergency contacts.

- Regulatory & installation compliance: Follow local fire-safety codes and standards for placement, audible levels, and approved sensor types where applicable.
- Future-proofing: Design sensor headers and firmware hooks to add camera-based flame detection or ML-anomaly modules later.
- Power and thermal management: Place electronics in ventilated enclosures away from direct heat sources to avoid false high-temperature triggers.

V. CONCLUSION

The Smart Fire Alarm System presented in this paper demonstrates an effective integration of IoT, multi-sensor technology, and rule-based decision logic for reliable fire detection. By combining smoke, gas, temperature, and flame sensors with an ESP32 microcontroller, the system significantly improves detection accuracy and minimizes false alarms. The inclusion of cloud connectivity enables real-time remote monitoring, instant alerts, and historical data analysis, which are not available in traditional fire alarm systems.

The system is low-cost, scalable, and flexible, making it suitable for residential, commercial, and small industrial environments. Future enhancements may include AI-based fire prediction, mobile app notifications, camera-based flame detection, and integration with emergency response services. Overall, this project represents a practical step toward intelligent and connected fire safety solutions.

REFERENCES

[1] Sarwar, B., "Fuzzy Logic-Based Fire Detection System for Smart Buildings," 2018.
[2] Tyagi, P., "Survey on Smart Fire Detection Systems Using IoT," 2020.
[3] Verma, K., "AI-Based Image Processing for Early Fire Detection," 2022.
[4] Ahmed, S., "AI-Enabled IoT Fire Alarm System," 2024.
[5] IEEE Sensors Journal, "Multi-Sensor Fire Detection Systems," 2023.