

Design and Implementation of an IoT-Based Smoke Detection and Automated Ventilation System

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Abstract: *This paper presents the design and implementation of an IoT-based smoke detection and automated ventilation system aimed at improving indoor safety and air quality monitoring. Traditional fire and smoke detection systems often rely on standalone alarms that provide limited response capability and lack real-time monitoring features. To address these limitations, the proposed system integrates a gas/smoke sensor (MQ series) with a microcontroller-based platform to continuously monitor smoke concentration levels in the environment.*

The system is designed to detect abnormal smoke levels based on predefined threshold values and trigger immediate response mechanisms. Upon detection, a visual alert is generated using an LED indicator, and an exhaust fan is automatically activated to remove smoke and improve air circulation. This automated response minimizes human intervention and reduces potential risks in indoor environments.

The implementation focuses on low-cost hardware components and efficient real-time processing, making the system suitable for residential and small-scale industrial applications. The system performance was evaluated under different smoke conditions, demonstrating reliable detection and quick response time. The results indicate that the proposed solution provides an effective, scalable, and practical approach for enhancing safety through early smoke detection and automated environmental control.

Keywords: IoT-Based Smoke Detection, MQ Gas Sensor, Arduino Microcontroller, Automated Ventilation System, Real-Time Monitoring, Indoor Air Safety, LED Alert System.

I. INTRODUCTION

Smoke detection and fire prevention are critical aspects of safety in residential, commercial, and industrial environments. Traditional smoke detection systems primarily rely on standalone alarm units that only provide audible alerts after detecting smoke, without offering any active response mechanism to control or reduce the hazardous condition. Such systems often depend heavily on human intervention, which can delay appropriate action and increase the risk of damage.

With the rapid advancement of Internet of Things (IoT) technologies, there is a growing opportunity to develop smart safety systems that not only detect potential hazards but also respond automatically in real time. IoT-based systems enable continuous environmental monitoring, faster data processing, and integration of multiple response mechanisms, making them more efficient and reliable compared to conventional methods.

However, many existing low-cost smoke detection solutions are limited in functionality, offering only basic detection without integrating automated control features such as ventilation or visual alert systems. Additionally, these systems often lack scalability and adaptability for different indoor environments.

To address these limitations, this paper presents the design and implementation of an IoT-based smoke detection and automated ventilation system. The proposed system uses a gas/smoke sensor to continuously monitor air quality and



detect abnormal smoke levels based on predefined threshold values. Upon detection, the system triggers an LED indicator for visual alert and automatically activates an exhaust fan to remove smoke from the environment, thereby reducing potential hazards.

The system is designed to be cost-effective, efficient, and suitable for real-time indoor safety applications. By integrating detection and automated response mechanisms, the proposed solution enhances safety, minimizes human dependency, and provides a practical approach for early hazard control.

II. LITERATURE REVIEW

The development of smart safety systems has gained significant attention with the advancement of IoT technologies and embedded systems. Several existing solutions have been proposed for smoke detection, fire alert systems, and environmental monitoring. However, many of these systems focus primarily on detection rather than integrating automated response mechanisms.

Traditional smoke detection systems are widely used in residential and industrial environments. These systems typically rely on sensors that trigger alarms when smoke is detected. While effective in providing alerts, they lack intelligent features such as real-time monitoring, remote accessibility, and automated control actions, which limits their effectiveness in critical situations.

Recent research has explored IoT-based fire detection systems that utilize microcontrollers and wireless communication to send alerts to users through mobile applications or cloud platforms. These systems improve monitoring capabilities by enabling real-time notifications. However, most of these solutions focus only on alert generation and do not incorporate immediate physical responses such as ventilation or smoke removal.

Some advanced systems integrate multiple sensors to monitor parameters such as temperature, gas concentration, and humidity. Although these systems provide better accuracy and reliability, they often increase system complexity and cost, making them less suitable for small-scale or low-budget applications.

Additionally, existing solutions that include automated control mechanisms are often limited to triggering alarms or notifications without actively mitigating the hazardous condition. There is a lack of simple, cost-effective systems that combine smoke detection with an immediate response such as activating ventilation to reduce smoke levels.

Based on the analysis of existing systems, it is evident that there is a gap in developing a low-cost, efficient, and real-time smoke detection system that not only detects hazards but also responds automatically to improve environmental safety. The proposed system addresses this gap by integrating smoke detection with an automated exhaust mechanism and visual alert system, providing a practical and scalable solution for indoor safety applications.

III. METHODOLOGY

The proposed system is designed as an IoT-based embedded solution for real-time smoke detection and automated response. It follows a modular architecture consisting of sensing, processing, and actuation units that work together to detect and control smoke levels in indoor environments.

System Architecture

The system is divided into three main components:

Sensing Unit:

An MQ-series gas/smoke sensor is used to continuously monitor the concentration of smoke and harmful gases in the environment. The sensor provides analog output proportional to the detected gas levels.

Processing Unit:

A microcontroller (such as Arduino) processes the analog data received from the sensor. It continuously compares the sensor values with predefined threshold levels to determine the presence of smoke.

Actuation Unit:

When the detected smoke level exceeds the threshold, the system activates:



An **LED indicator** for visual alert

An **exhaust fan** to remove smoke and improve air circulation

Working Principle

The system operates in a continuous monitoring loop:

- The MQ sensor detects smoke concentration in the air.
- The analog signal is sent to the microcontroller.
- The microcontroller converts the signal into a digital value.
- The value is compared with a predefined threshold level.
- If the value exceeds the threshold:
- LED is turned ON (alert signal)
- Exhaust fan is activated automatically
- If the value is below the threshold:
- System remains in normal monitoring state

Data Processing and Threshold Detection

The system uses a predefined threshold value (e.g., 400 units, adjustable based on calibration) to identify hazardous conditions. Proper calibration of the sensor is performed to ensure accurate detection and reduce false positives.

The threshold-based approach ensures:

- Fast decision-making
- Low computational complexity
- Real-time response

Hardware Components

The system is implemented using the following components:

- MQ Gas/Smoke Sensor (MQ-2 or similar)
- Arduino Microcontroller
- LED Indicator
- Exhaust Fan (controlled via relay or MOSFET)
- Power Supply Unit

System Flow

- Initialize system and sensor
- Continuously read sensor values
- Compare with threshold
- Trigger alert and ventilation if threshold is exceeded
- Repeat the process in real time

Advantages of Proposed Method

- Real-time smoke detection
- Automatic response without human intervention
- Low-cost and easy implementation
- Suitable for small-scale indoor environments
- Scalable for future IoT integration



IV. IMPLEMENTATION

The implementation of the proposed IoT-based smoke detection and automated ventilation system focuses on integrating hardware components with microcontroller-based programming to achieve real-time monitoring and response. The system is designed to be simple, cost-effective, and efficient for practical indoor applications.

Hardware Implementation

The hardware setup consists of an MQ-series smoke sensor, an Arduino microcontroller, an LED indicator, and an exhaust fan controlled through a switching device such as a relay module or MOSFET.

The **MQ sensor** is connected to the analog input pin of the Arduino to provide continuous smoke level readings.

The **LED indicator** is connected to a digital output pin to provide a visual alert.

The **exhaust fan** is connected through a relay or MOSFET circuit, allowing the Arduino to control high-power devices safely.

A regulated **power supply** is used to ensure stable system operation.

Proper circuit connections and grounding are maintained to avoid noise and ensure accurate sensor readings.

Software Implementation

The system is programmed using the Arduino IDE with embedded C/C++.

The sensor value is read using the `analogRead()` function.

The system continuously monitors the sensor output in a loop.

A predefined threshold value is used to detect abnormal smoke levels.

Conditional statements (if-else) are used to trigger actions based on sensor data.

Core Logic:

If sensor value > threshold → LED ON + Fan ON

Else → LED OFF + Fan OFF

This ensures immediate response when smoke is detected.

Sensor Calibration

Calibration of the MQ sensor is an important step to ensure accurate detection.

The sensor is initially tested in a clean air environment to determine baseline values.

Smoke is introduced gradually to observe variation in sensor readings.

A suitable threshold value (e.g., 350–450 range) is selected based on experimental observations.

This process helps in reducing false alarms and improving system reliability.

Circuit Design and Control Mechanism

The exhaust fan operates on higher voltage/current, so it cannot be connected directly to the microcontroller. Therefore:

A **relay module or MOSFET** is used as a switching device

The Arduino sends a control signal to activate the switch

The switch turns the fan ON/OFF based on the condition

This ensures electrical safety and proper isolation between low-power and high-power components.

System Testing

The system was tested under different conditions:

Normal Condition: No smoke → LED OFF, Fan OFF

Smoke Condition: Smoke detected → LED ON, Fan ON

Multiple trials were conducted to verify:



Response time
Accuracy of detection
Stability of system operation
The system consistently responded to smoke presence within a short time duration.

User Interaction and Output

The system provides simple and effective output:
LED indicator gives immediate visual feedback
Exhaust fan actively reduces smoke levels
No manual intervention required
This makes the system user-friendly and suitable for real-world applications.

V. RESULTS AND DISCUSSION

The proposed IoT-based smoke detection and automated ventilation system was tested under different environmental conditions to evaluate its performance, reliability, and response time. The system was able to successfully detect variations in smoke levels and respond automatically based on predefined threshold values.

Experimental Results

The system was tested in two primary conditions:

Normal Environment (Clean Air):

The sensor readings remained below the threshold value, and the system maintained a normal state with the LED and exhaust fan turned OFF.

Smoke Environment (Presence of Smoke):

When smoke was introduced near the sensor, the sensor readings increased rapidly and exceeded the threshold value.

The system responded immediately by:

- Turning ON the LED indicator
- Activating the exhaust fan

The response time of the system was observed to be within **2–3 seconds**, depending on the intensity of smoke.

Performance Analysis

The system demonstrated consistent performance across multiple test runs:

Fast Response:

Quick detection and activation of output devices ensured early hazard control.

Reliable Detection:

The MQ sensor showed stable readings with noticeable variation between clean air and smoke conditions.

Low False Trigger Rate:

Proper calibration minimized false alarms in normal environmental conditions.

Efficient Operation:

The system consumed low power and operated continuously without interruption.

Sample Observation Table

| Condition | Sensor Value Range | LED Status | Fan Status |
|----------------|--------------------|------------|------------|
| Clean Air | 150 – 300 | OFF | OFF |
| Moderate Smoke | 350 – 450 | ON | ON |
| Dense Smoke | 450+ | ON | ON |

(Values may vary slightly depending on calibration and environment)



VI. DISCUSSION

The results indicate that the proposed system effectively addresses the limitations of traditional smoke detection systems by integrating both detection and automated response mechanisms. Unlike conventional systems that only provide alerts, this system actively reduces smoke levels through ventilation, improving safety in indoor environments. The use of a threshold-based detection approach ensures simplicity and fast processing, making the system suitable for real-time applications. Additionally, the low-cost hardware design makes it accessible for small-scale deployment in homes, offices, and workshops.

However, the system has certain limitations. The MQ sensor may be affected by environmental factors such as humidity and temperature, which can influence accuracy. Furthermore, the current system is limited to local operation and does not include remote monitoring or notification features.

Despite these limitations, the overall performance demonstrates that the system is reliable, efficient, and practical for real-world applications.

VII. CONCLUSION

This paper presented the design and implementation of an IoT-based smoke detection and automated ventilation system for enhancing indoor safety. The proposed system successfully detects smoke levels in real time using an MQ-series sensor and responds automatically by activating a visual alert and an exhaust mechanism.

The implementation demonstrates that integrating detection with automated response significantly improves the effectiveness of traditional smoke detection systems. The system is cost-effective, easy to implement, and suitable for small-scale applications such as homes, offices, and workshops.

Experimental results confirm that the system provides reliable detection with quick response time and minimal false triggering when properly calibrated. Although the current system operates locally, it provides a strong foundation for future enhancements such as remote monitoring, mobile integration, and multi-sensor deployment.

Overall, the proposed solution offers a practical and scalable approach to improving safety through early smoke detection and automated environmental control.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the project guide for their continuous support, valuable guidance, and encouragement throughout the development of this project. Their insights and suggestions played a crucial role in the successful completion of this work.

We also extend our thanks to the Head of the Department and all faculty members for providing the necessary resources and a supportive environment to carry out this project.

We would like to acknowledge our teammates for their cooperation, coordination, and contribution during the implementation of the system.

Finally, we express our heartfelt appreciation to our family and friends for their constant support and motivation.

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