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Development of an IoT-Based Gas and Temperature Monitoring System

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Abstract

Gas leakage and sudden temperature rise are common causes of accidents in residential and industrial environments. Traditional detection systems usually rely on local alarms, which are not effective when the area is unattended. Modern Internet of Things (IoT) technology enables remote monitoring of environmental conditions and provides real-time alerts. In this work, a simple IoT-based gas and temperature monitoring system is developed using low-cost components. The system employs an MQ-2 gas sensor and a TMP35 temperature sensor connected to an Arduino microcontroller. Sensor data is transmitted to a cloud platform through an ESP8266 Wi-Fi module. When the gas concentration or temperature exceeds a predefined safety limit, the system activates a buzzer, warning LEDs, and a ventilation fan. The proposed system is affordable, easy to install, and suitable for homes, laboratories, and small industrial environments where continuous safety monitoring is required.

Keywords: IoT, Gas Detection, Temperature Monitoring, Arduino, ESP8266

1. Introduction

Gas leakage is a serious safety problem in residential, commercial, and industrial environments. Fuels such as LPG, methane, and natural gas are commonly used in daily life. If these gases leak and accumulate in closed spaces, they can lead to explosions, fires, or health hazards.

Traditional gas detection systems are usually limited to local alarms. These systems generate a sound or light signal when gas concentration exceeds a certain limit. However, they have several limitations. They only provide alerts within a small range, and if no one is present near the system, the warning may not be noticed. In addition, most traditional systems do not provide remote monitoring or data storage.

The Internet of Things has introduced new possibilities in safety and monitoring systems. IoT allows sensors to connect to the internet and send real-time data. This makes it possible to monitor environmental conditions from remote locations.

The objective of this research is to design a simple, cost-effective gas and temperature monitoring system using easily available components. The system focuses on real-time monitoring, automatic alert generation, and remote data access.

2. LITERATURE REVIEW

Various gas sensing technologies have been developed for safety and environmental monitoring. Metal Oxide Semiconductor sensors are widely used because they are affordable and easy to integrate with microcontrollers. Sensors from the MQ series are commonly used in small-scale safety projects.

However, MOS sensors have certain limitations. Their performance is affected by humidity and temperature changes. They also suffer from cross-sensitivity, which means they may respond to more than one type of gas.

Electrochemical sensors provide better selectivity and lower power consumption, but they are more expensive. Optical sensors offer high accuracy and long service life, but their cost and complexity limit their use in low-cost systems.

Recent research has focused on integrating gas sensors with IoT platforms. These systems use wireless communication to send data to cloud servers and provide remote alerts. Some systems also use machine learning techniques to improve detection accuracy.

Despite these advancements, many systems are complex and expensive. There is still a need for simple, low-cost monitoring solutions for homes and small industries.

3. METHODOLOGY

3.1 System Overview

The proposed system continuously monitors gas concentration and temperature. It uses sensors connected to a microcontroller, which processes the data and sends it to a cloud platform through a Wi-Fi module.

3.2 Main Components

The system uses the following components:

1. MQ-2 Gas Sensor
2. TMP35 Temperature Sensor
3. Arduino Uno Microcontroller
4. ESP8266 Wi-Fi Module
5. Buzzer
6. LEDs
7. DC Fan

3.3 MQ-2 Gas Sensor

The MQ-2 sensor is used to detect combustible gases such as LPG, methane, and smoke. It works on the principle of resistance change when exposed to gas particles. The sensor is widely used in low-cost gas detection systems.

Fig. 1 MQ-2 Gas Sensor

3.4 TMP35 Temperature Sensor

The TMP35 is a low-voltage temperature sensor that provides an output voltage proportional to temperature. It is factory-calibrated and provides reliable readings without additional calibration.

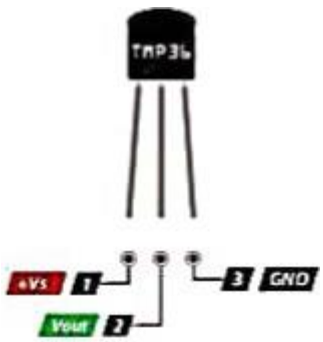

Fig. 2 TMP35 Temperature Sensor

3.5 Working Principle

The system operates in a continuous loop. The gas sensor detects combustible gases, and the temperature sensor measures ambient temperature. The Arduino reads the sensor values and compares them with predefined safety limits.

If the readings exceed the threshold:

- The buzzer is activated.
- Warning LEDs turn on.
- The ventilation fan starts automatically.

At the same time, sensor data is sent to the cloud through the ESP8266 module. The user can monitor the readings remotely.

4. SYSTEM ARCHITECTURE AND FEATURES

4.1 Overall Architecture

The proposed gas and temperature monitoring system is designed using a simple layered architecture. The primary objective of the system is to detect gas leakage and abnormal temperature conditions and provide immediate alerts. To achieve this goal, the system is divided into several functional layers. This layered approach makes the system easier to understand, maintain, and expand in the future.

The system operates on a continuous monitoring principle. Sensors collect environmental data, the microcontroller processes the data, and the communication module sends it to the cloud platform. When the readings exceed predefined safety limits, the alert system is activated automatically.

4.2 Sensor Layer

The sensor layer is responsible for collecting real-time environmental data. This layer includes two main sensors: the MQ-2 gas sensor and the TMP35 temperature sensor.

The MQ-2 sensor is used to detect combustible gases such as LPG, methane, and smoke. It works by sensing changes in electrical resistance when exposed to gas particles. This change in resistance is converted into an analog signal that is read by the microcontroller.

The TMP35 temperature sensor measures the ambient temperature. It produces an output voltage that varies linearly with temperature. Since the sensor is factory-calibrated, it provides reliable readings without additional calibration.

Note:

Images of the MQ-2 and TMP35 sensors should be placed in Section III, not here.

4.3 Processing Layer

The processing layer acts as the control unit of the system. In this design, the Arduino Uno microcontroller is used to process the sensor data. The Arduino reads the analog signals from the sensors and converts them into digital values.

The system program contains predefined threshold levels for gas concentration and temperature. When the readings are within the safe range, the system continues normal operation. If the values exceed the threshold, the Arduino activates the alert devices.

The microcontroller also prepares the data for transmission by formatting the sensor readings into data packets that can be sent through the communication module.

4.4 Communication Layer

The communication layer connects the system to the internet. It uses the ESP8266 Wi-Fi module to transmit sensor data to the cloud.

The ESP8266 receives data from the Arduino through serial communication. It then connects to a Wi-Fi network and uploads the data to a cloud server. This allows users to monitor the system remotely using a smartphone, tablet, or computer.

This layer ensures that the system is not limited to local alarms and provides real-time remote monitoring.

4.5 Cloud Layer

The cloud layer is responsible for storing and displaying sensor data. The data transmitted by the ESP8266 is stored on a cloud platform, where it is presented in graphical form.

The cloud interface typically displays:

- Gas concentration over time
- Temperature variation over time
- Historical data records

This feature allows users to monitor both real-time and past data, which is useful for safety analysis and maintenance planning.

4.6 Alert and Response Layer

The alert layer provides immediate safety responses when dangerous conditions are detected. This layer includes a buzzer, warning LEDs, and a DC ventilation fan.

When gas concentration or temperature exceeds the threshold:

- The buzzer produces an audible alert.
- The red LED provides a visual warning.
- The DC fan starts automatically.

The fan helps disperse accumulated gas, reducing the risk of explosion or fire.

4.7 Key Features of the System

- Continuous monitoring of gas and temperature
- Real-time alerts during hazardous conditions
- Remote data access through the cloud
- Automatic safety response
- Low-cost and simple design

5. TECHNOLOGY IMPLEMENTATION

5.1 Hardware Integration

The system hardware is designed using a simple and modular approach.

- The MQ-2 gas sensor is connected to an analog input pin of the Arduino.
- The TMP35 temperature sensor is also connected to an analog input pin.
- The ESP8266 Wi-Fi module is connected through serial communication.
- The buzzer, LEDs, and fan are connected to digital output pins.

This arrangement keeps the system compact and easy to maintain.

5.2 Software Design

The system software is developed using the Arduino IDE. The program is written in Embedded C.

The main tasks performed by the program include:

1. Reading sensor data
2. Comparing readings with threshold values
3. Activating alert devices
4. Transmitting data to the cloud through the Wi-Fi module

The program runs in a continuous loop, updating sensor readings at regular intervals.

5.3 Data Transmission Process

The data transmission process is carried out in the following steps:

1. The Arduino reads sensor values.

2. The readings are converted into digital data.
3. Data is sent to the ESP8266 module.
4. The ESP8266 uploads the data to the cloud server.
5. The cloud platform displays the data in graphical form.

6. IMPLEMENTATION AND RESULTS

The system was assembled as a prototype using the selected hardware components. The sensors were connected to the Arduino, and the ESP8266 module was configured to connect to a Wi-Fi network.
The system was tested under different environmental conditions. Gas was introduced near the sensor to observe its response, and the temperature sensor was tested using a controlled heat source.
When the readings exceeded the threshold values:

- The buzzer was activated.
- The warning LED turned on.
- The ventilation fan started automatically.
- The cloud platform displayed real-time updates.

Table 1 Comparison of Gas and Temperature Monitoring Systems

System	Average Gas Value (ppm)	Response Time (sec)	Detection Accuracy (%)	Power Consumption (W)
Arduino- Based System	230	0.8	91	0.45
Raspberry Pi-Based System	228	0.7	94	3.5
NodeMCU (ESP8266)	240	1.2	88	0.9
Standalone MQ Sensor (Direct)	260	1.5	78	0.2

This table compares:

- Arduino-based system
- Raspberry Pi-based system
- NodeMCU system
- Standalone sensor system

Gas Sensor Reading

The gas sensor readings were displayed on the cloud platform as a graph. The graph shows how gas concentration changes over time during testing.

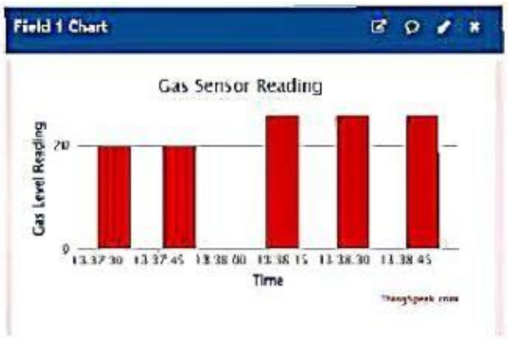

Fig. 3 Gas Sensor Reading

Temperature Sensor Reading

The temperature data was also monitored in real time. The graph shows the variation in temperature during the experiment.

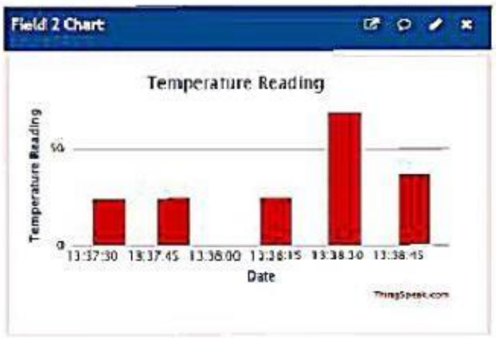

Fig. 4 Temperature Sensor Reading

7. MARKET ANALYSIS AND USER RESEARCH

The need for gas monitoring systems has increased due to rising safety concerns in homes, industries, and laboratories. Many accidents occur because gas leaks are not detected at an early stage. Traditional alarm systems only provide local alerts and do not support remote monitoring. This has created demand for simple and affordable IoT-based safety systems.

7.1 Market Need

Gas cylinders are widely used in residential kitchens and commercial environments. Leakage of gases such as LPG or methane can lead to fires, explosions, and health risks. In industrial settings, gas leaks can damage equipment and interrupt production. Because of these risks, there is a growing demand for systems that can monitor gas levels continuously and provide early warnings.

7.2 Target Users

The proposed system is suitable for different types of users:

- Residential households using LPG cylinders
- Small and medium industrial units
- Laboratories and educational institutions
- Restaurants and commercial kitchens

These users require simple and reliable monitoring systems that are easy to install and maintain.

7.3 User Requirements

Most users expect the following features from a gas monitoring system:

- Continuous gas and temperature monitoring
- Immediate alert during dangerous conditions
- Remote monitoring capability
- Low installation cost
- Easy operation and maintenance

The proposed system is designed to meet these requirements using low-cost components and a simple architecture.

8. ECONOMIC IMPACT AND BENEFITS

8.1 Benefits for System Owners and Installers

- **Low Initial Investment:** The system is built using affordable and easily available components such as Arduino, MQ-2 sensor, and ESP8266.
- **Reduced Maintenance Costs:** Simple hardware design reduces repair and maintenance expenses.
- **Easy Installation:** The system can be installed without complex infrastructure or specialized tools.
- **Scalability:** Multiple units can be installed in different locations without major additional costs.
- **Long-Term Reliability:** Durable components ensure stable operation over extended periods.

8.2 Benefits for End Users

- **Accident Prevention:** Early detection of gas leaks and high temperatures helps avoid fire accidents and property damage.
- **Cost Savings:** Preventing accidents reduces repair, replacement, and medical expenses.
- **Convenience:** Remote monitoring allows users to check system status from any location.
- **Energy Efficiency:** Automatic fan activation helps maintain safe environmental conditions without manual intervention.
- **Peace of Mind:** Continuous monitoring improves user confidence in the safety of their environment.

8.3 Economic Impact on Communities and Industries

- **Reduced Property Damage:** Early warning systems help prevent large-scale fire incidents.
- **Improved Workplace Safety:** Safer environments reduce accident-related costs and downtime.
- **Support for Small Industries:** Low-cost safety systems make it easier for small businesses to adopt monitoring solutions.

- **Increased Productivity:** Continuous monitoring reduces unexpected interruptions in industrial operations.
- **Promotion of Smart Safety Solutions:** Encourages adoption of affordable IoT-based safety technologies in local markets.

9. IMPLEMENTATION STRATEGY

Phase 1: Core System Development

- Basic hardware assembly of the monitoring unit
- Integration of MQ-2 gas sensor and TMP35 temperature sensor
- Arduino microcontroller programming for sensor reading
- Development of basic alert system using buzzer and LEDs
- Initial testing of gas and temperature detection functions

Phase 2: Communication and Cloud Integration

- Integration of ESP8266 Wi-Fi module with Arduino
- Configuration of wireless network connectivity
- Development of real-time data transmission to cloud platform
- Creation of basic cloud dashboard for data visualization
- Testing of remote monitoring functionality

Phase 3: System Testing and Deployment

- Prototype testing under different gas and temperature conditions
- Calibration of sensor threshold values
- Performance evaluation in real environments
- Installation in target locations such as kitchens or laboratories
- Monitoring system stability and alert response

Phase 4: Expansion and Enhancement

- Addition of multiple gas sensors for improved accuracy
- Development of mobile application for instant notifications
- Integration of advanced data analytics features
- Expansion of system deployment to industrial environments
- Collaboration with safety solution providers and institutions

10. FUTURE ENHANCEMENTS

10.1 Artificial Intelligence Integration

- Predictive Risk Analysis: AI models can analyze sensor data to predict possible gas leaks or overheating before they become critical.
- Smart Alert Prioritization: Intelligent algorithms can classify alerts based on severity and send priority notifications.
- Anomaly Detection: AI can identify unusual patterns in gas or temperature readings and trigger early warnings.

- Usage Pattern Analysis: System can study environmental data trends to improve safety recommendations.

10.2 IoT and Smart System Integration

- Smart Home Integration: The system can be connected with smart home platforms for centralized control.
- Mobile Application Support: A dedicated mobile app can provide instant notifications and remote system control.
- Automated Safety Actions: Integration with smart valves or switches to automatically shut off gas supply during leaks.
- Cloud-Based Monitoring: Enhanced cloud dashboards with advanced visualization and data logging features.

10.3 Advanced Sensor and Network Technologies

- Multi-Gas Detection: Integration of additional sensors to detect different types of gases.
- Low-Power Communication: Use of technologies such as LoRa or Zigbee for energy-efficient communication.
- Wireless Sensor Networks: Deployment of multiple interconnected sensors for large industrial areas.
- Miniaturized Sensor Modules: Use of MEMS-based sensors for compact and portable system designs.

11. CONCLUSION

The proposed IoT-based gas and temperature monitoring system demonstrates a practical and affordable solution for improving safety in residential, laboratory, and industrial environments. The system combines low-cost sensors, a microcontroller, and wireless communication to provide continuous monitoring and real-time alerts. By detecting hazardous conditions at an early stage, the system helps reduce the risk of accidents, equipment damage, and financial losses.

Key findings of this research include:

▪ Safety Improvement: Continuous gas and temperature monitoring helps prevent fire hazards and dangerous environmental conditions.

▪ Cost-Effective Design: The use of low-cost components makes the system affordable for homes and small industries.

▪ Real-Time Monitoring: Integration of Wi-Fi communication enables remote monitoring through cloud platforms.

▪ Automatic Response: The system can automatically activate alarms and ventilation to reduce risk.

▪ Scalability Potential: The design can be expanded with additional sensors and smart features for larger applications.

The success of the proposed system depends on proper sensor calibration, reliable network connectivity, and correct installation in the target environment. Future research can focus on improving detection accuracy, integrating intelligent decision-making systems, and developing mobile-based control interfaces.

Based on this research, the following recommendations are suggested:

1. For System Developers

- Improve sensor accuracy through calibration and filtering techniques
- Integrate multiple gas sensors for better detection capability
- Develop mobile applications for real-time notifications
- Design scalable and energy-efficient system architectures

2. For Users and Installers

- Install the system in high-risk areas such as kitchens and storage rooms
- Perform regular maintenance and sensor checks
- Ensure stable power supply and internet connectivity
- Follow safety guidelines for proper system operation

3. For Industries and Institutions

- Adopt low-cost monitoring systems to improve workplace safety
- Integrate monitoring units with existing safety infrastructure
- Provide training on the use of automated safety systems

4. For Future Research

- Development of AI-based predictive monitoring systems
- Integration with smart home and industrial automation platforms
- Study of long-term reliability and performance in real environments
- Exploration of advanced communication and sensor technologies

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