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IOT Based Predictive Monitoring System of Oxygen, Temperature and Human Density with Smart Alert Mechanism

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Abstract:

Ensuring environmental safety and effective crowd management is critical in both indoor spaces and outdoor gatherings such as public meetings and large-scale events. An IoT-based predictive monitoring system is developed to continuously track oxygen levels, ambient temperature and human density using appropriate sensors interfaced with a Wi-Fi-enabled microcontroller. The acquired sensor data is transmitted to a cloud platform for real-time visualization and analysis. A predictive monitoring strategy is implemented by analyzing real-time sensor data patterns to identify potential unsafe conditions such as oxygen depletion, abnormal temperature rise and overcrowding. When the monitored or predicted parameters exceed predefined safety thresholds, a smart alert mechanism is activated, providing local alerts through buzzers and LED indicators, along with remote notifications via cloud-based services. The system is cost-effective, scalable and easy to deploy, making it suitable for indoor environments, outdoor public gatherings and smart city safety applications.

Keywords — ESP32 Microcontroller, ESP8266 Microcontroller, Gas Sensor, GSM Module, Buzzer, Temperature Sensor.

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I. INTRODUCTION

In recent years, rapid urbanization and increasing population have led to overcrowded indoor environments, which can result in unsafe living and working conditions. Factors such as reduced oxygen levels, increased temperature and excessive human density can cause serious health issues, discomfort and even life-threatening situations. Hence, there is a strong need for a smart monitoring system that can ensure environmental safety in real time.

The IoT Based Predictive Monitoring System of Oxygen, Temperature and Human Density with Smart Alert Mechanism is designed to continuously observe and analyse these critical parameters. The system uses various sensors to measure oxygen concentration, ambient temperature and the number of people present in a particular area. These sensor values are processed using a microcontroller and transmitted to a cloud platform through IoT technology.

By utilizing predictive monitoring techniques, the system can identify abnormal trends and anticipate unsafe conditions before they occur. When the monitored parameters exceed predefined safety thresholds, the smart alert mechanism is activated. Alerts are sent to responsible authorities or users through mobile notifications, alarms or display units, enabling quick preventive actions.

This system minimizes human intervention and provides accurate, real-time data, making it reliable and efficient. It can be implemented in various environments such as hospitals, classrooms, shopping malls, industries and public places to enhance safety and ensure better environmental control.

Overall, the proposed system offers a smart, automated and cost-effective solution for monitoring environmental and human safety parameters using IoT technology.

II. LITERATURE REVIEW

Al-Fuqaha *et al.*, (2019) presented a comprehensive survey on Internet of Things architectures and applications in smart environments. The authors discussed how IoT enables seamless integration of sensors, embedded devices, communication networks and cloud platforms. Their work emphasized that multi-parameter sensing combined with intelligent data analysis can significantly improve safety and automation in smart buildings and public spaces. However, the study mainly focused on system architecture and did not provide a specific implementation for oxygen level and human density monitoring.

Hassan *et al.*, (2022) developed a smart crowd and environmental monitoring system using IoT for public safety applications. The system integrated temperature sensors and people-counting sensors to identify overcrowding situations. Alerts were generated when threshold values were exceeded. Although the system improved crowd safety, it lacked oxygen level monitoring and advanced predictive analysis.

Kumar *et al.*, (2016) developed an IoT-based environmental monitoring system that measured temperature and gas concentration in indoor environments. Sensor data was transmitted to a cloud server for remote monitoring and alerts were generated during abnormal conditions. Although the system improved real-time monitoring, it focused only on environmental parameters and did not include oxygen-specific sensing or human density estimation.

Singh *et al.*, (2020) implemented a smart indoor monitoring system using IoT technology to monitor temperature, humidity and air quality. Their system provided real-time alerts and remote access through a web dashboard. Although effective, the system followed a reactive approach and did not incorporate predictive analysis or direct oxygen concentration measurement.

Wang *et al.*, (2020) presented a cloud-based IoT monitoring framework for smart buildings. The system monitored multiple environmental parameters and used historical data for trend analysis. The authors emphasized the need for predictive monitoring to reduce risks in smart environments. However, the proposed framework did not specifically address oxygen concentration monitoring or real-time human density calculation.

III. EXISTING SYSTEM

The existing monitoring solutions typically use standalone devices to measure individual environmental parameters. Temperature monitoring is commonly performed using basic thermal sensors or thermostats, while oxygen and air quality measurements are restricted to specialized instruments used in laboratories, hospitals or industrial settings. These instruments are often expensive, bulky and not suitable for large-scale deployment in public spaces

. Although video surveillance provides visual information, it requires continuous human supervision and lacks accurate quantitative analysis.

Moreover, such systems are affected by poor lighting conditions, occlusion and privacy concerns. In outdoor environments, these limitations are further amplified due to changing environmental conditions. Most existing systems do not offer centralized data storage or cloud-based access. The collected data is rarely logged for long-term analysis, making it difficult to study trends or predict future risk conditions. Alert mechanisms, if available, are limited to local alarms and do not support remote notifications or automated control actions, as shown in Fig. 1.

Fig. 1 Existing System

IV. PROPOSED SYSTEM

The proposed system aims to develop an advanced IoT-based predictive monitoring solution capable of continuously monitoring oxygen levels, temperature and human density in both indoor and outdoor environments. Unlike traditional systems, this solution integrates multiple sensors into a single centralized platform and enables real-time data monitoring, intelligent analysis and automated alert mechanisms.

The system is designed to ensure safety during public gatherings, meetings, classrooms, industrial operations and outdoor events by detecting abnormal environmental conditions before they become critical. By utilizing IoT technology, cloud connectivity and smart alert features, the system enhances reliability, scalability and remote accessibility, as shown in Fig. 2.

Fig. 2 Proposed System

V. DEVELOPED MODEL

1.1 Working Model

The developed model of the IoT-Based Predictive Monitoring System is designed to monitor oxygen level, temperature and human density in real time. The system consists of sensors connected to a microcontroller, which acts as the main control unit. The microcontroller collects data from all sensors and processes the values continuously.

An LCD display is used to show the current readings of oxygen, temperature and human density. The system is connected to the internet using a Wi-Fi module, which sends the data to a cloud platform for remote monitoring. This allows users to check the environmental conditions from anywhere.

A smart alert mechanism is also included in the model. If any parameter exceeds the safe limit, a buzzer sounds and warning notifications can be sent. All components are neatly arranged on a base board with proper power supply and wiring. The developed model successfully demonstrates real-time monitoring, data transmission and automatic alert generation, as shown in Fig. 3.

Fig. 3 Snapshot of the Working Model

2.1 Hardware Components

A. *ESP32 Microcontroller*

The ESP32 microcontroller functions as the core controller of the IoT-based predictive monitoring system, allowing continuous monitoring and smart management of oxygen concentration, temperature and human density. It gathers data from the connected sensors, evaluates the readings against predefined safety limits and identifies whether the environment is safe or potentially dangerous. Using its integrated Wi-Fi capability, the ESP32 sends real-time data to cloud platforms for remote supervision, storage and predictive analysis. If unsafe conditions such as reduced oxygen levels, elevated temperature, or overcrowding occur, it triggers the smart alert system through buzzers, LED indicators and mobile notifications to enable quick response and improved safety. With its fast processing capability, energy efficiency, multiple GPIO interfaces and built-in wireless connectivity, the ESP32 provides a reliable and economical solution for continuous environmental monitoring and intelligent alert systems, as shown in Fig. 4.

Fig. 4 ESP32 Microcontroller

B. *ESP8266 Microcontroller*

The ESP8266, developed by Espressif Systems, functions as the central controller and communication device in the IoT-based predictive monitoring system for oxygen, temperature and human density with a smart alert mechanism. It gathers real-time readings from the respective sensors and evaluates them against preset safety limits to identify potential risks such as low oxygen levels, increased temperature, or overcrowding. Through its integrated Wi-Fi feature, the ESP8266 sends the collected data to a cloud server or online dashboard for continuous remote supervision. Whenever the system detects abnormal conditions, it triggers warning measures like a buzzer, LED signals, or mobile alerts to ensure prompt response and maintain a safe indoor atmosphere, as shown in Fig. 5.

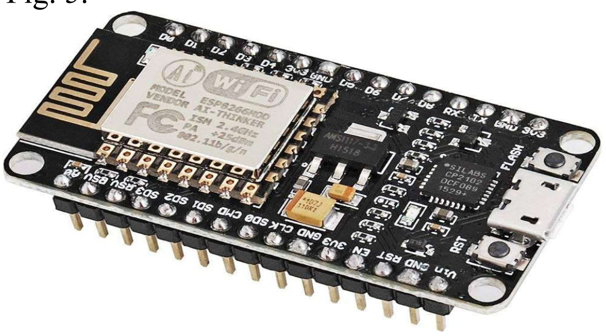

Fig. 5 ESP8266 Microcontroller

C. *Gas Sensors*

1. MQ-135
2. MQ-7
3. MQ-2

1. MQ-135

The MQ-135 is a semiconductor air quality sensor used to detect harmful gases such as carbon dioxide, ammonia, nitrogen oxides, and smoke in indoor environments. It provides an analog output based on gas concentration, which a microcontroller analyzes to monitor air quality and activate alerts when pollution levels exceed safe limits, as shown in Fig. 6.

Fig. 6 MQ-135

2. MQ-7

The MQ-7 is a semiconductor sensor designed to measure carbon monoxide (CO) levels in the air. It generates an analog signal that changes with CO concentration and is used in monitoring systems to activate alerts when the gas level rises above safe limits, as shown in Fig. 7.

Fig. 7 MQ-7

3. MQ-2

The MQ-2 is a gas sensor used to identify flammable gases such as LPG, methane, and smoke. It generates an analog output that a microcontroller uses to activate alarms when gas concentrations exceed safe levels, as shown in Fig. 8.

Fig. 8 MQ-2

D. *Temperature Sensor*

The DHT11 is an affordable digital sensor designed to measure temperature and humidity for real-time environmental monitoring. It uses a thermistor to sense temperature and a capacitive element to measure humidity, sending the readings as a digital signal to the microcontroller. In the IoT-based predictive monitoring system, the DHT11 monitors temperature changes in crowded or enclosed areas to maintain safety and comfort. When the temperature rises above the preset safety level, the system triggers alerts such as buzzers, LED indicators and remote notifications. Its easy interfacing, dependable operation and low power consumption make the DHT11 ideal for continuous environmental monitoring, as shown in Fig. 9.

Fig. 9 Temperature Sensor

E. LCD Display

The LCD display is utilized in the IoT-based predictive monitoring system to present real-time environmental information such as temperature, air quality, and human density. A 16×2 LCD module is commonly used to show sensor readings in a simple and easy-to-read format, enabling users to observe conditions instantly without relying on a mobile device or computer, as shown in Fig. 10.

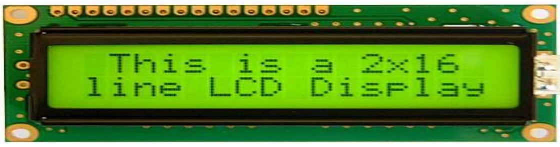

Fig. 10 LCD Display

F. Buzzer

The buzzer in the IoT-based predictive monitoring system provides an audible warning whenever unsafe environmental conditions are detected. It is triggered by the microcontroller when factors such as elevated temperature, poor air quality, or overcrowding exceed preset safety thresholds. This sound alert quickly notifies nearby individuals, even if they are not viewing the display or mobile alerts. With low power consumption and rapid response, the buzzer serves as an effective emergency warning device that enhances safety in real-time monitoring applications, as shown in Fig. 11.

Fig. 11 Buzzer

G. GSM Module

A GSM module is a hardware component that allows electronic devices and microcontrollers to communicate over a cellular network with the help of a SIM card. GSM, which stands for Global System for Mobile Communication, supports communication through SMS, voice calls and GPRS-based internet services. Popular modules such as SIM800L and SIM900 are commonly used in IoT and embedded system applications. These modules function by receiving AT commands from a microcontroller via serial communication, making them ideal for applications like gas leakage detection, security systems and IoT monitoring systems that require remote data transmission, as shown in Fig. 12.

Fig. 12 GSM Module

H. Jumper Wires

Jumper wires are used in the IoT-based predictive monitoring system to create electrical connections between components such as sensors, the microcontroller, display modules and alert devices. They allow quick and secure connections on breadboards and development boards without soldering, making circuit setup and modifications simple, as shown in Fig. 13.

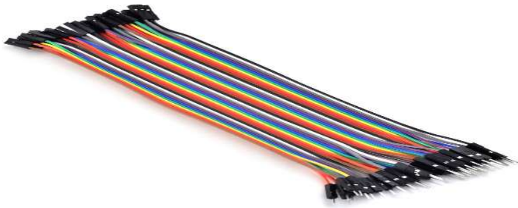

Fig. 13 Jumper Wires

VI. RESULT AND DISCUSSION

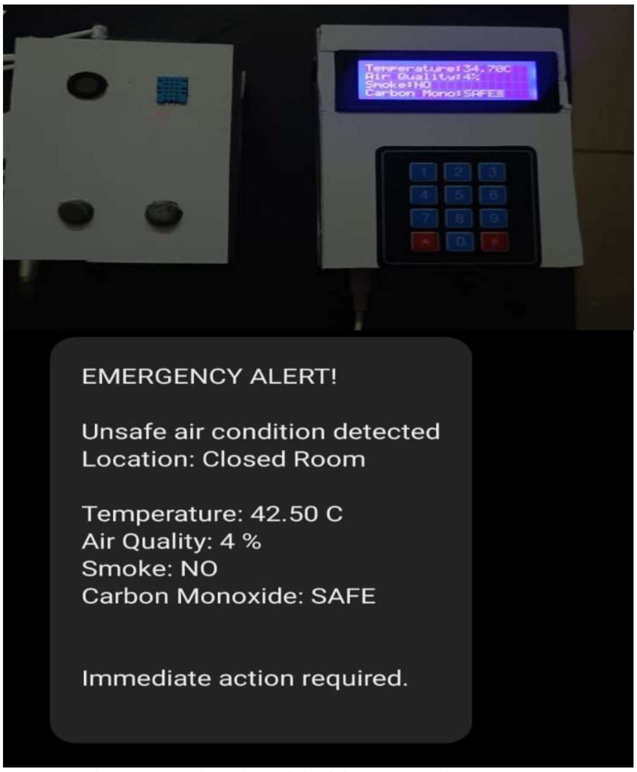

Fig. 14 Developed Model of the Proposed System

The developed IoT-based predictive monitoring system was effectively deployed and evaluated in a closed classroom setting. It continuously monitored oxygen concentration, temperature and human density in real time. During testing, it was noticed that an increase in the number of occupants led to a gradual reduction in oxygen levels and a corresponding rise in temperature. The sensors delivered stable and precise readings, while the ESP8266 ensured dependable wireless communication for remote data access.

The experimental findings indicate that indoor environmental quality is strongly influenced by occupancy levels and ventilation conditions. In classrooms with insufficient airflow, limited ventilation resulted in discomfort, tiredness and reduced focus among students. The system successfully detected data on the display unit, as shown in Fig. 14.

Whenever the measured values exceeded the preset threshold limits, the system triggered immediate alerts to signal abnormal conditions. This confirms the system's ability to promptly recognize environmental fluctuations and enable timely intervention. The test results highlight the efficiency of the sensing components and communication module in achieving continuous and reliable environmental monitoring.

VII. CONCLUSION

The developed IoT-based predictive monitoring system effectively enables real-time tracking of oxygen levels, temperature and human density within indoor spaces. It accurately identifies environmental variations and triggers immediate alerts whenever the measured values surpass preset threshold limits, allowing prompt corrective measures. The integration of sensors with the ESP8266 module ensures stable wireless communication and continuous data transmission. The observed results highlight that indoor air quality and temperature are greatly affected by occupancy levels and ventilation conditions. Overall, the system serves as an economical, reliable and practical approach to maintaining a safe, healthy and comfortable atmosphere in classrooms and similar enclosed environments.

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