Sciences Methods and Technologies International Journal (SciMeTech)

ISSN: 3085-5284, journal homepage: www.scimetech.com

Smart Indoor Air Quality Monitoring System Using an ESP32 Microcontroller with DHT11 and MQ135 Sensors

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How to cite :
Salma Lamribah, Imane Mahaimeur "Smart Indoor Air Quality Monitoring System Using an ESP32 Microcontroller with DHT11 and MQ135 Sensors", Sciences Methods and Technologies International Journal (SciMeTech), (2025) Vol 1, Issue 2, p 32-36

Keywords:
IoT
ESP32
Air Quality
Sensors
Web Dashboard

Abstract

Indoor air pollution is a growing concern, especially given the significant amount of time people spend indoors. This paper presents a smart air quality monitoring system based on the ESP32 microcontroller, which integrates DHT11 and MQ135 sensors to track temperature, humidity, and harmful gas levels in real time. The collected data is visualized via a web dashboard that refreshes every 5 seconds and includes dynamic alerts to inform users about air quality levels. Designed to be low-cost and user-friendly, this system supports healthier environments in homes, schools, and small offices. While the system is effective, limitations such as sensor accuracy and power dependency offer avenues for future improvement.

I. Introduction

The Internet of Things (IoT) plays an increasingly important role in modern applications, especially in smart environments where real-time data collection enhances safety and comfort [6], [7]. IoT deployments of this kind now span urban infrastructure [9] and residential buildings [10]. Among these applications, indoor air quality monitoring is gaining attention due to rising health concerns. Studies show that indoor air can be more polluted than outdoor air, leading to issues like respiratory problems and fatigue [1]. This matters because people spend the large majority of their time indoors [2], [3].

Despite growing awareness, many air quality systems remain costly and complex, limiting their accessibility. The emergence of low-cost sensing technologies has been identified as a way to widen access to air quality data [4], [5]. This project proposes a low-cost, IoT-based monitoring system using an ESP32 microcontroller and DHT11 and MQ135 sensors to measure temperature, humidity, and air pollution levels. Data is displayed through a web interface that updates every 5 seconds and includes alert messages when air quality is poor.

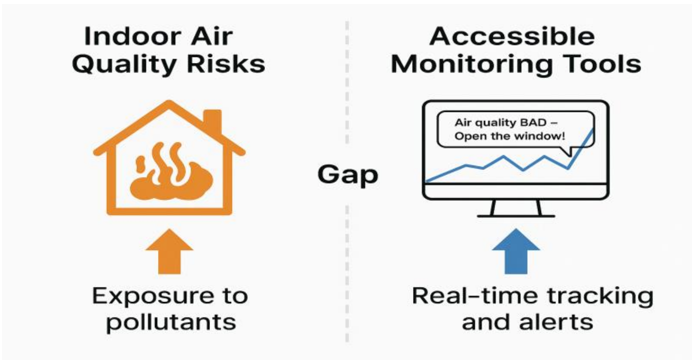

Figure 1. Overview of the proposed indoor air quality monitoring system.

The goal is to offer a simple, scalable, and user-friendly solution for homes, schools, and offices, contributing to healthier indoor environments.

II. Methods

This project was developed using Internet of Things (IoT) technology and a set of electronic components. The goal was to collect data from the environment and show it in real-time on a web page. Below are the main steps and components used to build the system.

a. Data Flow Diagram

The system continuously reads data from the sensors every 5 seconds, processes it via the ESP32, and sends it to a web dashboard for visualization. If poor air quality is detected, the system displays a real-time alert message. Figure 2 shows the corresponding data flow.

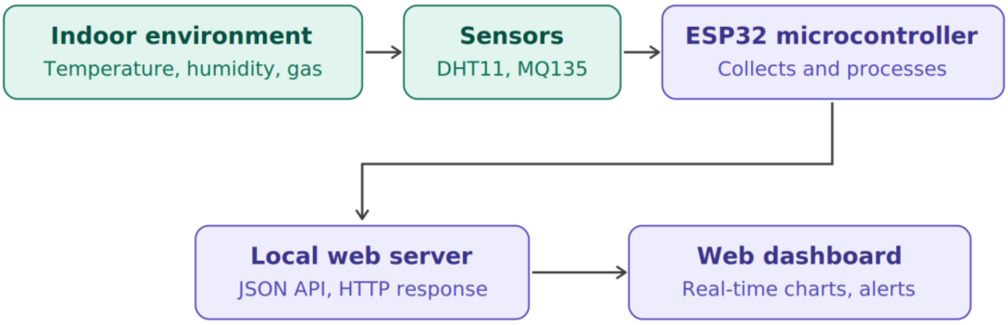

Figure 2. Data flow of the air quality monitoring system.

b. IoT Architecture

The architecture of our smart air quality monitoring system follows a classic four-layer IoT model: Perception, Network, Processing, and Application [7], [8]. Each layer has a specific role in ensuring efficient data collection, transmission, and visualization.

- Perception Layer: DHT11 (temperature & humidity), MQ135 (air quality)
- Network Layer: Wi-Fi via ESP32
- Processing Layer: ESP32 microcontroller logic and real-time sensor readings
- Application Layer: Web-based dashboard using HTML, Chart.js, and JSON API

c. Components Used

The main components used in this project are summarized in Table 1. The ESP32 was selected because it combines Wi-Fi connectivity, sufficient processing capability and a low unit cost, a combination that has been evaluated favourably against comparable microcontroller modules [12], [13], [15], [16], and that has already been applied successfully to building monitoring applications [14].

Table 1. Main hardware components used in the system.

Component	Description	Illustration
ESP32	A small microcontroller with Wi-Fi and camera. It can read data from sensors and send it to a web page. It is the main controller in the project.	
DHT11 sensor	A sensor that measures temperature and humidity. It gives digital data and is easy to use for weather projects.	
MQ135 gas sensor	A sensor used to detect air quality. It can sense gases like CO_2, smoke, and other pollutants. It gives an analog output.	

d. Circuit Design

The DHT11 sensor was connected to GPIO 4, and the MQ135 sensor was connected to GPIO 32 of the ESP32 board. The circuit was built on a breadboard to make it simple and easy to test. Power was supplied from the USB port of the computer. The resulting wiring is shown in Figure 3.

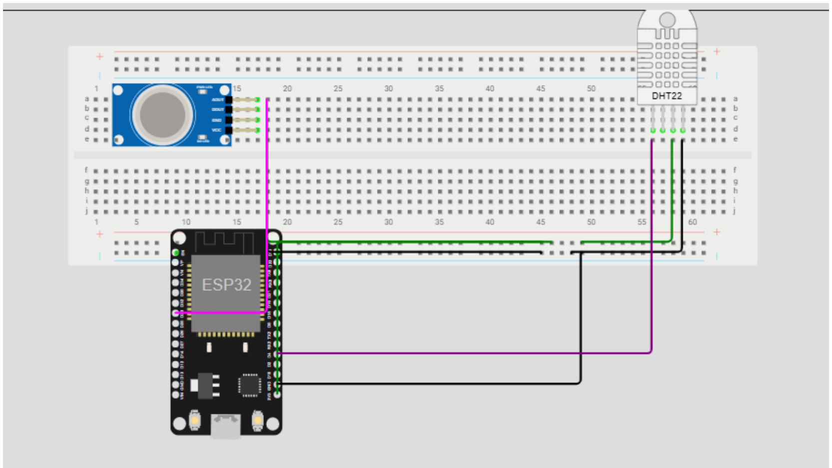

Figure 3. Circuit wiring of the ESP32 with the DHT11 and MQ135 sensors.

III. Results and discussion

a. System operation and web interface

After assembling the circuit and uploading the code to the ESP32-CAM, the system was powered on and successfully connected to the local Wi-Fi network. A web interface, hosted directly by the ESP32, was used to display real-time environmental data. Figure 4 shows the assembled prototype and Figure 5 the resulting dashboard.

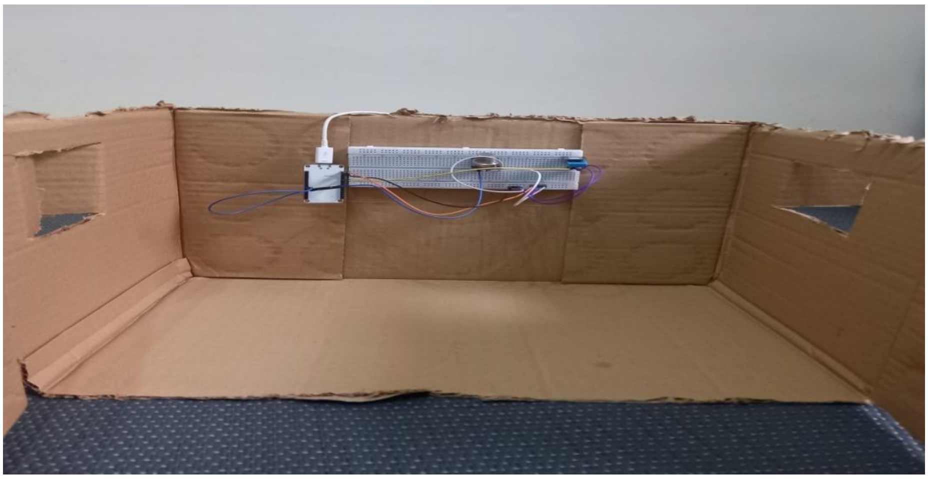

Figure 4. Assembled prototype during testing.

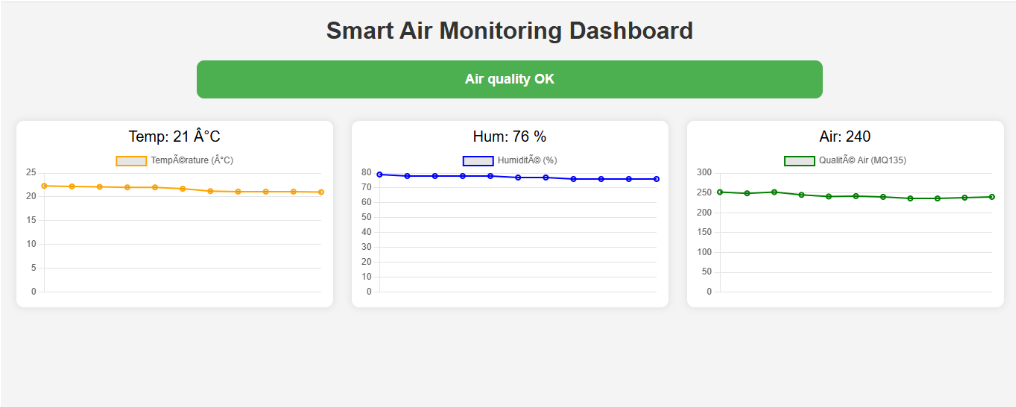

Figure 5. Web dashboard showing real-time temperature, humidity and air quality readings.

b. Discussion

The system effectively monitors and reports air quality in real time. The web interface makes the information accessible and actionable. However, limitations include sensor calibration and dependence on Wi-Fi and USB power. Calibration and long-term stability are recognized as the principal constraints of low-cost gas sensing devices in general [3], [5], so the readings reported here should be interpreted as indicative rather than metrological. Enhancements such as better sensors, solar power, or mobile alerts could increase system usability and accuracy.

Extending the system beyond a single room, for example to a whole building or a network of classrooms, would also raise the data security and privacy questions common to IoT deployments [11].

IV. Conclusion

This project presents an effective and low-cost air quality monitoring solution using the ESP32. The system provides real-time environmental feedback through a user-friendly web interface. It is suitable for various indoor environments like homes, schools, and offices. Future improvements can focus on sensor calibration, power independence, and broader IoT integrations.

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