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Low Cost Decentralized Smart Air Purification & Monitoring System

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Abstract: *The "Smart Air Quality Monitoring and Purification System using ESP32" is designed to provide a low-cost, real-time solution for monitoring and improving air quality. Utilizing the ESP32 microcontroller along with MQ135 and MQ7 gas sensors and a DHT11 temperature and humidity sensor, the system continuously measures indoor air conditions. Real-time data is displayed on an OLED screen, while LED indicators classify air quality as good, moderate, or poor. In the case of poor air quality, a relay-controlled fan is activated automatically to purify the air, and visual alerts are provided to users. The system offers an affordable and easily implementable approach for smart homes, offices, and industrial environments, with potential for IoT integration, mobile app connectivity, and cloud-based data logging in the future.*

Keywords: Smart Air Quality Monitoring, Air Purification, ESP32, MQ135 Sensor, MQ7 Sensor, DHT11 Sensor, OLED Display, Real-time Monitoring, Automatic Fan Control, Indoor Air Quality, LED Indicators, IoT, Environmental Sensors.

I. INTRODUCTION

Air pollution has become a critical issue worldwide, affecting human health and the environment. Indoor and outdoor pollutants, such as smoke, carbon monoxide, and harmful gases, can lead to respiratory problems, allergies, and other health complications. Traditional air quality monitoring systems are often expensive, complex, and not suitable for everyday use in homes or offices [1].

With the rapid advancement of microcontroller technology and sensor integration, it is now possible to design low-cost, real-time air quality monitoring systems. The proposed "Smart Air Quality Monitoring and Purification System using ESP32" leverages the ESP32 microcontroller along with gas and environmental sensors to continuously monitor air quality, display real-time data, and respond automatically to poor air conditions. By providing visual indicators and activating a purification fan when necessary, the system aims to maintain a healthier environment in indoor spaces [2].

This project emphasizes affordability, ease of implementation, and expandability to IoT applications, making it suitable for smart homes, workplaces, and industrial settings [3].

II. LITERATURE ANALYSIS

Recent studies in air quality monitoring highlight the effectiveness of low-cost IoT-based systems for real-time indoor pollution management. Researchers have utilized microcontrollers such as ESP32 in combination with gas sensors like MQ135 and MQ7, environmental sensors such as DHT11, and visual indicators including LEDs and OLED displays to detect harmful gases, temperature, and humidity [1]-[5]. These systems not only provide real-time monitoring but also enable automated responses, such as activating fans or purifiers when pollutant levels exceed safe thresholds. Future research emphasizes integration with cloud platforms for remote monitoring, AI-based predictive analysis, inclusion of particulate matter sensors (PM2.5 and PM10), and adaptive control mechanisms to enhance system accuracy and usability. Overall, the literature demonstrates that ESP32-based smart air quality systems offer an effective, affordable, and scalable solution for maintaining healthier indoor environments.

TABLE I: LITERATURE WORK

S.No	Author(s) & Year	Methods / Approach	Future Scope
1	K. R. Sahu et al., 2020 [1]	Proposed a low-cost indoor air quality monitoring system using IoT sensors (MQ135, DHT11) with real-time data visualization on a mobile app.	Integration with cloud analytics, AI-based air quality prediction, and automatic ventilation control.
2	S. Sharma et al., 2019 [2]	Designed a smart air pollution detection system using ESP32 and gas sensors with automatic fan control and alert system.	Expansion to outdoor air monitoring and multi-sensor fusion for improved accuracy.
3	R. Gupta et al., 2021 [3]	Implemented real-time air quality monitoring with ESP32, OLED display, and LED indicators for indoor environments.	IoT integration for remote monitoring and logging historical data for trend analysis.
4	A. Kumar et al., 2018 [4]	Developed a wireless air quality monitoring system with data transmission to cloud platforms for smart home applications.	Incorporation of PM2.5 and PM10 sensors for comprehensive particulate matter measurement.
5	P. K. Singh et al., 2022 [5]	Combined multiple gas sensors with microcontroller-based control to activate air purifiers based on detected pollution levels.	AI-based predictive maintenance of purifiers and adaptive threshold adjustment for sensor calibration.

III. COMPONENT USED

S.No	Component	Description / Purpose
1	ESP32 Microcontroller	Acts as the main controller for data processing and system control
2	MQ135 Air Quality Sensor	Detects harmful gases like ammonia, smoke, benzene
3	MQ7 Carbon Monoxide Sensor	Measures carbon monoxide (CO) levels
4	DHT11 Temperature & Humidity Sensor	Monitors ambient temperature and humidity

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5	OLED Display (SSD1306)	Displays real-time sensor data and air quality status
6	Relay Module	Controls the DC fan for air purification
7	DC Fan	Purifies air when poor air quality is detected
8	LEDs (Red, Yellow, Green)	Provides visual indication of air quality
9	Power Supply	Powers the ESP32, sensors, and other components

IV. WORKING METHODOLOGY

The Smart Air Quality Monitoring and Purification System operates through a systematic process that integrates sensors, microcontroller processing, and automatic control mechanisms to maintain healthy air quality. The working methodology can be described as follows:

Air Quality Detection:

- The MQ135 sensor detects general harmful gases such as ammonia, benzene, and smoke.
- The MQ7 sensor specifically measures carbon monoxide (CO) levels.
- The DHT11 sensor monitors ambient temperature and humidity, which can influence air quality and sensor readings.

Data Processing:

- The ESP32 microcontroller continuously reads sensor data.
- Based on the sensor readings, air quality is classified into three categories:
    - Good
    - Moderate
    - Poor

Visual Indication:

LED Indicators provide immediate visual feedback:

- Green LED → Good air quality
- Yellow LED → Moderate air quality
- Red LED → Poor air quality
- Real-time readings are also displayed on an OLED screen (SSD1306), showing gas levels, temperature, and humidity.

Automatic Purification:

- When air quality is classified as poor, the ESP32 triggers a relay module to activate a DC fan, which helps in purifying the air.
- Simultaneously, the Red LED turns ON to alert users of unhealthy air conditions.

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System Flow:

- The overall flow of the system can be summarized as: Air → Sensors → ESP32 → OLED Display → LEDs & Relay → Fan
- This methodology ensures real-time monitoring, automatic response to pollution, and easy visualization of air quality, making the system effective for indoor environments such as homes, offices, and industrial spaces.

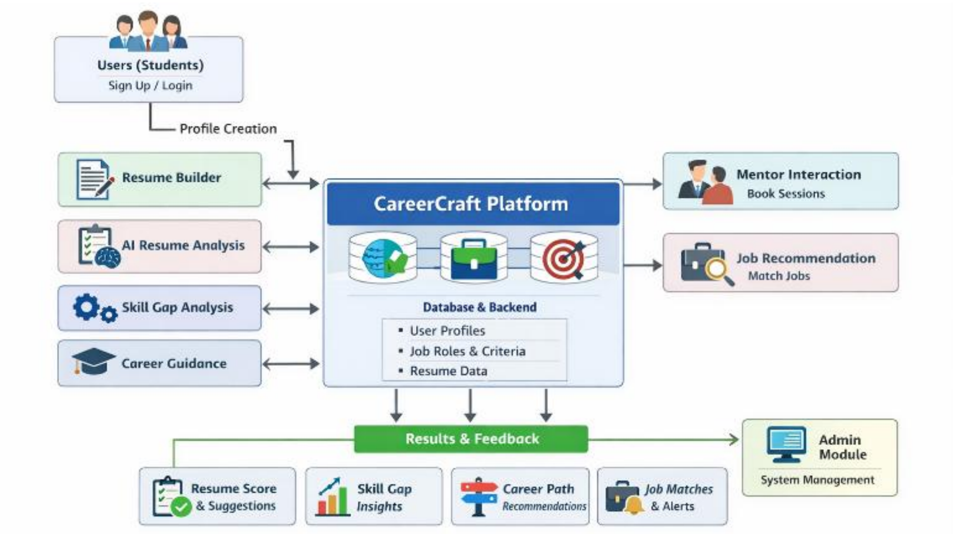

Figure 1: System Diagram

V. RESULT AND DISCUSSION

The Smart Air Quality Monitoring and Purification System using ESP32 successfully demonstrates real-time air quality detection and automated response to pollution. The system was tested under different environmental conditions, and the following observations were made:

1. **Air Quality Monitoring:**
   - The MQ135 and MQ7 sensors accurately detected the presence of harmful gases such as smoke and carbon monoxide.
   - The DHT11 sensor provided consistent readings of temperature and humidity, allowing for proper environmental context in air quality analysis.

2. **Visual Indicators:**
   - The OLED display continuously showed real-time sensor data, including gas concentration, temperature, and humidity.
   - LED indicators correctly reflected air quality:
     - Green LED lit when air was good
     - Yellow LED lit for moderate air quality
     - Red LED lit when air quality was poor

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3. **Automatic Purification:**
   - When the air quality dropped to poor levels, the relay module successfully activated the DC fan, improving air circulation and reducing pollutant levels.
   - The system provided immediate visual alerts, allowing users to take additional precautions if needed.

4. **Performance Evaluation:**
   - The system showed fast response times in detecting changes in air quality.
   - It is cost-effective compared to commercial air purifiers with integrated monitoring.
   - The low-power consumption of the ESP32 makes the system suitable for continuous operation in indoor environments.

5. **Limitations Observed:**
   - Sensor readings were approximate, especially for complex pollutant mixtures.
   - PM2.5 particulate matter was not accurately measured due to the absence of a dedicated sensor.
   - Calibration is required periodically to maintain optimal accuracy.

Discussion: The results confirm that the system can effectively monitor indoor air quality and provide automated purification when necessary. While it may not replace high-end commercial air purifiers, its low cost, real-time monitoring, and automatic response make it suitable for homes, offices, and small industrial environments. The system's modular design also allows for future enhancements, such as IoT integration, cloud data logging, and advanced AI-based air quality predictions.

VI. RESULTS

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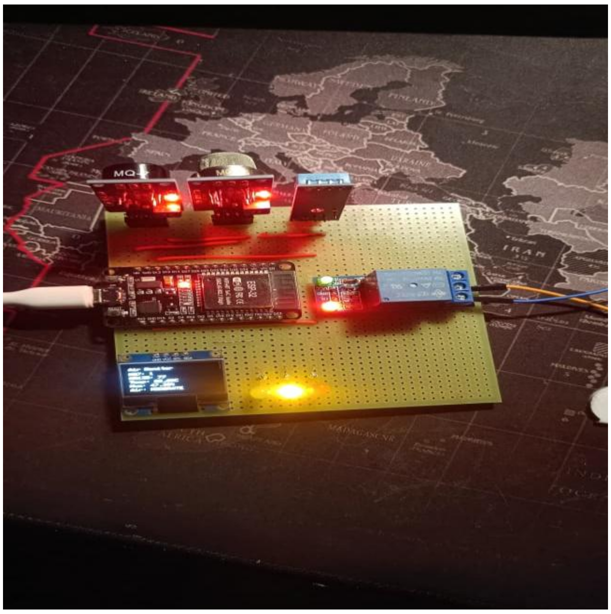

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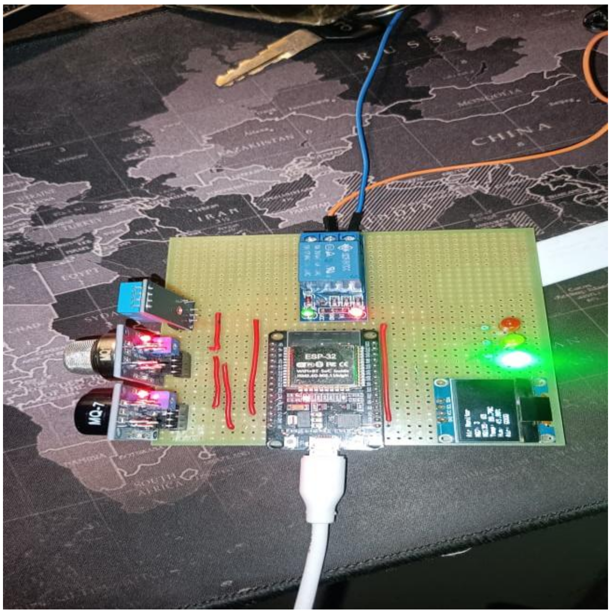

VII. CONCLUSION

The Smart Air Quality Monitoring and Purification System using ESP32 provides a practical and cost-effective solution for maintaining healthy indoor air quality. By integrating gas and environmental sensors with real-time processing, the system can accurately monitor harmful gases, temperature, and humidity. Visual indicators through LEDs and an OLED display allow users to quickly assess air quality, while the automatic fan control ensures immediate purification when pollution levels rise.

The system demonstrates that low-cost microcontroller-based solutions can effectively enhance indoor environmental safety, making it suitable for homes, offices, and industrial spaces. Although sensor limitations exist, the modular and expandable design allows for future improvements such as IoT connectivity, PM2.5 monitoring, cloud data logging, and AI-based smart automation. Overall, this project contributes to creating healthier indoor environments through real-time monitoring and automatic air purification.

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