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AI Based Ventilation KPI Using Embedded IOT Device

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Abstract: *The development of an embedded IOT device for real-time monitoring and control of artificial intelligence (AI)-driven ventilation systems. The device integrates sensors for air quality parameters (e.g., CO2, particulate matter, temperature, humidity) and transmits data wirelessly to a cloud platform.AI algorithms deployed on the cloud analyze the sensor data to optimize ventilation parameters, ensuring efficient energy usage and improved indoor air quality. Key Performance Indicators (KPIs) such as energy consumption, air exchange rate, and pollutant concentration are continuously monitored and displayed on a user dashboard. The embedded device facilitates closed-loop control, adjusting fan speeds and damper positions based on AI-derived insights. This system aims to enhance occupant comfort, reduce energy waste, and maintain optimal air quality in various environments like hospitals, offices, and residential buildings. The device's modular design allows for scalability and customization to specific ventilation system requirements. The IOT infrastructure enables remote monitoring, predictive maintenance, and data-driven decision-making for efficient AI-controlled ventilation.*

Keywords: *AI-Driven Ventilation, Indoor Air Quality Monitoring, Embedded IoT Systems, Real-Time Environmental Sensing, Cloud-Based Analytics and Closed-Loop Control Systems*

1. INTRODUCTION

The quality of indoor air significantly impacts human health, productivity, and overall well-being. Traditional ventilation systems, often operating on fixed schedules, struggle to adapt to dynamic changes in occupancy and environmental conditions, leading to energy waste and suboptimal air quality. This is a critical concern in spaces like hospitals, offices, and homes, where healthy air is essential. The integration of the Internet of Things (IOT) and artificial intelligence (AI) presents a solution to these challenges. This project focuses on developing an embedded IOT device for real time monitoring of key indoor air quality (IAQ) parameters, including carbon dioxide (CO2), particulate matter (PM2.5 and PM10), temperature, and humidity. The core of this system is the use of AI algorithms, hosted on a cloud platform, to analyze the sensor data and optimize ventilation strategies. By dynamically adjusting fan speeds and damper positions, the system aims to improve energy efficiency while maintaining ideal IAQ. To evaluate the system's performance, key performance indicators (KPIs) such as energy consumption, air exchange rates, and pollutant concentrations will be continuously monitored and displayed on a user dashboard. The embedded IOT device enables closed-loop control, allowing the system to respond quickly to changes in the environment and occupancy. This project aims to demonstrate the effectiveness of an AI-driven, IOT-enabled ventilation system in improving IAQ and reducing energy consumption. The modular design of the embedded device allows for flexibility and scalability, making it suitable for various ventilation systems. The IOT infrastructure also supports remote monitoring and predictive maintenance, contributing to a more sustainable and healthy built environment .Ultimately, this research seeks to create a robust system for intelligent ventilation, enhancing occupant comfort and resource efficiency through the combined power of IOT and AI.

2. EXISTING METHOD

Current ventilation control methods often fall short in delivering optimal indoor air quality (IAQ) and energy efficiency. Many systems rely on simple, pre-set schedules, activating ventilation at specific times regardless of actual occupancy levels or environmental conditions. This results in wasted energy during periods of low occupancy and inadequate ventilation during peak occupancy. Another common approach involves using basic sensor triggers, such as temperature or CO2 thresholds. When these thresholds are exceeded, the system responds by increasing ventilation. However, this reactive method lacks the capability to anticipate changes in IAQ, leading to delayed responses and potential discomfort for occupants. Furthermore, existing systems often lack comprehensive data collection and analysis capabilities. They may monitor only a limited number of IAQ parameters, neglecting crucial factors like particulate matter or humidity. This restricted data hampers the development of effective, data-driven ventilation strategies. Remote monitoring and control are also frequently absent, making it difficult for building managers to oversee and adjust ventilation settings—especially in large or complex buildings. Moreover, integration with other building automation systems is often limited, preventing holistic optimisation of overall building performance. Finally, the consistent use of key performance indicators (KPIs) to evaluate ventilation system effectiveness is rare. This lack of objective performance metrics makes it difficult to identify inefficiencies and improve system performance. As a result, many buildings continue to operate with outdated and inefficient ventilation systems, contributing to higher energy consumption and compromised IAQ.

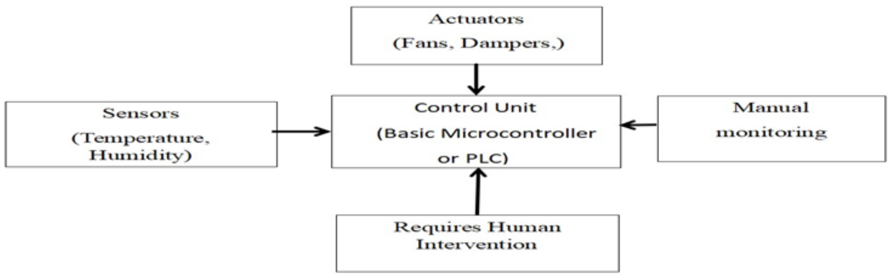

FIGURE 1. Block diagram of the Proposed Method

3. PROPOSD METHOD

Our proposed method aims to create an intelligent and efficient ventilation system using an embedded IoT device, driven by AI and monitored through key performance indicators (KPIs). The system begins with a network of low-power IoT sensors strategically placed throughout the target environment. These sensors continuously collect real-time data on critical indoor air quality (IAQ) parameters, including carbon dioxide (CO2), particulate matter (PM2.5 and PM10), temperature, and humidity. This data is then transmitted wirelessly to a cloud-based platform using a secure communication protocol.

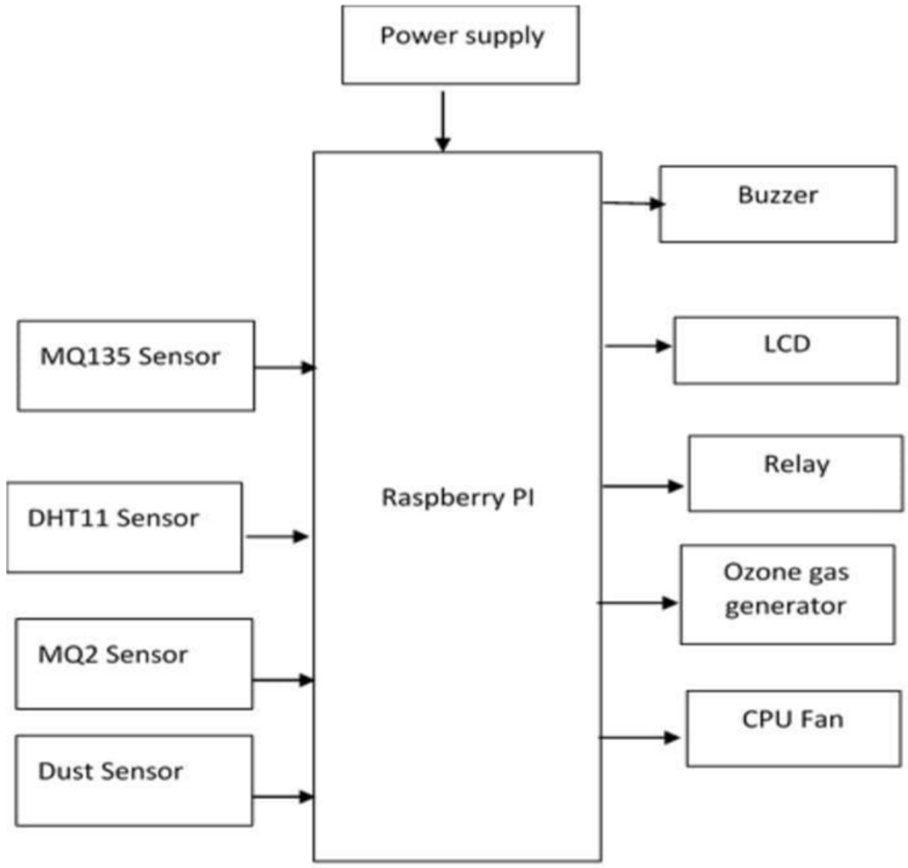

FIGURE 2. Block diagram of the Proposed Method

On the cloud platform, artificial intelligence algorithms, specifically machine learning models, analyze the incoming sensor data. These models are trained using historical data and continuously learn from real-time inputs to predict IAQ trends and optimise ventilation parameters. The system dynamically adjusts fan speeds and damper positions based on the AI's recommendations, taking into account occupancy patterns, external environmental factors, and user preferences. To ensure effective performance, we define and monitor key performance indicators (KPIs). These include: energy consumption (measured in kWh), air exchange rate (measured in air changes per hour, ACH), and pollutant concentrations (measured in ppm for CO2 and µg/m³ for particulate matter). A user-friendly dashboard provides real-time visualisation of these KPIs, enabling data-driven decisions and system monitoring. The embedded IoT device facilitates closed-loop control, allowing the system to react quickly to changes in IAQ. In certain situations, edge computing can be implemented to enable fast, localised responses to critical events, such as a sudden spike in CO2 levels, while the cloud platform handles long-term analytics and model updates. The system's modular design allows for scalability and integration with various ventilation systems, making it adaptable to diverse environments. Continuous performance evaluation and model retraining will ensure optimal system performance and ongoing improvement.

4. RESULT

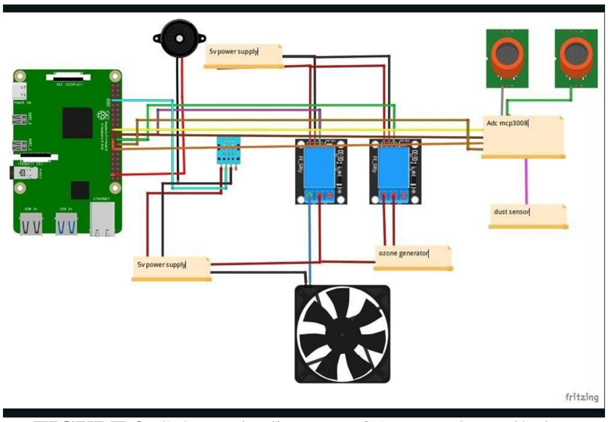

FIGURE 3. Schematic diagram of AI Based Ventilation

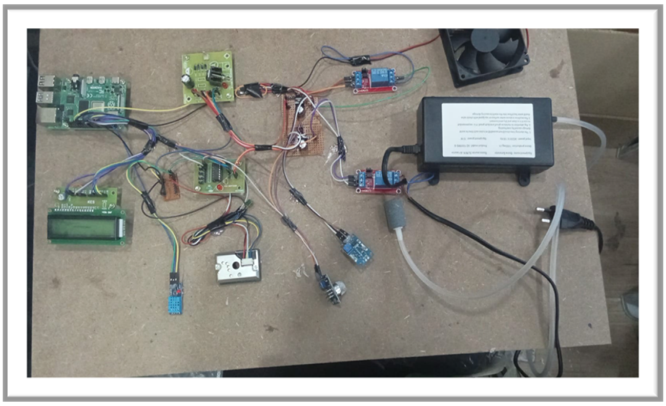

FIGURE 4. Lcd display

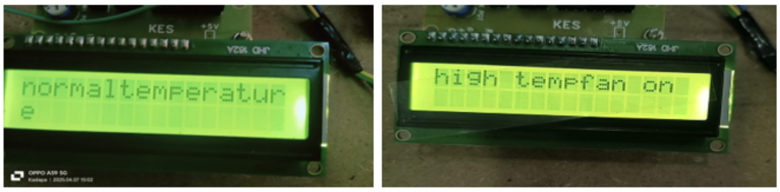

FIGURE 5. LCD display detecting Humidity

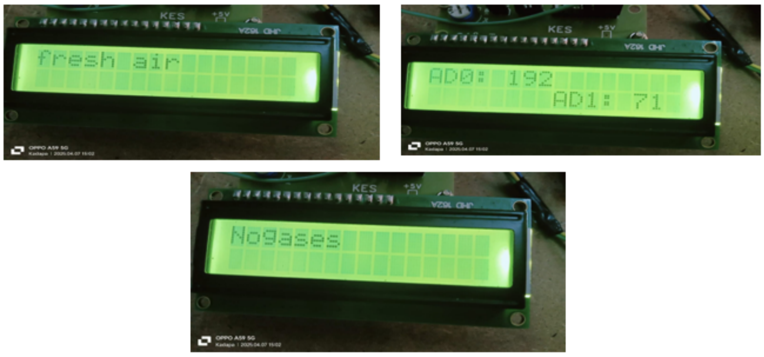

FIGURE 6. LCD displaying results

5. CONCLUSION

The AI-based KPI system for indoor air quality monitoring and ventilation improvement offers a comprehensive solution for maintaining healthy indoor environments. Using a Raspberry Pi and multiple sensors, the system provides real-time data on harmful gases, particulate matter, temperature, and humidity. Equipped with an automated ozone generator and fan for air purification, the system also uses linear regression for predictive insights on ventilation efficiency. This IoT and AI-driven approach enables data-driven actions, promoting safer, healthier, and more sustainable indoor spaces

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