Raspberry-Pi Based Smart Environmental Monitoring and Controlling System

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Abstract

This study presents the design and implementation of an Internet of Things (IoT) based framework for continuous monitoring and control of air quality parameters. The system incorporates various sensors, including the DHT11 for temperature and humidity measurement, the MQ-135 for gas detection, an LM393 comparator sensor for rainfall detection, and an additional 12V fan controlled by a relay. These sensors seamlessly interface with a Raspberry Pi, serving as the central control unit. The collected data is transmitted to the ThingSpeak cloud platform for real-time visualization and analysis. The system's architecture allows for remote monitoring and control of air quality parameters, facilitating proactive decision-making for environmental management. Experimental results demonstrate the system's effectiveness in providing accurate and timely information about temperature, humidity, rainfall, and gas concentrations in the air, making it a valuable tool for environmental monitoring and control applications.

Keywords: IoT, Raspberry-Pi, Sensors, ThingSpeak cloud.

1. Introduction

In today's rapidly changing world, the quality of the existing environment is an increasing source of concern. Air quality, in particular, plays a crucial role in our overall well-being and the sustainability of our ecosystems. Monitoring and controlling air quality

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parameters, such as temperature, humidity, rainfall, and gas concentrations in the air, has gained paramount importance in various applications, including urban planning, agriculture, and industrial health. To address these pressing concerns, this study introduces an innovative Internet of Things (IoT)-based system designed to monitor and control air quality parameters with a high level of accuracy and efficiency conventional air quality monitoring system often face limitations such as high costs, limited flexibility, and fixed data collection points. In contrast, the proposed system uses IoT, a set of sensors to enable real-time data acquisition and cloud-based visualization. The important components of the system include the DHT11 sensor for temperature and humidity, the MQ-135 sensor for gas detection, and an LM393 comparator sensor for rain sensing. These sensors are seamlessly integrated with a Raspberry Pi, a versatile single-board computer serving as the central control unit. The collected data is transmitted to the ThingSpeak cloud platform, allowing users to access air quality information from anywhere in the world. This cloud-based approach not only enhances accessibility but also facilitates data analysis and autonomous decision-making. Furthermore, it provides a foundation for the control and automation of systems reliant on air quality parameters.

This study outlines the engineering, design considerations, and implementation details of our IoT-based environmental monitoring and control system. Additionally, it presents the results of extensive trials conducted to validate the system's accuracy and effectiveness in monitoring and controlling temperature, humidity, rainfall, and gas concentrations in the air By providing a cost-effective and scalable solution that addresses the fundamental issue of air quality, our system holds significant promise for a multitude of applications.

2. Literature Survey

Meghana, et al. [1] explores the development of an air quality monitoring system. The literature survey extensively covers existing approaches and technologies for air quality monitoring, emphasizing the importance of real-time monitoring systems in urban environments. Various methodologies such as IoT-based systems, sensor networks, and machine learning algorithms have been reviewed to understand their applicability and effectiveness in monitoring air quality parameters. The study employs a machine learning algorithm, possibly a supervised learning technique such as regression or classification, to analyse collected data and predict air quality levels. The conclusion drawn from the survey suggests that the integration of IoT devices with machine learning algorithms offers a promising approach for accurate and efficient air quality monitoring, which is crucial for mitigating the adverse effects of air pollution on human health and the environment.

Nidhi, et al. [3] presents a literature survey focused on environmental monitoring systems leveraging Internet of Things (IoT) technology. The survey extensively covers existing methodologies and technologies utilized in environmental monitoring, emphasizing the role of IoT in enabling real-time data collection and analysis. Various approaches such as wireless sensor networks, cloud-based platforms, and IoT-based frameworks have been reviewed to understand their applicability and effectiveness in monitoring environmental parameters. The study employs the ThingSpeak platform for data collection and analysis, possibly integrating it with IoT devices for real-time monitoring. While the specific algorithm used is not explicitly mentioned, it can be inferred that the data analysis process may involve techniques such as data visualization, statistical analysis, or machine learning for pattern recognition and anomaly detection. The conclusion drawn from the survey suggests that IoT-enabled environmental monitoring systems, particularly those integrated with cloud-based platforms like ThingSpeak, offer a scalable and efficient solution for gathering and analyzing environmental data. Such systems hold significant promise for various applications, including pollution control, climate monitoring, and disaster management.

Hirak Dipak,et al.[4] presents a comprehensive literature survey on the Raspberry Pi platform and its diverse applications. The survey extensively covers various domains where Raspberry Pi has been applied, including but not limited to education, robotics, home automation, and IoT. The study explores the technical specifications, capabilities, and features of Raspberry Pi boards, along with discussing its advantages and limitations compared to other platforms. While the specific algorithm used is not explicitly mentioned, it can be inferred that the review encompasses a wide range of software and algorithms utilized in conjunction with Raspberry Pi for different applications, such as image processing, machine learning, and data analysis. The conclusion drawn from the survey emphasizes the versatility and affordability of Raspberry Pi as a computing platform, making it a popular choice for hobbyists, educators, and professionals alike. The study underscores the potential for further innovation and development in leveraging Raspberry Pi for various practical applications across different industries and fields.

Sajjan, et al. [5] conducts a literature survey focused on industrial pollution monitoring systems enhanced by Internet of Things (IoT) technology, particularly those utilizing Raspberry Pi and the Blynk server. The survey extensively explores existing methodologies and technologies in industrial pollution monitoring, emphasizing the integration of IoT for real-time data collection and control. Various approaches such as sensor networks, data analytics, and remote monitoring systems are reviewed to assess their suitability and effectiveness in industrial settings. While the specific algorithm used is not explicitly mentioned, it can be inferred that the paper likely employs data processing and control algorithms to analyze pollution data and trigger control actions. The conclusion drawn from the survey underscores the potential of IoT-enabled systems, especially when integrated with Raspberry Pi and Blynk server, for efficient industrial pollution monitoring and control. The paper suggests that such systems offer a robust and scalable solution for addressing environmental concerns in industrial environments, facilitating proactive pollution management and compliance with regulatory standards.

3. Proposed Methodology

The block diagram of the Environmental Monitoring System through Raspberry-Pi is as shown in the Fig. 1.

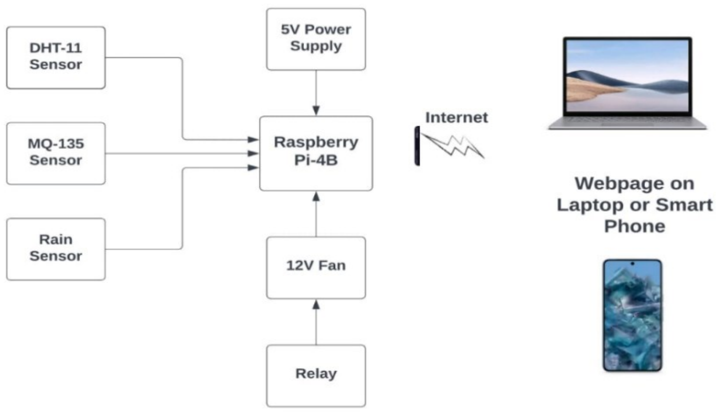


Figure 1. A Schematic Diagram of the System

The proposed methodology using Raspberry Pi for smart environmental monitoring and controlling system encompasses a series of essential steps. Initially, we undertake the hardware setup, carefully integrating components like the Raspberry Pi, DHT11 sensor for temperature and humidity monitoring, MQ-135 sensor for gas detection, and a rain sensor. Following this, we define threshold limits for gas ppm values and rain detection, crucial for guiding subsequent actions. Continuous data collection from the sensors enables real-time monitoring, allowing us to compare sensor readings against predefined thresholds. The local display of collected data offers immediate insights into environmental conditions. Moreover, integration with the ThingSpeak IoT platform facilitates remote monitoring and control, empowering users to visualize trends, set alerts, and adjust control parameters as required. Through rigorous testing and validation, we ensure the reliability and adherence of the system's performance to established standards. Once deployed, ongoing maintenance ensures sustained functionality. This methodology promises comprehensive environmental monitoring and control, with potential applications spanning indoor air quality management to weather monitoring.

4. Design and Implementation.

The Figure.2 illustrates the circuit diagram of the proposed environmental monitoring. The details of the hardware components used in the proposed method are listed in the Table.1 below.

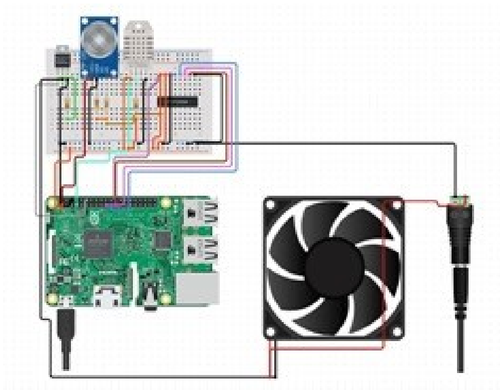
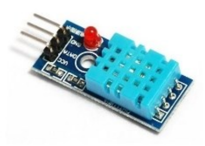
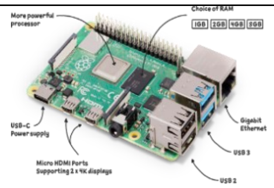


Figure 2. Circuit Diagram

4.1 Hardware and Software Specifications

Table 1. Hardware Components, Specification and Uses

Sl. No	Name	Specifications	Uses	Image
1	DHT-11 Sensor	1.Operating Voltage: It typically operates on 3.5 to 5.5 volts DC. 2.Temperature Measurement Range: 0°C to 50°C (32°F to 122°F) with an accuracy of ±2°C. 3.Humidity Measurement Range: 20% to 90% RH (Relative Humidity) with an accuracy of ±5% RH.	The DHT11 sensor is commonly used in weather stations, home automation systems, and industrial monitoring for measuring temperature and humidity with low-cost, basic accuracy. Its simple interface and affordability make it popular for DIY projects and prototyping applications.	
2	MQ-135 Sensor	1.Operating Voltage: It operates on a DC voltage typically between 5V to 15V. 2.Power Consumption: The power consumption is relatively low, usually below 150 mW. 2.Operating Temperature Range: The operating temperature range is approximately -10°C to 50°C.	The MQ-135 sensor is commonly used in air quality monitoring systems, indoor air purifiers, and gas leakage detection devices due to its ability to detect a variety of harmful gases such as ammonia, nitrogen oxides, and smoke with a wide detection range and sensitivity.	

3	Rain Sensor	1.Accuracy: The accuracy of the rain sensor is crucial for reliable measurements. It's usually specified as a percentage or in terms of the deviation from the actual rainfall. 2.Operating Temperature Range: Rain sensors should be able to operate within a certain temperature range without malfunctioning. This range is typically provided in degrees Celsius or Fahrenheit. 3.Power Requirements: Rain sensors may require power to operate, so the voltage and current requirements should be specified.	Rain sensors are used in weather stations to measure rainfall intensity and in automated irrigation systems to prevent unnecessary watering during rainy conditions.	
4	Raspberry Pi-4B	1.Processor: Broadcom BCM2711, Quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz. 2.Memory (RAM): Options of 2GB, 4GB, or 8GB LPDDR4-3200 SDRAM. 3.Power supply: 5V DC via USB-C connector (minimum 3A required).	The Raspberry Pi 4 Model B microprocessor is utilized for a wide range of applications including DIY projects, robotics, home automation, media centers, and educational purposes.	
5	Relay	1.Coil Voltage: The voltage required to energize the relay coil and activate the contacts. This is typically specified in volts (V) and can be AC or DC.	Relays are used to control electrical circuits by allowing a low-power signal to switch a higher-power load on or off.	

		2.Coil Power: The power consumed by the relay coil when energized. It's often specified in watts (W).		
6	Thonny Python IDE	1.Language Support: Thonny primarily supports Python programming language, offering features tailored for Python development. 2.Cross-Platform Compatibility: Thonny is compatible with multiple operating systems, including Windows, macOS, and Linux, providing a consistent development environment across different platforms.	"Thony is a software tool for Python programming, offering an integrated development environment (IDE) with features such as code editing, debugging, and execution."	
7	ThingSpeak	1.IoT Platform: ThingSpeak is an open-source IoT platform that enables users to collect, analyse, and visualize data from various sensors and devices. 2.Real-time Data Processing: It offers real-time data processing capabilities, allowing users to monitor and analyse data as it is generated.	"ThingSpeak is an IoT analytics platform that allows you to collect, visualize, and analyse data from your sensors or devices in real-time."	

The flowchart in figure.3 illustrates the work flow of the module developed

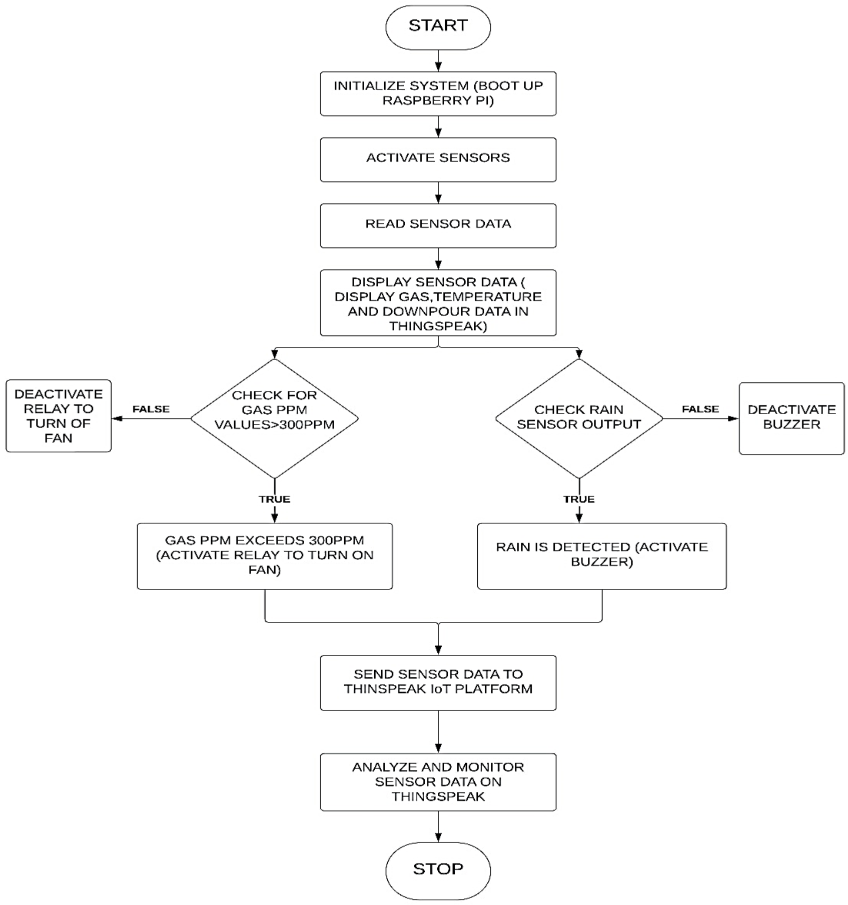


Figure 3. Flowchart of the System

4.2 Hardware Implementation

To begin, Raspberry Pi with the necessary operating system and libraries, ensuring peripherals like the keyboard, mouse, and display are connected for initial configuration. Then, wire the DHT11 sensor, MQ135 sensor, and rain sensor to the appropriate GPIO pins of the Raspberry Pi, referring to datasheets and pinout diagrams for proper connections. Utilize the output from the MQ135 sensor to control a fan through a relay module based on air quality readings, activating the fan when air quality falls below a certain threshold to enhance ventilation. Develop a Python script to acquire data from the sensors using appropriate libraries and GPIO access, such as the Adafruit library for temperature and humidity from the DHT11 sensor, and monitoring the rain sensor by checking GPIO pin states. Process the acquired sensor data to calculate relevant weather parameters like temperature, humidity, air quality index, and rainfall intensity, employing formulas or lookup tables for conversion. Finally, trigger alerts using the buzzer or speaker connected to the Raspberry Pi based on weather conditions, such as activating the buzzer for poor air quality to provide an audible warning.

4.3 Software Implementation

To start the research, Raspberry Pi OS (previously Raspbian) was chosen as the operating system, and it was updated for reliability and security. Python was chosen because of its powerful libraries and ability to communicate with sensors. The required sensor libraries, including Adafruit Python MCP3008 for ADC and manufacturer-specific libraries, were installed. The air quality sensor, specifically the MQ135, was connected by GPIO or ADC, with sensor libraries used for data conversion. Python scripts were created for data processing, including calibration and scaling. Data storage options included local storage NoSQL database management system MongoDB. Additionally, ThingSpeak, a cloud platform, was integrated to facilitate real-time data visualization and analysis.

Stable internet connectivity and remote access (SSH, VNC) were provided, along with error handling systems.

5. Result

The air quality monitoring system provides real-time data on air quality parameters such as particulate matter, temperature, humidity, and rainfall. A Raspberry Pi-based smart environmental monitoring and control system has many advantages for creating a more sustainable and efficient environment. By combining multiple sensors, actuators, and control logic, the system can efficiently monitor environmental conditions, analyze data, and operate devices. Here are some key aspects to outline the advantages and capabilities of such a system.

The system offers real-time monitoring of environmental parameters such as temperature, humidity, and air quality, providing useful information on current weather conditions. With the integration of control logic, the system may manage devices autonomously in response to external circumstances. This allows for automatic modifications to optimize energy use, keep temperatures comfortable, and respond to changing environmental circumstances. The Raspberry Pi's networking capabilities enable remote access and control of the machine. Users can monitor and manage environmental parameters from any location using a web interface, mobile app, or command-line interface. The sensor data gathered can be used to discover patterns, trends, and abnormalities. This data analysis provides insights for making better decisions, saving energy, and improving environmental management.

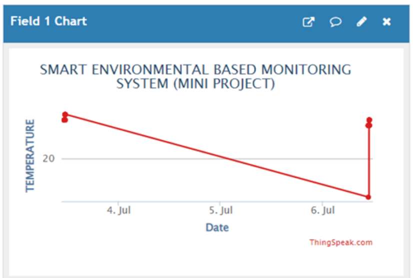


Figure 4. Temperature Data

This graph in Figure.4 depicts the temperature variations over a specific period, likely recorded by a temperature sensor. The y-axis represents the temperature in degrees Celsius (°C), while the x-axis denotes the time frame of data collection. The graph illustrates fluctuations in temperature, which could be influenced by factors such as weather patterns, time of day, or environmental conditions. Understanding temperature trends is crucial for various applications, including climate monitoring, building automation, and agricultural processes.

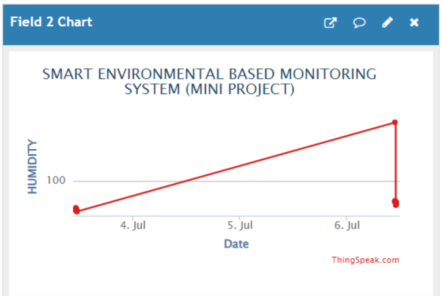


Figure 5. Humidity Data

This graph in Figure.5 showcases the humidity levels recorded over time, typically monitored using a humidity sensor. The y-axis indicates the relative humidity percentage (%), while the x-axis signifies the time intervals during data collection. Humidity levels play a significant role in indoor comfort, industrial processes, and agricultural cultivation. Analysing humidity fluctuations helps in managing environmental conditions effectively, preventing issues such as mold growth, corrosion, or discomfort due to excessive moisture or dryness.

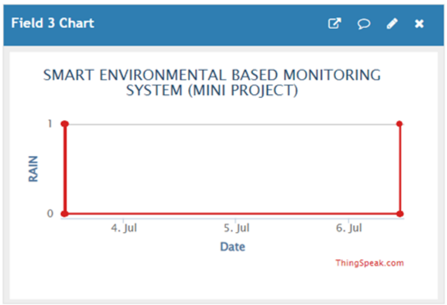


Figure 6. Rain Sensor Data

This graph in Figure.6 displays data captured by a rain sensor, depicting precipitation occurrences over time. The y-axis typically represents binary values indicating the presence or absence of rain, while the x-axis indicates the time intervals. Rain sensors are essential for weather monitoring, irrigation systems, and flood detection. Analysing rain patterns helps in water resource management, agricultural planning, and urban infrastructure design.

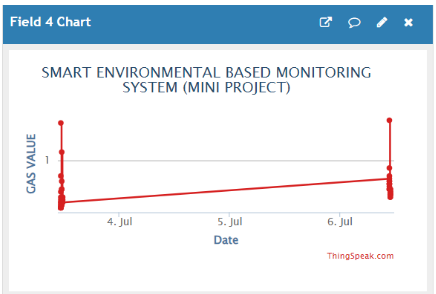


Figure 7. Gas Value

This graph in Figure.7 illustrates the gas concentration levels measured by the MQ135 gas sensor, often represented in parts per million (ppm). The y-axis represents the gas concentration in ppm, while the x-axis denotes the time duration of data collection. MQ135 sensors are commonly used to detect various gases, including carbon dioxide, carbon monoxide, ammonia, and volatile organic compounds. Monitoring gas levels is crucial for ensuring indoor air quality, detecting gas leaks, and maintaining safety in industrial environments.

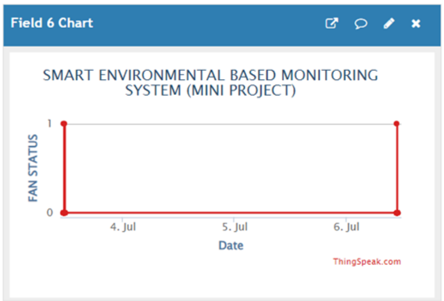


Figure 8. Fan Status

This graph in Figure.8 illustrates the operational status of a fan system, indicating whether the fan is ON or OFF during specific time intervals. The y-axis typically represents binary values, where '1' may indicate the fan is ON, and '0' signifies the fan is OFF. The x-axis denotes the time duration. Monitoring the fan status is crucial for maintaining ventilation, controlling indoor air quality, and managing energy consumption. The Figure 9 and 10 depicts the prototype of the proposed framework for environment monitoring.

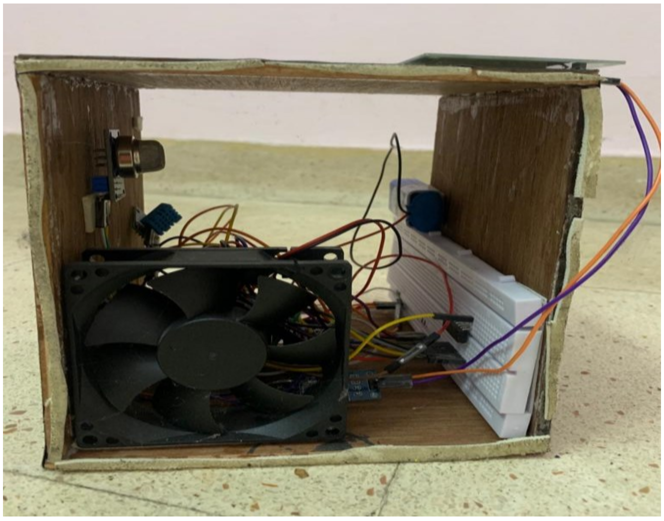


Figure 9. Prototype

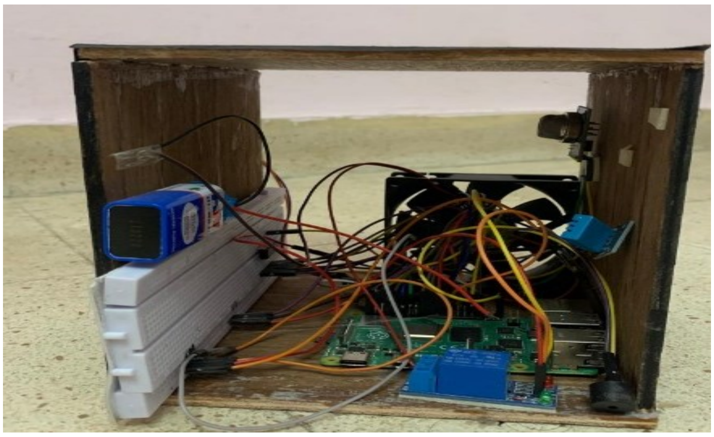


Figure 10. Prototype

6. Future Scope

The future scope of this environmental monitoring and control system involves incorporating advanced sensors, AI, and machine learning for decision-making and predictive capabilities. Additionally, edge computing will be employed to process data closer to the source. Furthermore, the implementation of voice-activated control through Alexa routines is also likely to be added.

7. Conclusion

The development of a Raspberry Pi-based smart environmental monitoring and control system encompasses a comprehensive approach to managing environmental parameters effectively. Through meticulous hardware selection, setup, and software development, the system facilitates real-time monitoring of crucial factors like temperature, humidity, and air quality. By integrating intelligent control logic, the system autonomously adjusts devices to optimize energy usage and maintain comfortable conditions. The inclusion of remote access capabilities enhances accessibility, enabling users to monitor and control the system from anywhere. Moreover, the system's data analysis capabilities provide valuable insights for informed decision-making and efficient environmental management. Overall, the integration of sensors, actuators, and sophisticated control mechanisms yields a sustainable and efficient solution for creating a conducive environment.

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