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Air Quality Monitoring System: A Comprehensive Overview of an advanced Air Quality monitoring system using Arduino

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ABSTRACT

This study focuses on enhancing sensor technology and shrinking the size of sensors utilized in monitoring the quality of atmospheric air. With the escalating concerns over air pollution due to factors such as increased vehicular traffic, industrialization, and urbanization, there is a pressing need for effective monitoring solutions. The innovation at the core of this study involves implementing IoT technology via a Wi-Fi module interfaced with a gas sensor, facilitated by an Arduino UNO microcontroller. Specifically, the study proposes the utilization of the MQ 135 Air Quality Monitoring Gas Sensor for measuring air pollutant concentrations. The setup primarily comprises an Arduino UNO board integrated with an ESP8266 module for IoT connectivity. This IoT which depends on Air Quality Monitoring System is designed to monitor the air quality via a web server using the ESP8266 Wi-Fi device. Additionally, it is equipped to trigger an alarm when air quality deteriorates to a certain level, indicating the presence of harmful gases like CO_2. The system displays air quality depends in Parts Per Million categorizing it into Fresh Air, Poor Air, or Danger Air, allowing users to monitor the air condition status effectively.

Keywords: Air quality monitoring; IoT connectivity; Wi-Fi device; ESP8266; MQ 135; Arduino UNO microcontroller.

1. Introduction

The Air Excellence Guide (AEG) serves as a widely accepted measure of air quality. The Air Quality Indicator (AQI) is determined based on pollutants such as CO_2 and NO_2, which have adverse effects on both the environment and human health. The AQI provides a comprehensive representation of specific airborne substances at any given time.

We propose the development of a monitoring system for both air quality and pollution, enabling real-time assessment through the Internet of Things (IoT). This system utilizes air sensors like the Gas Sensor MQ135 to detect harmful gases/compounds in the air and continuously transmit this data. Additionally, it continually measures air levels and reports them. These sensors interface with an Arduino Uno (Microcontroller) for data processing and transmission via an application. This capability allows authorities to monitor air pollution across various areas and take appropriate actions.

Moreover, authorities can focus on monitoring air pollution in sensitive locations such as schools and hospitals. Typically, concentrations are measured in parts per billion (PPB) or parts per million (PPM), representing mass units of a material per one billion or one million units of total mass, respectively. Assessing the needs of a new system involves analyzing product and resource requirements crucial for its success. Product requirements specify input and output needs to achieve desired productivity, while resource requirements outline necessary hardware for functionality.

In this study, we aim to develop an IoT-based Air Quality Monitoring System that tracks air quality via a web server using an ESP8266 Wi-Fi device, triggering an alarm when air quality deteriorates to a certain level, indicating the presence of harmful gases like CO_2.

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2. Block Diagram

The primary components of this study are outlined as follows: The gas sensor and Wi-Fi device are connected to the Arduino board, and an LCD is also linked to the Arduino board to display information. The Air Quality Monitoring Gas Sensor MQ135 nodes are utilized to gauge the concentration of air pollutants. These gas sensors are integrated with a compact embedded platform alongside other components. The MQ135 Gas Sensor is employed to gather measurements of gas concentration, with the collected data transmitted to the Arduino UNO for IoT-based data acquisition. Air quality is continuously monitored using the gas sensor. The air quality declines below a certain threshold value, indicating the presence of toxic gases like CO_2, smoke, benzene, and NH3, an alarm is triggered. The sensor like MQ135 sensor is selected for its effectiveness in observing air quality level, as it can accurately detect a wide range of toxic gases and measure their concentrations. The air quality level can be observed or we can watch it remotely from any location using a computer or Wi-Fi-enabled devices.

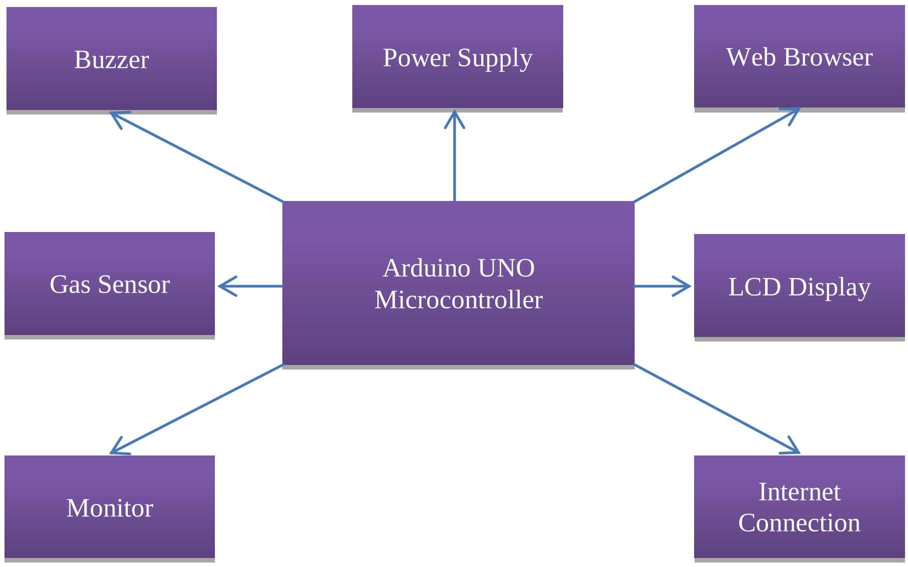

Figure 1. Block diagram representation

3. Block Diagram Description

The ESP8266 is linked to the Arduino, operating at 3.3V. To power it, connect VCC and CH_EN to the Arduino's 3.3V pin. The RX pin of the ESP8266 communicates directly with the Arduino at 3.3V. Alternatively, a voltage divider can be used to adapt 5V to 3.3V. This involves setting up three resistors in series, as demonstrated in the circuit. Connect the ESP8266's TX pin to Arduino pin 8 and its RX pin to Arduino pin 9. This module grants Wi-Fi or internet access.

Next, connect the MQ135 sensor to the Arduino. Link the sensor's VCC and ground pins to Arduino's 5V and ground, respectively, and connect its analog pin to Arduino's A0. Attach a buzzer to Arduino pin 7, triggering when the designated condition is met.

Finally, connect the LCD to the Arduino as follows: VCC to Arduino's 5V, GND to Arduino's ground, RS to Arduino pin 12, RW to a jumper pin (or GND), and E to Arduino pin 11. Four data pins facilitate communication with the Arduino: D4 to pin 5, D5 to pin 4, D6 to pin 3, and D7 to pin 2.

4. Hardware Description

4.1. Arduino UNO

Our model centers around Arduino as its foundation. Arduino is a platform of open-source devices renowned for its user-friendly hardware and software. It consists of a physical programmable circuit board (microcontroller) and an Integrated Development Environment (IDE) installed on our computer, enabling us to write and upload code to the board. Arduino has gained widespread popularity among beginners in electronics for its versatility. It can interface with various components such as buttons, LEDs, motors, speakers, GPS units, cameras, the internet, smartphones, and televisions.

The Arduino Uno serves as the ideal starting point for electronics enthusiasts, offering engaging hands-on designs. It serves as an introduction to the distinctive Arduino experience, facilitating learning about sensors, measurements, and rapid prototyping.

4.2. Gas Sensor MQ135

The implementation of the MQ-135 gas sensor enables the detection of smoke and various harmful gases. It possesses the capability to identify several harmful gases, including NH3, NO, alcohol, benzene, smoke, and CO_2. The MQ-135 sensor exhibits high sensitivity to Ammonia, Sulphide, and Benzene vapors, along with being responsive to smoke and other dangerous gases. This module utilizes the MQ-135 air quality and hazardous gas detection chip, along with additional circuit components such as the LM393 analog comparator chip, facilitating easy integration into the model designed to detect hazardous gases. Operating on a 5V power supply, the module provides both digital logic output (1 or 0) and analog level output (0-4V).

The digital logic output remains LOW (0) in the absence of gas detection but switches to HIGH (1) when the concentration of hazardous gas in the environment surpasses the set threshold adjusted via a potentiometer on the module. Meanwhile, the analog level output delivers a voltage output ranging from 0 to 4V, corresponding to the concentration of hazardous gas in the environment, with 0V representing the lowest concentration and 4V indicating the highest concentration.

4.3. 16x2 LCD Display

The LCD (Liquid Crystal Display) screen or display serves as an electronic screen module with a wide array of applications. Among these, the 16x2 LCD display stands out as a fundamental module extensively utilized in various electronic devices and circuits. Unlike seven-segment displays and other multi-segment LED display, these modules are most likely preferred due to several reasons: they are cost-effective, easily programmable, and capable of displaying special characters, custom animations, and more without limitations. The term "16x2" indicates its capacity to display 16 characters per line across 2 lines, with each character represented in a 5x7 pixel matrix. This type of LCD comprises two registers: the Command register, responsible for storing instructions given to the LCD display such as initial it, clearing the display and controlling display functions, and the Data register, which stores the ASCII values of characters to be displayed on the LCD display. If you'd like to delve deeper into the internal structure of an LCD, we can click here to learn more.

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4.4. ESP8266 Wi-Fi Device

The ESP8266, an affordable Wi-Fi microchip equipped with a complete TCP/IP stack and microcontroller capabilities, gained attention among Western developers in August 2014 through the introduction of the ESP-01 module produced by third-party manufacturer Ai-Thinker. This compact module enables microcontrollers to establish connections to Wi-Fi networks and perform basic TCP/IP operations using commands resembling those of the Hayes command set. Initially, there was a scarcity of English-language resources detailing the chip and its command set. Nonetheless, it is remarkably low cost and minimal external component requirement hinted at the potential for significant cost reduction with mass production, enticing numerous enthusiasts to delve into the module, the chip itself, and its software, often translating Chinese documentation in the process. Additionally, the ESP8285 variant of the ESP8266 also contains 1MiB of built-in flash memory, enabling the creation of single-chip devices capable of Wi-Fi connectivity.

4.5. Buzzer

This device typically emits a constant beep when powered, though with appropriate coding, you can produce various tones by connecting it to a microcontroller. The buzzer essentially functions as a miniature speaker that can be directly linked to an Arduino. By employing the 'tone' function in Arduino; we can generate sounds through the buzzer. You'll need to specify the buzzer's pin, the desired frequency, and the duration for which you want the tone to persist.

5. Results

The MQ135 sensor is capable of detecting CO_2 and several other gases, making it an ideal choice for an "Air Quality Monitoring System." It provides voltage-based output, which requires conversion into parts per million (PPM). To accomplish this conversion, the sensor provides a reference value of 0.1. The acceptable air quality level is set at 0.5 PPM, which should not be exceeded. Exceeding this threshold can lead to symptoms such as headaches, drowsiness, and a feeling of stale air. If the PPM level surpasses this threshold, it can even result in an increased heart beat rate and various health issues. When the PPM value is below 0.5, both the LCD display and webpage will indicate "Fresh Air."

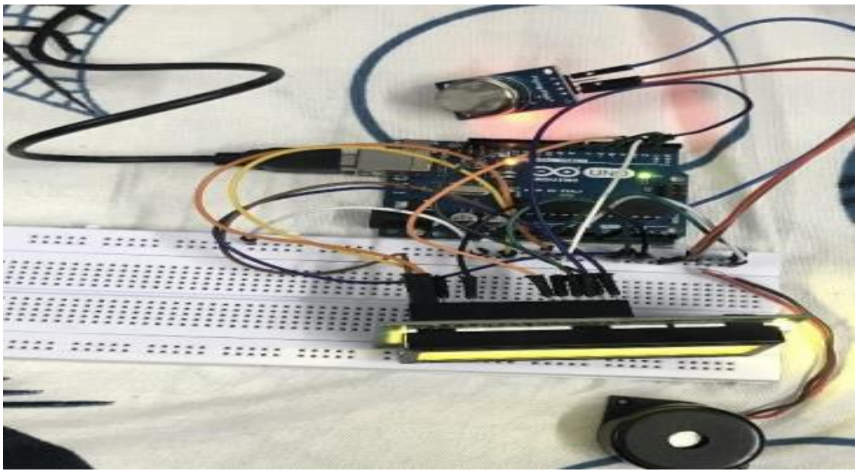

Figure 2. Circuit diagram of proposed solution

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Once the value exceeds 0.5 PPM, the LCD display and webpage will switch to "Poor Air, Open Windows." If the PPM level reaches 1 or higher, the buzzer will continuously sound, and the LCD display and webpage will show "Danger! Please Move to Fresh Air."

6. Result Analysis

Table 1 show that the air quality health and its risk through a 0.1-1.0 base scale. It is divided into three parts like as Fresh Air, Poor Air & Danger Air. It detects the air pollution level and indicates the risk through this scale. When the updated data compared to the base data then it shows the result accordingly to this scale. The compared data is between 0.1-0.5 it shows that health risk is low and indicate open window, when it increases up to 0.6-1.0 it shows that the pollution in the air is considered dangerous for human being and we take some steps quickly.

Table 1. Result analysis tabulation

Air Quality Indicator Range (PPM)	**Result**	**Health Impacts**
0 - 0.5	Fresh air	Minimal Impact.
0.6 - 0.9	Poor air	May cause minor breathing discomfort to sensitive people.
Above 1	Danger air	May cause breathing discomfort to people with lung diseases such as asthma, and discomfort to people with heart diseases, children and other adults.

7. Conclusion

The implementation of an Air Quality monitoring system, employing an Arduino microcontroller and IoT Technology, has proven successful in enhancing air quality. By integrating IoT technology, the monitoring process for various environmental factors, such as air quality, is significantly improved. The utilization of the MQ135 sensor enables the detection of different types of hazardous gases, with Arduino serving as the central component controlling the entire operation. The Arduino module facilitates connectivity with the LCD display, while the serial monitor provides visual output.

Future advancements could involve miniaturizing the device for compactness, enabling easier deployment or modifications. For instance, there's potential for detecting vehicle emissions to assess pollution levels. Additionally, expanding the range of frequencies could accommodate high-range monitoring needs. Further research could focus on educating individuals about environmental welfare, guiding them towards beneficial actions. Moreover, integrating the system into a mobile app could extend its accessibility, allowing users to receive updates via GSM mobile phones, thereby enhancing its utility.

Declarations

Source of Funding

The study has not received any funds from any organization.

Competing Interests Statement

The authors have declared no competing interests.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contributions

All the authors took part in literature review, research, and manuscript writing equally.

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