Smart Air Quality Monitoing System

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*Abstract* —This study presents the development and evaluation of a smart air quality monitoring system designed to collect and analyze data on air quality parameters, including harmful gases, dust concentration, and ambient temperature. The system, consisting of Arduino UNO, MQ135 gas sensor, GP2Y1010AU0F dust sensor, and DHT11 temperature sensor, integrates IoT (Internet of Things) and cloud technologies for remote data transmission and analysis. Results indicate the system's effectiveness in detecting air pollutants and monitoring environmental conditions in real-time. The discussion highlights the system's performance, implications for public health and environmental management, and future research directions. This study contributes to advancing air quality monitoring capabilities and promoting sustainable urban development initiatives.

Keyword: IOT, Air Monitoring, Smart System

# Introduction

The advancement in technology has made everything convenient these days, one of the commendable technologies among many is IoT. IoT (Internet of Things) is a network of different types of devices interconnected in a system with the purpose of collecting, processing, and sharing the data. Mainly the system consists of different sensors, internet-connected devices such as smartphones and so on. The use of IoT can vary from small range such as smart h

ouse security system, appliances etc. to large industrial use [(Qin *et al*., 2020)](#link7). Contrary to this progressive development of technology the quality of the air has been of a rising concern, for both the indoor and outdoor environment. In case of, poor indoor air quality is caused because of a continuous buildup of air pollutants indoor, which causes some very common health problems such as eye or nose irritation and other airborne diseases [(Sung and Hsiao, 2021)](#link10). Every year, diseases brought on by incomplete combustion of solid fuels and cooking kerosene result in the early death of 3.2 million individuals monitoring [(World Health Organization: WHO, 2023)](#link12). So, to ensure that the quality of air is up-par for a healthy life there are smart IoT based air quality monitoring systems which are responsible for detecting harmful particles and gases in the air. This report briefly touches on the system and purpose behind the development of indoor air quality monitoring system.

1. LITERATURE REVIEW
2. *IOT*

In 1999, Ashton initially used the phrase "Internet of Things" to emphasize the potential of linking Radio Frequency Identification Tags to the Internet for Supply Chain Management [(Sharma, Shamkuwar, and Singh, 2019, pp. 27-51)](#link9). Long Term Evolution (LTE), Bluetooth, Near-Field Communication (NFC), Wireless Sensor Networks (WSN), Radio-frequency identification (RFID), and such several other smart communication technologies enable the association of objects over the Internet resulting into IoT to be known as “association of things over the internet” [(Khanna and Kaur, 2020)](#link3). Concisely a systematic network of embedded devices which are interconnected and are responsible for either the transmission of data or the execution of any performance based on the data provided, is the Internet of Things or IoT.

1. *INNOVATION*

Deploying IoT based systems even for small or simple tasks has proven to have made things more convenient and beneficial, which is why, as of now, there’s multiple devices aiding with various tasks in different fields and sectors. Likewise, keeping our health in concern and to be aware of the quality of air that we intake on a regular basis the idea of air quality monitoring system came in light. Data on air quality are mostly large scaled based and so are the systems developed to monitor it which shows that there might be negligence towards the indoor air quality.

The system is a small-ranged monitoring system consisting of Arduino UNO, a gas sensor (MQ135), dust sensor (GP2Y1010AU0F), and temperature sensor (DHT11) which are then integrated with ESP8266 with the purpose of transmitting the data to the cloud server [(Sung and Hsiao, 2021)](#link10). As depending on the ventilation settings and indoor or outdoor production, the concentrations of certain variables or indoor pollutants (CO2, VOCs, PM, and NO2) precisely correspond with those measured outdoors so by making this very system portable and wearable it will make monitoring the air quality around the wearer possible too [(Salamone, Masullo and Sibilio, 2021)](#link8).

1. *SECURITY*

The security implementations in any system provides a dependable and strong solution by adhering to current policies, best practices, and standards [(Toma *et al.*, 2019).](#link11) The Internet of Things (IoT) solution for air quality monitoring systems uses several IoT devices and connected sensors to monitor pollution levels, particularly those found in urban settlements. So, for those with wide range monitoring, to prevent indirect assaults on the data collecting process, the Message Queuing Telemetry Transport (MQTT) communication protocol is implemented for the gathered data. Additionally, making the system resistant to hostile threats that carry a significant risk, such as cyberterrorism [(Toma *et al.*, 2019)](#link11). The collected data are stored and communicated through a widely known cloud platform ThingSpeak which encrypts data transmissions and complies with standard regulations regarding data security and privacy [(Marques *et al.*, 2020)](#link8).

1. *FUTURE AND CURRENT TRENDS*

There’s clearly a wide range of uses of the system to collect real time data of air quality in any city or place, which is shown in Air Quality Index (AQI). The fundamental purpose of the AQI, a nonlinear indicator that quantitatively describes air quality, is to explain why more severe air pollution is bad for human health, especially the respiratory system, and why it results in higher categories [(Sung and Hsiao, 2021)](#link10). Also, the Internet of Things (IoT) is playing a significant role in the evolution of air quality monitoring systems. IoT-enabled sensors can collect data from various locations in real-time, allowing for comprehensive monitoring and analysis of air quality trends over time.

The system can transfer and show the changes in the IAQ (Indoor Air Quality) by connecting it to Wi-Fi modules and through a web-application [(Marques *et al.*, 2020)](#link5). The use of data analytics and artificial intelligence (AI) algorithms is also enhancing the capabilities of air quality monitoring systems as these technologies enable the analysis of large datasets to identify pollution sources, predict air quality trends, and assess the effectiveness of mitigation measures. In future, with the extreme miniaturization of sensors and electronic components and the conveniency of the wearable devices will make this system reachable to every person in form of a much cheaper and more portable device.

1. METHODOLOGY

This system is constructed with the idea of monitoring the concentration level of particularly harmful gases or other matters in the air. While the Air Quality Index (AQI) has been continuously determining the quality of air mostly outdoor, a similar system that detects some harmful level of gas’s concentration and the high level of matters in air such as dust, alcohol etc. can be simply constructed and use for indoor monitoring. There are variety of air pollutants prevalent in indoor surroundings, among which NO2 (Nitrogen Dioxide), SO2 (Sulfur Dioxide) and CO (Carbon Monoxide) poses the highest level of dangers [(Kwon *et al.*, 2023)](#link4).

Some of the most common indoor air pollutants and the level of concentration in the air that is considered harmful is presented in the table.

|  |  |
| --- | --- |
| **Pollutants** | **Dangerous levels** |
| Carbon Monoxide (CO) | Greater than 101 ppm (parts per million) |
| Fine Dust | PM 2.5: 10 µg/m3 average per year |
| Nitrogen Dioxide (NO2) | Greater than 20ppm |
| Carbon Dioxide (CO2) | 10 µg/m3 maximum daily |

Table 1. Indoor air pollutants and their dangerous levels

1. *SENSORS AND COMPONENTS*

The system’s hardware consists of Arduino UNO, dust sensor, gas sensor and temperature sensor. The sensors are all connected to the Arduino UNO which is used as the main microcontroller unit board for the system. Particularly, for dust sensor GP2Y1010AU0F sensor is used while, MQ135 is used for the detection of quality of air and DHT11 is used to measure the room temperature. The sensors and Arduino board are briefly explained.

1. Arduino UNO

Arduino is a Microcontroller Unit (MCU) board that can be programmed easily with Arduino IDE (An Integrated Development Environment available for programming of Arduino). Arduino microcontrollers are equipped with inputs and outputs that may be used to obtain data and deliver outputs in response to that data [(Ismailov and Jo’rayev, 2022).](#link13) For this system, all the sensors are connected to it through a breadboard and all the data collected by those sensors are analyzed and processed by Arduino which gives the processed data as outputs.

1. Dust sensor

The dust sensor is frequently used in air purifier systems and operates on the idea of laser scattering. It is particularly good at detecting extremely small particles, such as cigarette smoke. The dust sensor that is recommended to use for this system is GP2Y1010AU0F. It operates on a DC supply voltage range of 4.5V to 5.5V [(*Optical Dust Sensor - GP2Y1010AU0F*)](#link6). It measures the dust concentration in the air, the more the dust concentration is in the air the unhealthier and more polluted the environment is, as it is connected to Arduino, the output for its data reading is shown as an alert.

1. Gas sensor

A gas sensor is a device that detects the presence of gasses in the air and measures the concentration levels of them. This sensor is often offered as a module with comparators, which may be adjusted to a certain concentration threshold value and when this threshold value is exceeded by a gas’s concentration then its’s digital pin goes high [(*Introduction to gas sensors: construction types and working*)](#link2). For the real construction of the system, for the gas sensor, MQ135 is the most common gas sensor used because of its wide range of pollutants measurement ability. MQ135 sensor can detect nitrogen dioxide, alcohol particles, benzene, Carbon dioxide and so on, these are some major indoor air pollutants affecting the air quality but instead of individual readings, it will help in assessment of the overall quality of air in certain distanced periphery.

1. Temperature sensor

Room temperature itself is not inherently bad for air quality. However, certain temperature extremes or conditions can exacerbate indoor air quality issues. For example, high humid temperature lets indoor allergens thrive more which can cause some respiratory problems as well as allergic reactions. That is why the system includes a temperature sensor that will help monitor the temperature and help focus on adverse effects of extreme temperature conditions. For this system DHT-11, a common temperature and humidity sensor is used for measurement of the room temperature and humidity level, it checks the condition and processes whether the temperature is cool or high which is passed to Arduino from where, an alert message as an output is shown in LCD display.

These are some basic, foundational but the main components of this system. With data regarding, air, dust and temperature is collected by these sensors, and transmitted to Arduino board is responsible for processing the provided data and determine how the output should be, this is how the basic system is set up to be and formed of these components.

1. *WORKING MECHANISM*

The flowchart demonstrates the basic structure of how this system works. Once it is initialized all the sensors should be on so that the data reading can be a continuous process. The sensors collect their respective measurements and transmit that data to Arduino UNO, the system’s main MCU board, where the data are further processed, and output is determined.

A diagram of a computer flowchart

Description automatically generated

Fig.1. Flowchart of system’s working mechanism

1. *LOGIC CIRCUITS*

Logic circuits are fundamental building blocks in computer systems. These circuits are formed by chaining together logic gates, where the output of one gate becomes the input for another gate. Logic gates are electronic components that process binary signals (0s and 1s). Some of the types of logic gates are: AND, OR, XOR etc. To build these circuits, first a truth table is needed from which we can make Boolean expressions, that will make the logic circuits easy to make.

The functional values of logical expressions for each of their functional arguments, or on any combination of values taken by their logical variables, are shown in a truth table, which is a mathematical table used in logic. An organized depiction of every conceivable pairing of truth values for the input variables and matching output values of a Boolean function is called a truth table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Power Supply**  **A** | **Gas Sensor**  **B** | **Dust Sensor**  **C** | **Temperature Sensor**  **D** | **OUTPUT**  **Q** |
| **1** | **1** | **0** | **0** | **1** |
| **1** | **1** | **1** | **0** | **1** |
| **1** | **1** | **1** | **1** | **1** |
| **1** | **0** | **1** | **1** | **1** |
| **1** | **0** | **0** | **1** | **1** |
| **1** | **0** | **0** | **0** | **1** |
| **1** | **1** | **0** | **1** | **1** |
| **1** | **0** | **1** | **0** | **1** |
| **0** | **1** | **1** | **1** | **0** |
| **0** | **0** | **1** | **1** | **0** |
| **0** | **0** | **0** | **1** | **0** |
| **0** | **0** | **0** | **0** | **0** |
| **0** | **1** | **0** | **0** | **0** |
| **0** | **1** | **1** | **0** | **0** |
| **0** | **0** | **1** | **0** | **0** |
| **0** | **1** | **1** | **0** | **0** |

Table.2. Truth table of inputs and possible outputs

The inputs A, B, C and D in truth table represent, main control system, Gas sensor, Dust sensor and temperature sensor respectively. It shows the various outputs given by the system as per the conditions of inputs. This truth table creates this Boolean expression.

= Q

This can be simplified to just AB+AC+AD by solving it through various Boolean rules and law. This simplified algebra is used to create the system’s logic circuits in logic.ly. The gates required are AND and OR gate. In this AB, AC and AD case, the A.B (.) represents AND gate and the (+) sign represents OR gate which means, all sensors are connected to the main power supply through AND gate and later every circuit with power supply connects with OR gate for outputs.

Below is the circuit of the whole system, made based on the (AB+AC+AD) Boolean expression. The switches are used as inputs while the light bulb is used to show the output. For the light bulb to light up means the given condition is True, and the conditions for the output to come True or On are explained more.

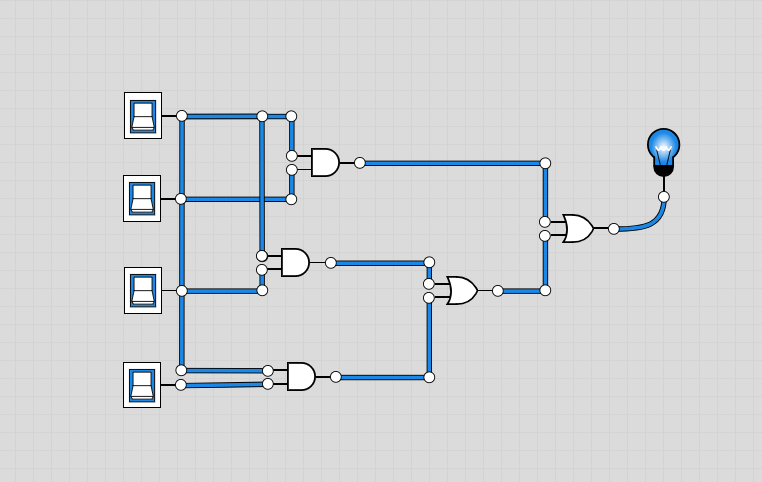


Fig.2. Logic circuit of the system

In the above figure, the switches represent input A, B, C and D respectively, while the bulb represents the output in the system. As the Boolean algebra required the first connection is of input A and B the condition is that only when both the inputs are True then only output will be True too, which is same case with other cases of AC and AD. Finally, all the AND connections are connected through OR gates to the output, which states that if any of the three connections gives True input, then the output will also be True, or if none gives True input, the output will be False, despite the input A giving True.

Now, looking at this circuit with the system, the input A represents the main power supply so for the whole system to run it must always satisfy the True condition, if its not On or doesn’t give True input even if the other inputs B, C and D which represent the sensors used in this system (gas, dust, temperature), are On or give any input the output will be False. Likewise, the condition AB set that the output will come True only when both the power supply is On and Gas sensor is collecting data too, which is same with all the other sensors. Connecting all these connections to OR gate means, even when only one or not all the sensors are giving inputs, the output should still be shown, which states that if any of the inputs satisfies the True condition then the output will be True too.

1. *TINKERCAD DESIGN AND CODE*
2. DESIGN

This system’s design was constructed in tinkercad for realistic demonstration and experimentation, where some components are used in place of similar working device, because of unavailability in tinkercad. There is use of two Arduino’s to build a serial communication between both. Likewise, a basic gas sensor is used with piezo as a buzzer when the air quality gets bad, a potentiometer instead of dust sensor, a temperature sensor to measure the temperature too which are all connected to Arduino board through a small breadboard. The LCD screen displays the readings of all the sensors, whether the air quality is bad or nice, or how much dust is in the air and also, the temperature condition.

A diagram of a circuit board

Description automatically generated

Fig.3. Tinkercad design of the system

1. CODING

After the sensors and Arduino were connected as required, for the system to demonstrate it’s functionality, Arduino is required to be programmed. All the outputs are processed data from the inputs given to the sensors. The overall code can be break downed in following parts:

1. Libraries and LCD initialization

#include <LiquidCrystal.h>

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

The code includes the LiquidCrystal library for interfacing with the LCD display. The lcd object is initialized with the pins connected to the LCD display.

1. Variables declaration

int pin8 = 8;

int analogPin = A0;

int sensorValue = A0;

int tempReading=A1;

int potPin = A2;

const int buttonPin = 6;

const int ledPin = 7;

Variables are declared for various pins used in the system, including analog pins for sensor readings, digital pins for output control, and pins for buttons and LEDs.

1. Setup function

void setup()

{

pinMode(analogPin,INPUT);

pinMode(pin8, OUTPUT);

pinMode(buttonPin, INPUT);

pinMode(ledPin, OUTPUT);

lcd.begin(16,2);

lcd.print("How is the air? ");

delay(40);

Serial.begin(9600);

lcd.display();

}

In the setup function, pins are configured as either inputs or outputs, LCD display is initialized, and a serial communication has been established to debug anything from the code.

1. Loop function

In the loop function, the three sensors are given a certain threshold for certain outputs that will be displayed in LCD. The analog pin is read to obtain sensor values for air quality assessment, temperature reading and Dust concentration assessment.

void loop()

{

sensorValue = analogRead(analogPin);

if (sensorValue<=500)

{

Serial.print("Nice Air");

lcd.setCursor(0,1);

lcd.print("Nice Air");

delay(30);

lcd.clear();

}

else if( sensorValue>=500 && sensorValue<=650 )

{

Serial.print("Polluted Air");

lcd.setCursor(0,1);

lcd.print("Polluted Air");

delay(30);

lcd.clear();

}

Depending on the sensor value, air quality is categorized as "Nice Air," "Polluted Air," or "Very Bad Air." Other codes are written in if, else statement just like this one for gas sensor.

// Measure temperature

float temperatureC = tempReading;

lcd.print("Temperature: ");

delay(30);

Serial.print("Temperature: ");

Serial.print(temperatureC);

Serial.println(" °C");

if (temperatureC > 40) {

lcd.setCursor(0,1);

lcd.print("High temperature");

delay(20);

lcd.clear();

}

else if (temperatureC < 10) {

lcd.setCursor(0,1);

lcd.print("Extreme cold temp");

delay(20);

lcd.clear();

}

**Temperature sensor**

As for Temperature sensor and Dust sensor’s measurements it still lack proper calibration and interpretation.

sensorValue = analogRead(potPin);

lcd.setCursor(0, 0);

lcd.print("Dust Conc:");

lcd.setCursor(0, 1);

lcd.print(sensorValue);

Serial.print("Dust concentration: ");

Serial.println(sensorValue);

delay(30);

lcd.clear();

}

**Dust sensor**

Overall, the code provides a basic framework for air quality monitoring, but it requires refinement and additional programming to accurately measure and assess temperature and dust concentration levels.

1. RESULTS

This Smart Air Quality Monitoring System is suitable for small scale measurement of air quality, which is why the focus in this article is mostly on indoor environment. The smart air quality monitoring system successfully collects data pertaining to air quality, dust concentration, and temperature using sensors integrated with an Arduino UNO board. The sensors employed in the system include the MQ135 gas sensor for detecting harmful gases, the GP2Y1010AU0F dust sensor for measuring dust concentration, and the DHT11 temperature sensor. The MQ135 gas sensor effectively detects the presence of gases known to be detrimental to human health, such as carbon monoxide, ammonia, and nitrogen oxides. The GP2Y1010AU0F dust sensor accurately measures the concentration of airborne particles, enabling the assessment of air quality in terms of particulate matter pollution. Additionally, the DHT11 temperature sensor provides temperature readings, allowing for the monitoring of ambient temperature conditions. The Arduino board processes the collected data and determines the appropriate output based on predefined thresholds and parameters.

1. DISCUSSIONS

The sensors can detect the required factor’s perfectly, but the output depends on how Arduino is programmed so, the code for Arduino board must be free of error for an effective deployment of the system. If this system is integrated with ESP8266, a Wi-Fi module remote accessing of data and real time monitoring of the environment becomes possible. With real-time data and timely measurements, different measures can be taken to improve the quality of air or prevent any possible harmful consequences of air pollutants.

1. CONCLUSIONS

In conclusion, the small-range air quality monitoring system, comprising Arduino UNO, MQ135 gas sensor, GP2Y1010AU0F dust sensor, and DHT11 temperature sensor, proved to be effective in collecting and processing data related to air quality parameters. The integration of these sensors with the Arduino board facilitates real-time monitoring of harmful gases, particulate matter, and temperature levels in the environment. The system's ability to transmit data to a cloud server via ESP8266 further enhances its functionality by enabling remote access to the collected data and facilitating data analysis and visualization. This feature ensures timely response to fluctuations in air quality and provides valuable information for decision-making processes related to environmental management and public health.

Overall, the smart air quality monitoring system demonstrates promise as a valuable tool for monitoring and managing air quality in various indoor and outdoor settings. Further research and development efforts may focus on refining the system's accuracy, reliability, and scalability to address broader environmental monitoring needs and contribute to sustainable urban development initiatives.

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