IoT based Air Quality Index Monitoring using ESP32

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Abstract - *The continuous augmentation of pollution is a problem that must be addressed straightaway. Pollution impacts our health as well as causes major environmental changes like Global warming and weather variations. Air pollution is one of the biggest challenges that the world is facing today as it has got adverse effects on human health like lung cancer, respiratory and heart diseases. There is a need to constantly measure, analyze and monitor the air quality on a real-time basis so that appropriate measures can be taken whenever needed. For this, we have proposed a model that uses the concept of the Internet of Things to let the user know about the concentration of harmful gases present around him and thus letting the user know the quality of air. The parameters that are monitored here are PM2.5, Carbon monoxide (CO), Carbon dioxide (CO2), temperature, and humidity. The values of these parameters are further displayed on an IoT platform, ThingSpeak, in the form of a graph as well as a number. If the concentration of Carbon dioxide exceeds a certain threshold, the buzzer gets triggered.*

Key Words: **Air Quality Index Monitoring, Internet of Things, ESP32, ThingSpeak**

1. INTRODUCTION

Air is one of the most crucial elements in the life of human beings [1]. In today's world, air pollution is rising at an alarming rate because of which there is climate change, and this has adverse consequences on everyone. The air around us is getting polluted because of the release of poisonous gases by industries, vehicle emissions which leads to an increase in the concentration of harmful gases and particulate matter in the atmosphere [2]. The emission of various toxic gases from industries and vehicles is precarious for both the terrestrial organism, as well as marine life. Health problems like stroke, heart diseases, lung cancer, respiratory diseases, etc are arising due to poor air quality. Poor air quality poses a significant risk to children, asthmatics, pregnant women, as well as elderly people [5]. These pollutants are also responsible for the corrosion of our infrastructure and monuments. People must come to know the extent to which their activities affect air quality. WHO statistics have reported that there are millions of premature death cases every year worldwide due to air pollution [3]. From the studies, it has been found that particulate matter has a major contribution to increasing air pollution. Thus, air quality has become one of the major causes of concern around the world. Hence, it is necessary to constantly monitor the air quality index to make our surrounding environment healthy and hence, worth living.

Air quality monitoring is a concept of providing the user with a platform where he/she can check the quality of air around them. The air quality monitoring system will help us to indicate the status of the quality of the air we breathe. Internet of Things is now finding a profound use in every sector, it plays a key role in our air quality monitoring system too. This paper focuses on the design and implementation of an IoT based Air Quality Index Monitoring System that we have intended to develop using ESP 32 microcontroller. The setup is going to show the air quality in PPM, temperature, and humidity with the help of various sensors and further, it would be displayed on the IoT Platform, ThingSpeak. The dashboard of the platform is to be set to public so that everyone and anyone can keep a track of the quality of air at the location where the system would be installed [2]. In this way, we can monitor it very easily by using our computer or mobile. The motivation behind our project is to protect our environment by curbing the release of harmful gases emitted by industries, vehicles, etc. We get to know about the quality of air on a real-time basis and hence necessary precautions can be taken immediately whenever needed.

1.1 Related Work

We have considered and studied various existing systems that have been developed to solve this issue. With the system we have proposed, we have tried to reduce the overall cost by using better alternatives, giving us almost accurate readings.

Kumar S et al [4] have proposed a system in which Raspberry pi is playing the major node controlling role. The sensors that they have used in their system are used for measuring particulate matter, temperature, humidity, pressure, CO, and CO2. Since Raspberry pi does not have analog-to-digital converter (ADC) pins on board, additional ADC is required to be connected. Here, they have interfaced it with Arduino Uno that is providing an effective ADC. Since they have used Raspberry pi 2 model B, it does not have an in-built Wi-Fi adapter hence an external Wi-Fi adapter is used. Further, using the MQTT protocol, they have displayed the outputs on the IBM Watson IoT Platform. Raspberry pi 3B has an in-built Wi-Fi adapter which, if used, would comparatively lead to less circuitry. This is implemented by Gupta, Harsh et al [5] in their system.

Another approach for measuring air quality is using Arduino Uno as the main unit and this is proposed by Kennedy Okokpujie et al [1] in their paper. Since Arduino does not have an in-built Wi-Fi module, an external Wi-Fi module had to be interfaced with it. This module was NodeMCU ESP8266. NodeMCU ESP8266 is a specially targeted development board for IoT-based applications and hence it can also be used as a major node controlling in a system. This is presented by Kumar A et al [6] in their paper. NodeMCU ESP8266 has just one ADC pin onboard, hence if more are required, an additional ADC chip has to be connected.

One more approach for this is by using an ESP32 microcontroller. ESP32 has dual processing cores which makes it faster as compared to others, an in-built Wi-Fi module, and enough ADC pins. Asra Noorain F et al [7] have presented this in their paper. They have sent the sensor's values to the cloud using the Blynk Platform.

As compared to the other sensors, particulate matter sensors are quite expensive. Jayaratne R et al [8], in their paper, have mentioned six low-cost PM2.5 sensors and have assessed their suitability for various applications. This helps in making an inexpensive system.

2. PROPOSED SYSTEM DESIGN

A. Project Overview

The proposed structure is an air quality monitoring system based on the Internet of Things. The sensors that we have used are helping in sensing the presence and concentration of few harmful gases, dust particles present in the air at that very time and also to check temperature and humidity at that particular time. These sensors are connected to the controller according to their output type that is an analog or digital output. The controller won't only gather data from various sensors but via an in-built Wi-Fi module, it is also responsible to send the recorded data to an IoT platform. IoT platform will store real-time sensor data and also plot graphs, charts, and numeric values. Thus, we would be able to monitor the air quality at the location where the system would be installed on a real-time basis.

B. Block diagram

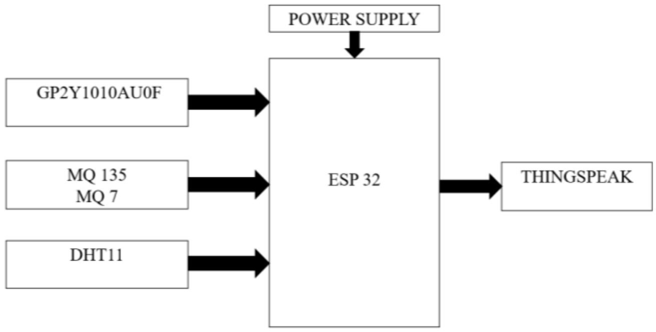

Fig -1: System Architecture

Fig-1 demonstrates the block architecture of our air quality monitoring system. ESP32 is serving as the main controlling unit in our system. Different environmental parameters like Carbon Dioxide, Carbon Monoxide, particulate matter, Temperature, and Humidity are being sensed by the sensors. The sensors are connected to ESP32. ESP32 gathers data sensed by the sensors and continuously transmits it to the cloud over the internet. The sensor we have used for detecting particulate matter is, GP2Y1010AU0F. It is a dust sensor module, which means it can detect cigarette smoke, house dust present around us. Dust might not seem harmful but in reality, it is small particles of 2.5um and 10um in diameter and these particles can easily penetrate the lungs that can cause various health problems. The measurement of the particles of diameter 2.5um and 10um is called 2.5PM and 10PM respectively. This sensor can sense up to 2.5PM. It gives an analog output. Other analog sensors used in our system are MQ7 (Gas sensor) and MQ135 (air quality sensor) and they are used for measuring Carbon Monoxide and Carbon Dioxide respectively. DHT11 is the sensor that is used for measuring temperature and humidity sensor and it gives digital output. These sensor data are continuously sent to an IoT platform for monitoring air quality on a real-time basis. The IoT platform we have used is ThingSpeak. The sensor data is displayed in the form of graphs and numeric values on ThingSpeak. A buzzer is also connected to ESP32 that would start ringing when the concentration of Carbon Dioxide in the air exceeds a particular value i.e., the limit above which it is harmful to our health. Buzzer gives digital output.

3. HARDWARE DESCRIPTION

3.1 Microcontroller:

The microcontroller we have used in this project is ESP32. ESP32 microcontroller has a powerful chip with a dual processing core. This makes it faster than the other controllers discussed above. It is a low-cost, low-power microcontroller and it has an in-built Wi-Fi module, on-chip Bluetooth Low Energy (BLE), good deep sleep modes. It supports 18 channels for 12-bit ADC and 2 channels for 8-bit DAC. All the incoming data from the sensors is processed by ESP32.

3.2 Sensing unit:

The sensing unit includes four sensors that are used for monitoring air quality.

3.2.1 MQ135:

MQ135 is an air quality sensor that detects a wide variety of gases like Ammonia (NH_3), Nitrogen Oxide (NO_x), benzene, alcohol, smoke, Carbon dioxide, etc. For our project, we are measuring Carbon dioxide (CO_2) with the help of this sensor. Its measuring range is from 10-1000 PPM. This sensor gives output in the form of voltage levels and hence it needs to be converted to PPM. This can be done by writing appropriate code. Since it gives analog output, it is connected to the analog pin of ESP32.

3.2.2 MQ7:

MQ7 is a Carbon dioxide sensor. It detects the concentration of Carbon monoxide in the air and gives analog output. The sensor can measure concentrations from 10 to 10,000 PPM.

3.2.3 GP2Y1010AU0F:

GP2Y1010AU0F is a dust sensor that we have used for detecting fine particles like dust, cigarette smoke and it is very effective in detecting it. Sensing is based on optical phenomenon. The reflected light of dust in the air is detected by the sensor. It is easily able to differentiate smoke from house dust and this is done by the pulse pattern of output voltage. It is a low-power sensor. It is responsive to really low values. It responds in less than one second. It gives an analog output.

3.2.4 DHT11:

DHT11 is an extremely low power, low cost, ultra-small size digital temperature, and humidity sensor. It gives digital output. It can measure temperature from 0-50° C and humidity from 20-90% with an accuracy of ±1°C and ±1% respectively.

4. SOFTWARE DESCRIPTION

4.1 Arduino Integrated Development Environment:

Arduino IDE is a publicly accessible software where one can easily write codes and upload them to the board. It makes code compilation very easy. Being a cross-platform application, codes can be written in C and C++ language for Windows, macOS, and Linux.

4.2 ThingSpeak:

ThingSpeak is an open-source IoT platform where one can combine, picture, and examine live streams of data in the cloud. Graphs, charts, numeric values of sensor data can be plotted on ThingSpeak. The sensor data is stored and resolved over HTTP which works based on a request and response system.

5. METHODOLOGY

Our IoT-based air quality monitoring system is highly accurate, easy to use, and quite affordable. GP2Y1010AU0F is a PM sensor connected to pin 36 of ESP32. MQ135 and MQ7 are connected to analog pin 32 and 34 of ESP32 respectively. DHT11 is connected to digital pin 2 of ESP32. The buzzer is connected to digital pin 18 of ESP32. GP2Y1010AU0F has a hollow part at its center. So, whenever the fine particles are in the hollow detecting area, only then they can be sensed, and accordingly, appropriate values can be obtained. The output was calculated using the Dust density characteristics curve and is measured in mg/m^3. Before starting to work with MQ135 and MQ7, they need to be preheated and then calibrated. Preheating means they need to be given a 5V power supply for 24 hours at least since they work on the heating principle. Since they give output in voltage levels, with the help of their respective sensitivity characteristics curve they need to be converted to PPM. We have used MQ135 for measuring CO_2 concentration. CO_2 levels in the air are 250- 400 PPM: Normal. From 400 to 1000 PPM: Typical with good air exchange. More than 1000 PPM: Poor air. As we also know, the normal range of CO_2 in our environment should be around 390-450 PPM. As soon as CO_2 concentration goes above 1000 PPM, the buzzer would start ringing. We have used MQ7 for measuring CO concentration. CO levels in the air and its potential health problems are 0-9 ppm: normal CO levels in the air, no risk. 10-29 ppm: chronic problems over long-term exposure. 100+ ppm CO: severe symptoms, intense headaches, brain damage, coma, and/or death, especially at levels 300-400+ ppm. The live data of the air at the location where the system would be installed can be seen on the dashboard of ThingSpeak from anywhere in the world and to achieve this, the device should be connected to the internet.

6. EXPERIMENTAL SETUP

In fig-2, the complete setup for the system consisting of sensors, ESP32, buzzer has been shown.

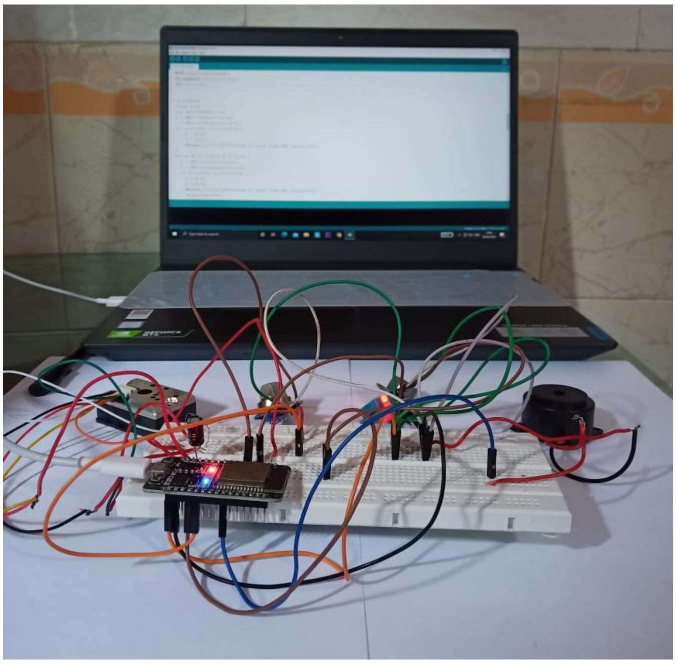

Fig -2: Experimental Setup

In fig-3, connection of sensors and buzzer to ESP32 has been shown.

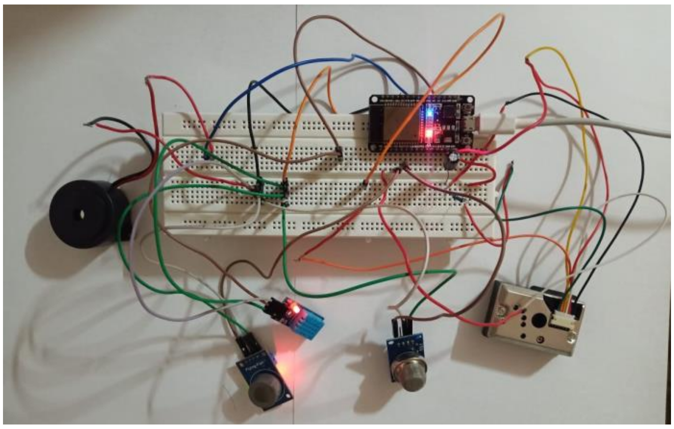

Fig -3: Connections

7. RESULTS

The obtained values of air quality were measured in a room of 300m^2 and displayed on ThingSpeak. The X-axis of all the graphs represents date and time, whereas the Y-axis represents different parameters.

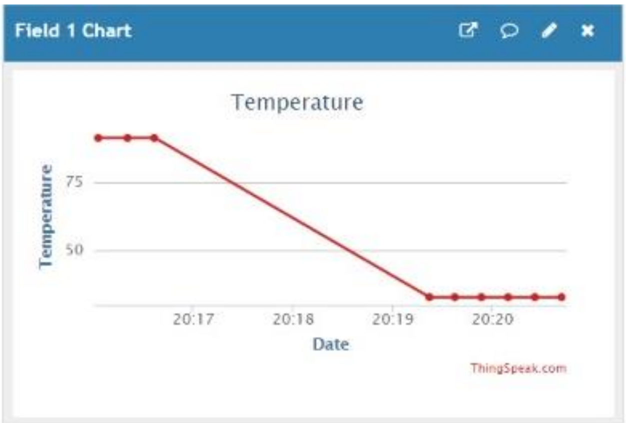

Chart -1: Temperature (°C) in atmosphere w.r.t time

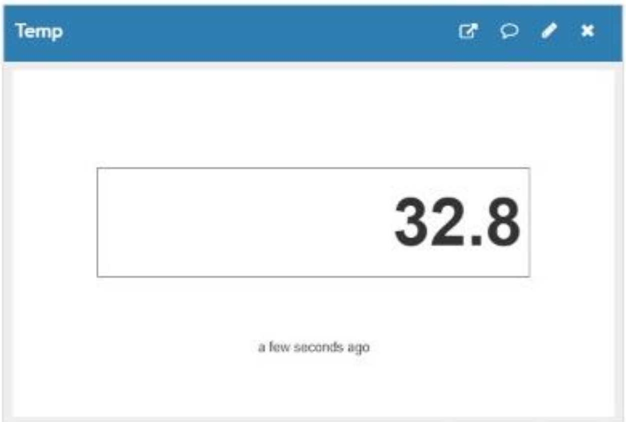

Chart -2: Temperature in °C (numeric display)

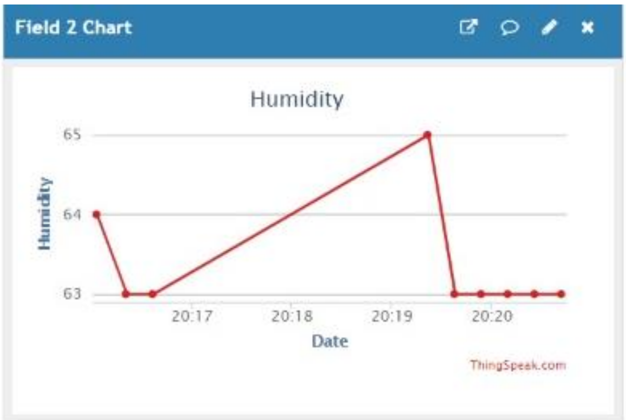

Chart -3: Humidity (%) in atmosphere w.r.t time

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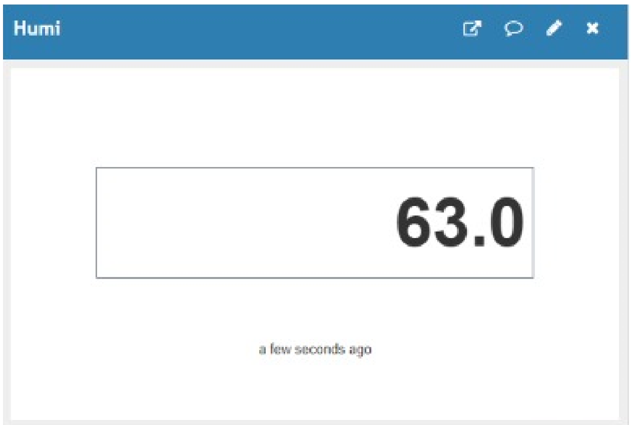

Chart -4: Humidity in % (numeric display)

Chart -5: CO2 content (PPM) in atmosphere w.r.t time

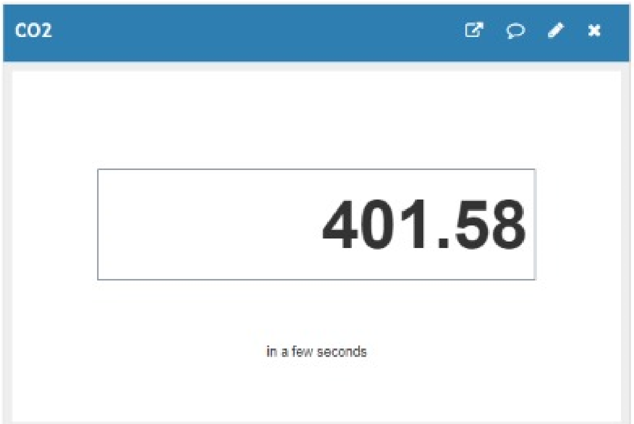

Chart -6: CO2 content in PPM (numeric display)

Chart -7: CO content (PPM) in atmosphere w.r.t time

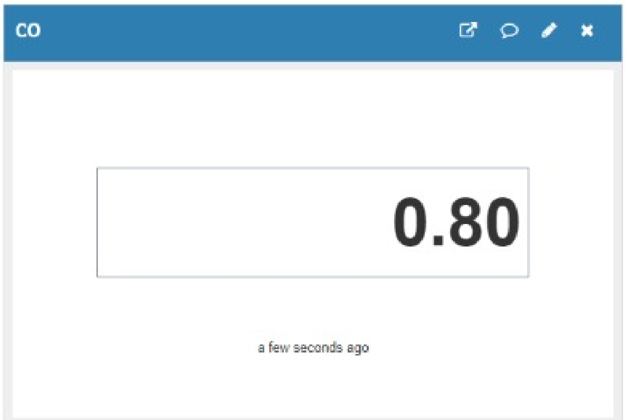

Chart -:8 CO content in PPM (numeric display)

Chart -9: Dust density (mg/m^3) in atmosphere w.r.t time

Chart -10: Dust density in mg/m³ (gauge)

8. CONCLUSION

This paper proposes a system that is cost-efficient, low power consuming and highly accurate system for monitoring air quality on a real-time basis on a small scale with the help of dedicated sensors and alerts people when its level goes beyond a certain limit and displays the data in a way anyone can understand. Leveraging the concept of IoT, the air around the installed system can be monitored by anyone and from anywhere using a phone or a computer. The continuous updating of data enables the users to take timely actions immediately whenever needed. This helps in curbing air pollution in the environment around us which is a big concern. Apart from being low in cost and power consumption, it covers less space and can be installed anywhere. This provides great efficiency and flexibility.

FUTURE SCOPE

Such type of system can be used in two ways, one is as a stand-alone device as shown above or it can be installed in vehicles. By installing it in vehicles, it could make drivers educated and aware about driving patterns they follow and how it is impacting the surrounding and increasing the pollution. By adopting better driving habits will in turn lead to a reduction in pollution. It is going to benefit them as well as others by reducing pollution so everyone can breathe cleaner air.

In the future, more sensors can also be added to this hence extending the system. Further, we can also modify the system by adding a feature of sending SMS to the user when the quantity of any gas in the atmosphere exceeds a certain value. Such systems can also be implemented on a large scale and help in making a smart city.

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