

Design and Implementation of Air Pollution Monitoring System

The progress in technology has made it easy for researchers to explore more in different areas. One such development is in the area of sensor technology which completely changed the outlook of different application level problems. In this chapter, I share my hands-on experience in the development, design, integration, and operation of the air pollution system using commodity sensor. Earlier, the approach for understanding air pollution used complex and stationary equipment which collects data and used these data for analyzing, but things have changed after the low cost, easy to use, portable sensors came in markets [8].

Design Goals

There are many factors which need to be considered for the development of a simple yet reliable system. In this section, I have mentioned the factors which should be considered for an effective air pollution monitoring system.

1. Sensor Identification

The very first task is to figure out which all sensors need to be included for the completion of the system. There are sensors available in the market for the measurement of almost all types of gases in the atmosphere. It should be very clear that which all gases need to be measured and this definitely changes from region to region as in certain places the concentration of a particular gas is more. Having said that, there will be a certain set of gases which must be included for measurement regardless of the region.

2. Communication Module

As the system is completely based on wireless sensors the selection of data transmission is another crucial factor. The communication between the server and the sensors should be taken into consideration. The collected data from the sensors should be transferred over a database or to the sever. For that the type of communication module can be either Wi-Fi or bluetooth module.

3. Reliability

The success of the system depends upon how much accurate the data is. The value which we obtain from the sensor should make sense to the audience. There will be a lot of noise coming with the collection of data, the sensor should have the ability to remove the noise data or it should allow the programmer to make changes or apply certain algorithm so that the data sets will be refined.

4. Easy Integration

The integration of sensors with the processor is one important factor that needs to be kept in mind. Some sensors can be easily integrated with any processor but others needs driver codes to be written in order to work with the processor.

5. Printed Circuit Board

The final system should be build on a printed circuit board as it is more dependable. Circuit build on basic breadboard might even come out as it is not permanently fixed and this will cause frequent breakdown. Its always easy to work on breadboard but that will be useful only for the initial set up. The system should be transformed to PCB.

6. Maintenance

In case of any sensor damage it should be easily replaceable which means the complete system should be a plug and play type model. On building up such a model like that will help in debugging the problems caused by sensors if any. It should also be considered that the sensors selected for the system should be easily available in market so that it can be replaced if needed.

7. Easy Replication

The idea behind creating such a system is that it can be replicated by anyone without even knowing the dept knowledge. The system should be designed in such a way that it should use the most available sensors and processors in the market. The programming part of the sensors to processor will be easy if the selection of processor is simple. This could definitely bring down a lot of work done at the hardware level.

8. Low Cost

Within the available sensors in the market one could find sensors ranging from a very low price to costliest of all. There was a budget set for the the complete system and finding the right sensors with the affordable cost is one crucial factor.

Targeted Pollutants

Our surrounding is filled with various gases, these gases will become harmful if the concentration of it increases to an undesired level. On the development of a air pollution system measurement of all the gases in the atmosphere is not necessary as the collected data from all the sensor will make no sense to the public. Our main idea here is to make the general people aware about the dominant gases and the extend of health hazard caused by these gases. This can be identified through different indexes know as Air Quality Health Index(AQHI) which is a scale from one to ten developed by health and environmental professionals [6] and Air Quality index (AQI)which gives the level of air quality status in an area [1].

The development of such indexes by the scientists will give the general public more idea of the pollution. The main gases to be included for the measurement for the indexes are $PM_{2.5}$, O_3 , NO_2 , and CO along with temperature and humidity sensor for awareness. These gases are mainly caused due to industrialization, urbanization and motorization [7]. Industrial and vehicles release greenhouse emissions which are largely responsible for air pollution [2]. The sensors thus can be limited to five which will also make the system compact.

Methodology

The proposed architecture contains three major components i.e, the hardware architecture which is the sensor system and the processor, the communication middle ware for transferring of the collected data and the software architecture which does the analysis and display.

1. Hardware Architecture

The idea is to come up with a low cost commodity hardware with most accurate values of measurement. As the choices for the hardware is enormous and is keep changing as the technologies advance, suggesting one specific is hard and also not helpful if it is not available globally at low cost. Therefore, I decided to experiment with a few options of using most commonly available hardware components which are low cost.

The Hardware system can be further divided into three main components as:

- (a) Sensors
- (b) Microcontroller board
- (c) Communication module

(a) Sensors

Sensor networks are new instruments useful to detect the conditions in remote places in the physical world in environmental monitoring applications such as pollution monitoring, transportation management, intrusion detection and many more [5]. With the help of sensors, it is possible to collect data remotely and collected data can be transferred to the required platform. There are different sensors available in market which can measure the pollutants and display the value, but the idea here is to select the one which is of low cost and also gives the most accurate values.

Having said that there is a huge classification of sensors based on the way it measures the pollutants. One such category is electro-chemical gas sensor, which is used to detect the concentration of any hazardous gases in the atmosphere by changing its resistance. The most popular series available in market for this category is MQ-XX sensors which is popular for its wide detecting scope, long life, stability, high sensitivity, fast response and also simple drive circuit [3]. The sensing material is made up from Aluminum Oxide (Al_2O_3) based ceramic which increases the heat efficiency and has a coating of Tin Oxide SnO_2 that acts as the sensing material for the desired gas. The sensing element is heated through Platinum wires which is connected to leads made up of Nickel-Chromium, well known conductive alloy. The gas to be detected has a specific temperature at which it gets ionized and the duty of the sensor is to work at that temperature. Once the gas gets ionized it gets absorbed by the sensing material which changes the resistance and inturn changes the current flow and gives the output [4].

(b) Microcontroller Board

For simplicity and ease of programming when compared , Arduino Uno can be used which has ATmega328 microcontroller board. Since it is open-source based platform with rich software support, it is a widely used platform for various applications. Arduino supports both digital and analog inputs. As edge computing is preferred in this context, most of the calculation such as measuring gas concentration and computing air quality and air quality health indices are done in Arduino.

(c) Communication Module

For the sensor device to communicate with the IoT software platform or the software for data analytic and visualization services, I have used ESP8266 WiFi module that has a networkable microcontroller. This module is very compact and has high durability and power saving features. This module transfers the collected data from the microcontroller to the data repository in the software environment where the further visualization and data management will be done.

2. Software Architecture

This component is to provide statistical data analysis and visualization through intuitive graphics services to help users to make decisions. Particularly, analytic component is needed to performs statistical functionality and animation component is to display the necessary data to users. I am aiming at a Customizable Layered Visualization (CLV) which will concentrate the delivering of data for different stakeholders based on their interest. There will be a

hierarchical visualization option in which the user themselves can drive through the data and keep on expanding the information as needed.

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