Wearable Pollution Sensor with BME680 Connected via Bluetooth to a Smartphone for Air Quality Measurements

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ABSTRACT

The effect of air quality on life comfort and on wellbeing is well-established. Conventionally, indoor air quality parameters are critical to make a sound and clean indoor environment and these parameters are altogether different from those categorized as solid qualities. Considering the fact that we spend about 95% of our lives indoor, it is essential to monitor the indoor air quality progressively to differentiate issues in the nature of air and surrounding conditions in the building or in the ventilation frameworks so as to enhance air quality. The aim of this research is to perform air quality monitoring with the help of Internet of Things (IoT) by using the BME680 gas sensor from BOSCH, and ESP32 WiFi & Bluetooth Microcontroller (MCU). In this paper, the application of the device is mainly focused on the detection of atmospheric pollutants (Volatile Organic Compounds) where it has been tested in different humidity conditions. Lastly, a simple mobile application has been developed to provide updates on the air quality parameters, where a simple neural network has been trained and integrated into a smartphone to process the information retrieved from the ESP32 MCU and also predict the air conditions for the next hour or so.

KEYWORDS: air quality monitoring; BME680 gas sensor; VOC; ESP32 MCU; smartphone

1. INTRODUCTION

In recent years, there is an increasing demand of massive databases of air quality to help and aid in decision making in various fields, such as the fight against climate change, protection of health and environment especially during this COVID-19 era, and the optimization of industrial processes or traffic management. However, nowadays this challenge is unbearable to the society, mainly due to the high cost and size of the available instruments to monitor air contamination. Due to this issue, the combination of non-specific gas sensors with enhanced features like low power and high precision integrated together with a smartphone could be used as an alternative and could develop largely portable intelligent systems. This approach will allow for massive, distributed and ubiquitous measurements of atmospheric contaminants of the spatial and temporal resolution. VOCs start from various diverse conceivable sources such as building materials, tobacco smoke, indoor substance responses and individuals. Moreover, high levels of VOCs are found in new structures or after renovation or redesign. VOCs incorporate a wide range of synthetic exacerbates such as beauty care products, cleaning specialists and solvents, and paints. Due to the high VOC concentration, the serious potential health effects are dryness of the eye, nose and throat, asthma-like indications and skin itching [1]. To reduce VOC level we can provide good ventilation, air purification and keeping away the things which will increase VOC levels. Most importantly, in this paper, a smartphone has been integrated with VOC sensor which will display the appropriate air quality conditions and VOC levels and whether it is safe to go outdoors.

2. METHODOLOGY

The BME sensor family has been intended to empower pressure, temperature, humidity, and gas measurements which is the BME680 sensor used in this work. The sensors can be worked in various modes determined in provided header files. For example, ULP mode offers output data at slow rate thereby minimizing power con sumption. As a rule, higher information rate relates to higher power utilization. The temperature sensor inside the BME680 is relied upon to be mounted at an area that empowers great air and temperature trade. The coordinated temperature sensor has been streamlined for extremely low clamor and high goals. The temperature estimation precision is determined in the comparing information sheet of the utilized equipment. The moistness sensor inside BME680 estimates relative mugginess from 0 to 100 percent over a temperature extend from - 40 degrees centigrade to +85 degrees centigrade. The gas sensor inside the BME680 can identify a wide scope of gases to gauge indoor air quality for individual prosperity. Gases that can be distinguished by the BME680 incorporate unpredictable natural mixes (VOC) from paints, veneers, cleaning supplies, goods, office gear and liquor [2].

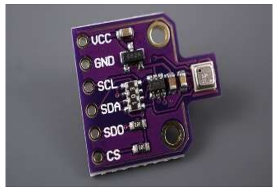

Figure 1: Bosch BME680 Sensor – Temperature, Humidity, Pressure and Gas Sensor

The ESP WiFi & Bluetooth microcontroller integrates a wealth of hardware peripherals, including capacitive touch sensors, Hall sensors, low noise sensor amplifiers, SD card interfaces and Ethernet interfaces. Engineered for mobile devices, wearable electronics and Internet of Things (IoT) applications, the ESP32 WROOM32 MCU achieves ultra-low power consumption with a combination of several proprietary software applications. The state-of-the-art power saving features include fine resolution clock gating, power modes, and dynamic power scaling. This microcontroller is the brain of this project as it helps in integrating the BME680 sensor with the smartphone which will display the necessary readings using the Bluetooth and WiFi features from the microcontroller.

Figure 2: ESP32 WiFi & Bluetooth Microcontroller

The proposed system consists of the ESP32 WROOM MCU connected in series with the BME680 sensor with necessary jumper wires on a breadboard as shown in **Figure 3**. Initially, the BME680 sensor will capture the air quality parameters like air conditions from the environment or surroundings, which will then be stored in the ESP32 MCU and can be displayed on an Arduino serial monitor for testing and debugging purposes. Then, using the necessary and captured information from the ESP32 MCU, a software tool (mobile application) has been developed for processing the data provided by the microcontroller. The following requirements have been considered: Portability, Connectivity, Data processing, Data Classification and Response Time. To deal with all these specifications, Android has been selected as the mobile operating system due to its great advantage that it's widely spread over millions of devices around the world. A Bluetooth low-energy communication module has been selected from the ESP32 MCU to interconnect both systems because of the long autonomy that this alternative provides. Next, data normalization and feature extraction algorithms have been applied. Finally, machine learning algorithms have been selected as the best approach to classify data retrieved from the ESP32 microcontroller. In this case, neural networks have been applied, since performance and short response times are achieved once the neural network has been previously trained and also to predict the air quality parameters and environmental conditions for the next couple of hours or so.

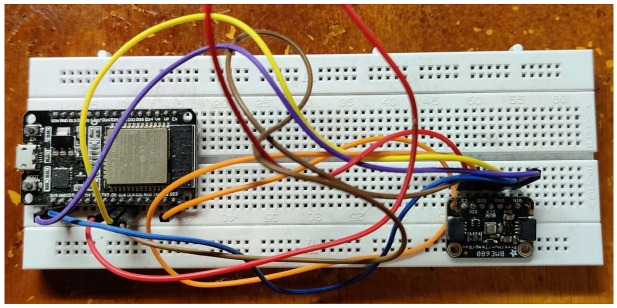

Figure 3: Experimental Setup of the ESP32 MCU and the BME680 sensor

The aim of this level is building and training a neural network using the data extracted from a set of experiments. In this level, Neuroph software has been used to build and train a multilayer neural network composed by three layers with 10 inputs (one for each sensor signal) and nine outputs (one for each compound classified). This is an open source tool for machine learning development and has been selected among others because it provides specific libraries to connect mobile applications with neural networks. A mobile app has been implemented to monitor and process all the information retrieved from microcontroller. The Android Studio software has been used for developing this software and Neuroph libraries have been integrated in order to manage the neural network. The functionality of this tool is diverse: from connecting with the external device through Bluetooth low energy to applying classification algorithms to categorizing sensor data, passing by the processing and the storing of the data for later analysis [3]. The steps involved from retrieving the data to passing the information to the smartphone is shown in **Figure 4**.

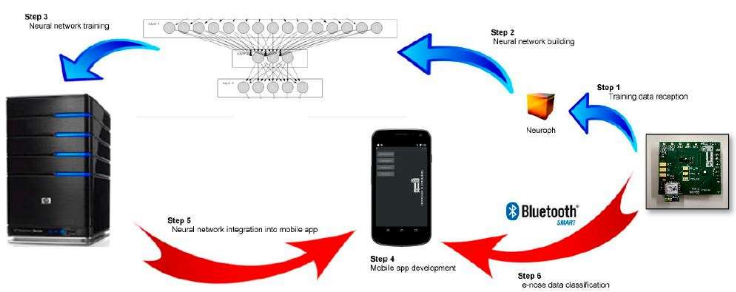

Figure 4: Methodology implemented to develop the mobile application integrated with ESP32 MCU [2]

3. RESULTS & DISCUSSIONS

According to the guidelines issued by the Department of Occupational Safety and Health (DOSH), Malaysia, exceeding 25 mg/m^3 of total VOC leads to headache and nausea and further neurotoxic impact on health. By using the standards provided by DOSH, Malaysia, we can predict the air conditions and VOC levels everyday and determine if it is safe and unharmful to exit outdoors. Using the above proposed system, a graph is generated to view the VOC levels and air quality parameters such as CO_2 levels, VOC levels and other gas levels as shown in **Figure 5**. From the below plot, we can observe that CO_2 equivalent gas levels are very high. The VOC levels exceed 400 which denotes the air quality is very poor. Hence, a notification will be popped up in a smartphone indicating all these information and that it is not advised to travel outside as shown in **Figure 6**. The operating range in the sensor used in this work may not be the same for all other sensors. As a result, the detection of VOC levels in very high humidity conditons will be very difficult. Therefore, a filtering unit or humidity correction algorithm should be added in high humidity environments for the detection of low concentration of pollutants. This must be taken into account for future improvements of this work.

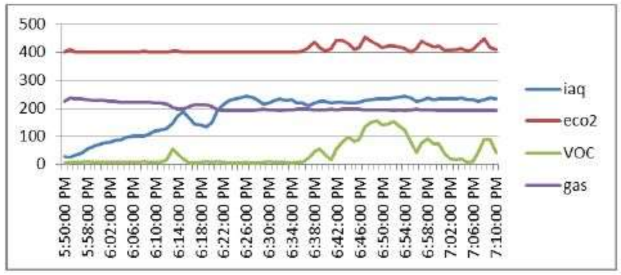

Figure 5: VOC levels in environment at a specific time and day

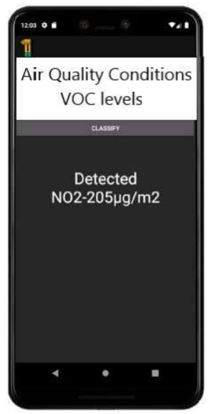

Figure 6: A simple mobile app indicating the VOC and its concentration/levels from a smartphone

4. CONCLUSIONS

The conclusions of this study are:

i) In this paper, a low-cost, low-consumption, and a compact sensor integrated with a microcontroller for air quality monitoring has been illustrated. Typical gas sensors based on metal oxide technology that have been used in VOC chips for decades are not appropriate for miniaturized instruments due to their high power consumption and size. MEMS technology has allowed the integration of gas sensors within CMOS technology modules, which embed signal processing, A/D converter, and communication circuits.

ii) The results obtained indicate that significant future work will be required to improve the reliability and accuracy of VOC sensors in the presence of humidity in order to obtain a good prediction in the concentration of pollutants in air. However, these digital sensors may be integrated in the near future in smart devices, such as phones, watches, or tablets, following the trend of increasing the number of sensors in these devices. Such prototypes and advanced algorithms for signal processing are already under development, as discussed, and will likely be required for the widespread and successful deployment of ESP32 MCU and BME680 in a very much compact design as personal devices for air quality monitoring [2].

5. REFERENCES

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