Development of Cloud-based Electronic Nose for University Laboratories Air Monitoring

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Abstract. Indoor air in area such as house, shopping complex, hospital, university, office and hotel should be monitor for human safety and wellbeing. These closed areas are prone to harmful air pollutants i.e. allergens, smoke, mold, particles, radon and hazardous gas. Laboratories in university are special room in which workers (student, technician, teaching/research assistants, researcher and lecturer) conduct their works and experiments. These activities and the environment will generate air pollutants which concentration depending on their parameters. Anyone in the environment that exposure to these pollutants may have safety and health issue. This paper propose a study of development of a cloud-based electronic nose system for university laboratories air monitoring. The system consists of five dsPIC33-based electronic nose (e-nose) as node which measure main indoor air pollutants along with two thermal comfort variables, i.e. temperature and relative humidity. The nodes are placed at five different laboratories for acquiring air pollutants data in real time. The data will be sent to a web server and the cloud-based system will process, analyse and display by a website in real time. The system will monitor the laboratories main air pollutants and thermal comfort by forecast the contaminants concentration and dispersion in the area. In case of air hazard safety (e.g., gas spills detection and pollution monitoring), the system will alert the security by activate an alarm and through e-mail. The website will display the Air Pollution Index (API) of the area in real-time. Results show that the system performance is good and can be used to monitor the air pollution in the university laboratories.

1. Introduction

The Indoor air in area such as house, shopping complex, hospital, university, office and hotel should be monitor for human safety and wellbeing. These closed areas are prone to harmful air pollutants i.e. allergens, smoke, mold, particles, radon and hazardous gas. Anybody in the environment that exposure to these pollutants may have safety and health issue. Today it is estimates that peoples are spending more
than 90% of their time indoor [1]. The indoor air pollution are two to five times higher than outside because of the pollutants source and occupants’ activities that increase its concentration [2]. Indeed, indoor air pollution are among the main five ecological hazards to general human wellbeing [3]. That why the indoor air quality monitoring is important to ensure the human wellbeing.

The air pollutant is consequences from the interaction of the location, environment, building structure and its sources (interior material, office equipment, ventilation system and outdoor pollutants) and the occupants [4]. The main pollutants are Particulate Matter (PM), Volatile Organic Compounds (VOCs) and Carbon Monoxide (CO). The exposure of hazardous air pollutant to the occupants may result in health issue that can affect their activities and productivity [5]. The PM will cause threat to occupants respiratory system and the detail substance may causes toxicity. VOCs, a group of substances including formaldehyde, acetaldehyde, toluene, xylene, p-dichlorobenzene, ethylbenzene and styrene can cause Sick Building Syndrome (SBS). The symptom are e.g. headache, breath, eyes and skin problem. The CO is a poisonous, colourless and odourless that often mixed with other gases that can be malodorous. It will displace oxygen in blood and deprives heart, brain and other vital organs that causing the person to lose consciousness and suffocate. The room temperature and Relative Humidity (RH), pressure and Carbon Dioxide (CO2) are the main parameters for the occupant’s thermal comfort [6].

Laboratories in university are special room in which workers (student, technician, teaching/research assistants, researcher and lecturer) conduct their works and experiments. The activities and the environment will generate air pollutants which concentration depending to their parameters. It is necessary to investigate regarding to this issue for safety of the occupants. However, current monitoring methods are quite costly and time-consuming where limitations in sampling and analytical techniques are also exist. Clearly, a need exists for accurate, inexpensive long-term monitoring of environmental air pollution using low-cost gas sensors that are able to operate on-site and in real time.

This paper presents the development of cloud-based electronic nose (e-nose) for university laboratories air monitoring. The system consists of dsPIC33-based e-nose which measure air pollutants along with temperature and relative humidity. The system will monitor the laboratories main pollutants and thermal comfort by forecast its concentration and dispersion in the area. In case of air hazard safety (e.g., gas spills detection and pollution monitoring), the system will alert the security by activate an alarm and through e-mail.

2. System Architecture
The system architecture is shown in Figure 1 consist of five e-nose known as node and a cloud-based system. The developed instrument will acquire the air sample and environment condition where the data being transmitted to a SQL web server through a GPRS/GSM communication module. The cloud-based system will retrieve the data, process and analyse before being display on a website.

![Figure 1. The system architecture.](image-url)
2.1 Electronic Nose (e-nose)

The e-nose is an instrument that mimics human sense of smell, comprises of sensors, sensing chamber, microcontroller, electronic circuit, GSM/GPRS communication module, DC power supply and embedded control software. The developed instrument as shown by Figure 2, is using selected Metal-Oxide (MOS) sensors i.e. CO, CO₂, organic solvent vapour, solvent vapour and PM₂.₅, along with two thermal comfort variables, temperature and RH. The sensors were used because of their sensitivity, robustness, compact size and fast response time [7]. A humidity and temperature sensor, was attached to the instrument enclosure to monitor the environment condition. A sensing chamber was used as air sample delivery system to the sensor arrays. The chamber design was simulated by using simulation software to optimise the air sample flow. The chamber material and enclosure were selected to withstand sensor heater high temperature Teflon was selected as the chamber material because of its odourless and inert characteristic that will minimize the air pollutants memory effect [8]. The instrument uses a dsPIC33 microcontroller as its embedded controller to control its operation [9]. An air-pump was used to draw-in the sample to chamber during Sniff cycle for acquiring sample and for purging cycle to flush out air from the sensing chamber.

A signal conditioning circuits was used to control the output signal from sensors before being acquired by the instruments embedded controller. The sensors interface circuit as shown in Figure 3, where voltage divider circuit using variable load resistor was used to set the suitable resistance baseline value. The heater voltage of the sensor was controlled by the embedded controller. The sensor’s output voltage, \( V_{\text{out}} \) known as the sensor response signal is based on the conductance change in the sensing element when interact with the air sample. The sensor’s response signal is amplified using “voltage follower” circuit which characteristic of unity gain, high input impedance and low output impedance. The amplifier impedance matching is used to determine suitable dynamic measurement range for the sensor response signal amplitude. A Low Pass Filter (LPF) was used for filtering the response noise by eliminating unwanted frequencies. After that the signal is being converted to a digital signal using the embedded controller on-board Analog to Digital Converter (ADC). All of the circuit and the embedded controller were powered by an AC power supply through 12-volt DC regulated power supply. The instrument is capable of classifying the sensor output data into classes corresponding to the air pollutant fingerprint [10].

![Figure 2. The developed e-nose.](image)
2.2 Cloud-Based System

Internet of Things (IoT) operation is applied the website by acquiring and processing the information acquired from the environment by using internet [11]. The IoT system is normally consists of sensors known as nodes, wireless network and cloud-based system that has connected to the Internet. The developed system website, monitors the laboratories internal environment and alert the user for any unusual situation. The cloud-based system development consists of four components as show in Figure 4.

Data collection from the e-nose or node is transmitted via wireless communication i.e. GSM/GPRS communication module to web server and saving it in database. After that the data will be process by analyse and classified using Artificial Neural Network (ANN) model to obtain the location Air Pollution Index (API). The website will display of corresponding API as graphic representative in real time. The area safety condition is also being displayed and monitor in the website. The cloud-based system is trained to recognize, by different sets of measurements, hazard patterns for different polluting factors acting in the monitored area, as well as identify accidental patterns of the pollutants.

The programming coding for the website development is done by using PHP language. It is a standard mark-up language to create and develop website applications [12]. The language is open source general-purpose scripting language for the website development that can be embedded into HTML language [13]. The MySQL software is use for the acquired data from the web server for processing. It is a relational database management system (RDBMS) which is based on Structured Query Language (SQL) [14].

The data acquired form the web server will be converts from digital values to Part Per Million (PPM) for standard gas measurement unit. Every sensor used has different formula for sensor resistance, Rs and the value of resistance in clean air as reference, Ro which value vary according to the respective sensor. The value of gradient, m is determined by using a formula in equation (1). The value for y and x axis is acquire from individual sensors datasheet. The value for k is calculated by selecting a specific value of y and x axis in equation (2). The value of PPM in percentage is calculate by using equation (3).

\[
m = \frac{\Delta (\log y)}{\Delta (\log x)}
\]

\[
k = \frac{y}{x}
\]

\[
\text{PPM} = \frac{Rs}{Ro} 	imes 10^k
\]

![Image of signal conditioning circuit](image_url)

**Figure 3.** The signal conditioning circuit.

![Image of data processing system](image_url)

**Figure 4.** The data processing system.
\[ k = \frac{y}{x^m} \]  

(2)

\[ x_{\text{ppm}} = \frac{x_{\text{ppm}}}{10000} \]  

(3)

Where, \( R_s \) is sensor resistance at target gas concentration, \( R_0 \) is sensor resistance in reference air, \( k \) is \( y \) axis value that cross \( x \) axis and \( m \) is the gradient.

Then the process data were analyse by using Artificial Neural Networks (ANN) classification model. The classifier was used because of its good flexibility (training, generalisation and noise acceptance) which is suitable for the instrument non-linear data. It has the capability to train the interaction between the indoor air pollutants sample [15]. The Multiple Layer Perceptron (MLP) ANN model is used to forecast the area API. The training model will generate a gas concentration index model which being trial for forecast success rate. It is forecast the gas concentration API based on air sample of the location.

3. Methodology

Testing was conducted to test the developed e-nose capability with the laboratories air pollution. The data acquisition process was conducted on-site at five different laboratories at Malaysia Perlis University. The developed e-nose was linked wirelessly with the cloud-based system as illustrated in Figure 5.

A sampling system will deliver the air sample to flow properly into the instrument sensing chamber that ensure all sensors exposure to the air sample effectively. The instrument data acquisition process uses the Purge and Sniff method whose parameter settings are shown in Table 1. This Purge and Sniff method will hold the air sample inside the sensing chamber to stable the data before being measured during acquisition process. The duration for Purge and Sniff method of the instrument is based on the sensor’s characteristics and trial and error [7]. Primarily the instrument is being Purge using active carbon module to clean the sensing chamber from any gases. Then the instruments will Sniff the reference air that the data being used as the baseline. After that the instrument will acquire data from the location and send the acquired data wirelessly to the website through GPRS/GSM communication module.

![Figure 5. The data acquisition process.](image-url)
4. Results and Discussion

4.1 Sensor Output
The developed e-nose sensor output is a time series of waveform profiles as shown in Figure 6. The system data acquisition process is appropriate because the sensor output data value is within the measurement range. This shown that the instrument can operate as the expectation in laboratories at the University. An active filter and relative baseline manipulation were used to pre-process the instrument acquired data. The baseline manipulation is used to calculate the actual data i.e. the difference value between the sample and reference air. This pre-processing method will enhance the instrument classification capabilities.

![Figure 6. The developed instrument sensor output.](image)

4.2 Cloud-Based System
The data acquired from the location is transmitted wirelessly by GSM/GPRS communication module to the web server. MySQL software is used to build a database to store the received instrument acquired data. Hypertext Mark-up Language (HTML) and JavaScript have been used in order to design and develop the website and analyze data retrieve from MySQL server. The instrument data that being retrieved from server is being converted to PPM as shown in Table 2.

| Air Pollutant          | Loc. P1 | Loc. P2 | Loc. P3 | Loc. P4 | Loc. P5 |
|------------------------|---------|---------|---------|---------|---------|
| Carbon Monoxide        | 0.29    | 0.05    | 0.48    | 0.27    | 0.20    |
| Carbon Dioxide         | 0.32    | 0.07    | 0.41    | 0.33    | 0.15    |
| Organic Solvent Vapour | 0.36    | 0.09    | 0.54    | 0.45    | 0.18    |
| PM$_{2.5}$             | 0.33    | 0.12    | 0.45    | 0.36    | 0.13    |
| Temperature            | 0.46    | 0.13    | 0.46    | 0.37    | 0.10    |
| Humidity               | 0.25    | 0.07    | 0.48    | 0.21    | 0.23    |
The Multilayer Perceptron (MLP) is used to generate the system API ANN model. The model used 70% of the data for training and 30% for testing. The output will be set in between 0.0 to 1.0. Table 3 shows the systems API colour coding.

| Colour   | Concentration Index | Condition        |
|----------|---------------------|------------------|
| Green    | 0 – 0.20            | Very low - exceptional |
| Brown    | 0.21 – 0.30         | Low – good       |
| Light Blue | 0.31 – 0.39     | Medium - normal  |
| Yellow   | 0.40 – 0.59         | High - caution   |
| Red      | 0.60 – 0.70         | Very high - hazard |

The developed system website is shown in Figure 7. The API of each location will be arranged in graphic representation as shown by webpage in Figure 8. The website will show the API of each and all laboratories in rotational order for every 30 second interval. The API is represented by five different colour code that give different information about hazardous gas of the area as shown in Table 3.

![LABMON cloud-based website](image1)

**Figure 7.** LABMON cloud-based website.

![API layout](image2)

**Figure 8.** The API layout.

All of the results indicate that the acquired testing data classifications were correlate with air sample location. The results show that the developed cloud-based e-nose system was able to forecast the API according to their location. The system performs good and reliable data acquisition, processing and
analyse of the sample data. It is very useful in the new information age to forecast the indoor air pollutants i.e. university laboratories API.

5. Conclusion
A cloud-based system using an e-nose integrate with cloud had been successfully developed. The system was tested to acquire the university laboratories air samples and transmitted wirelessly to cloud-based system using GSM/GPRS communication module. The system for forecast the laboratories API was developed by using HTML and JavaScript programming language. The cloud-based system is using MySQL database to store the acquired data the and the API was generate using ANN model. The API of the air pollutants, environment temperature and humidity were displayed by the website. The system also able to send alert signal once the API exceed the safety limit. Future work on this project should consider the used of Neuro-fuzzy logic classification model to reduce the uncertainties in generating the indoor API.

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