Cloud-based System for University Laboratories Air Monitoring

A H Abdullah¹, S Sudin², M H Mustafa³, M A A Bakar¹, F S A Saad², Z A Ahmad¹, M Elshaikh³, K A Ismail⁴, A G Ahmad⁵ and S Y A Yusuf⁶

¹Faculty of Engineering Technology, Universiti Malaysia Perlis, Perlis, Malaysia
²School of Mechatronic Engineering, Universiti Malaysia Perlis, Perlis, Malaysia
³School of Computer & Communication Engineering, Universiti Malaysia Perlis, Perlis, Malaysia
⁴School of Manufacturing Engineering, Universiti Malaysia Perlis, Perlis, Malaysia
⁵School of Environmental Engineering, Universiti Malaysia Perlis, Perlis, Malaysia

abu.hassan@unimap.edu.my

Abstract. Indoor air such as house, shopping complex, hospital, university, office and hotel should be monitored 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 experiment. The activities and the environment will generate specific air pollutant which concentration depending to their parameters. Anyone in the environment that exposure to these pollutants may affect safety and health issue. This paper proposes a study of development of a cloud-based electronic nose system for university laboratories air monitoring. The system consists of DSP33-based electronic nose (e-nose) as nodes which measure main indoor air pollutant along with two thermal comfort variables, temperature and relative humidity. The e-noses are placed at five different laboratories for acquiring data in real time. The data will be sent to a web server and the cloud-based system will process, analyse using Neuro-Fuzzy classifier and display on a website in real time. The system will monitor the laboratories air pollutants and thermal comfort by predict the pollutant concentration and dispersion in the area i.e. Air Pollution Index (API). 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 API of the area in real-time. Results show that the system performance is good and can be used to monitor the air pollutant in the university laboratories.

1. Introduction

Laboratories in university are room in which workers (student, technician, teaching/research assistants, researcher and lecturer) conduct their practical. Despite rigorous work ethics and procedures in the laboratories, harmful air pollutants, i.e. mould, particles and hazardous gases, can still be found resulted from various processes in the laboratories such as treatment of residuals chemical, machining and heat treatment of material. In addition, the air pollutants are consequences from interaction of the environment, building structure and pollutants sources (building interior material, office equipment, ventilation system and outdoor pollutants) and the occupants [1]. The exposure of the air pollutant to
the occupants may result in safety issue and well-being that can affect their productivity [2]. An effective air pollutant monitoring and alert system is needed that operate continuously and in real time.

Cloud-based Electronic Nose (e-nose) is a technique which provides interaction with the real world that accumulates its acquired data and transmits into a cloud system by storing, processing, analysing, interpreting the results and reporting in real-time. Cloud computing is cost effective technique that used internet and web server for storing and process the interaction data with outside world. The technique allows access to data and computer from anywhere as along as a network connection is available. It provides sharing of resources, including data storage space, networks, computer processing, service, user interface and applications. The technology invented by Google is suitable for real-time big data storage and processing with vast coverage [3-6].

Generally, cloud service includes Infrastructure as a Service (IaaS), Software as a Service (SaaS) and Platform as a Service (PaaS). The taxonomy defined evaluates Cloud Architecture, Virtualization Environment, Service, Fault Tolerance, Security, and Other Issues (Load Balancing, Interoperability, and Scalable Data Storage) [7].

Cloud provides significant amount of storage capacity. The sensory data from e-nose are sending to be stored and process in cloud gateway. Several web companies that offer cloud computing platform i.e. data storage to hire such as Amazon Web Services, Microsoft Windows Azure, Google App Engine, IBM, Simple Storage Solution and Digital Ocean. This allows data to be stored remotely in unstructured storage types, structured storage types and other storage types. This data is temporarily cached on notebooks, mobile phones or other Internet-linked devices at user request for analysis [8].

The system contains of users that can access the cloud by using web browser. Portal server will provide the user, menus for logging in, logging out, registering or removing nodes. The cloud server will provide access to integrate nodes and timely delivery of acquired data to the database. The system will then analyse the stored data accordingly. The monitoring information and alert system from the cloud can be access in real time by the user through web browser [9]. Furthermore, the system processing agility can also be access by using real-time mobile interactive applications. The system applications include landfill monitoring, forest fire detection, city air monitoring, river pollution monitoring, office monitoring and etc. [10].

The cloud-based system will handle the nodes acquired data activities efficiently by using timely, flexible and scalable data storage server and software. The good accuracy and reliability processing infrastructure will able to perform both online and offline analysis to fully utilise the valuable information. User just switch to their application by connecting to the server on cloud and start working without any trouble via desktop computers, notebook or smartphone with an internet connection to monitor and display real time monitoring information and alert system [9, 11].

The system has its own challenges especially for interface and interconnect of various types of hardware. It is being used for fixed and specific applications that cannot be easily changed once deployed to other applications. The system also has other technical issues such as security, integration process, integration framework, routing, the end to end delay constraint, lifetime of the sensor and energy consumption [5].

This paper presents the cloud-based system using wireless e-nose and cloud computing for university laboratories air monitoring. The system data acquisition consists of microcontroller-based e-nose known as nodes which measure air pollutants along with environment temperature and humidity. Each e-nose is responsible for real time data acquisition in the specific laboratory. The e-nose is organized in flat topology and being integrated together by the cloud. Data acquired from e-nose which been placed at multiple laboratories will be wirelessly transmitted to MYSQL database server through GSM/GPRS module. The cloud-based system will process, analyse using Neuro-Fuzzy classifier, report and display the Air Pollution Index (API) and thermal comfort on a website in real time. The system also alerts the relevant authorities in case of safety hazards by activate an alarm and e-mail notification.
2. System Architecture
The system architecture is shown in Figure 1 consist of five e-nose (e-noses) and a cloud-based system. The e-noses will acquire the air sample, temperature and humidity where the data will be transmitted to a MYSQL database server through a GPRS/GSM module. The cloud-based system will store the data, process and analyse before being display or report on a website.

2.1. Electronic Nose
The e-nose (node) is an instrument that mimics human sense of smell. It comprises array of gas sensors, microcontroller, GSM/GPRS module, power supply unit, electronic circuit and embedded software. The sampling system will direct the air sample to the array of gas sensors appropriately for effective exposure. The instrument is capable of classifying the sensor signals into class and grade corresponding to the air sample fingerprint [12]. The instruments were powered by an AC power supply through a 12-volt DC regulated power supply.

2.2. Cloud-based System
Internet of Things (IoT) can applied the cloud service by collecting and applying information in the environment by using web server [13]. Cloud-based e-nose system is wireless communication networks that have e-noses connected to the Internet. The system’s data processing can be divided into four sections as shown in Figure 2.

![Figure 1. The system architecture.](image)

The e-nose embedded software was programmed using C language. The flow chart of the data acquisition process is shown in Figure 3. Initially the e-nose is in sleep mode and it will wake up to start heating-up the sensors 10 minute before the acquiring data. The e-nose will send the acquired data by using GSM/GPRS module to MySQL database server for every 30 minutes. The MySQL database server which acted as the cloud database system was created and managed using PHP software. After the process finish, the server will send an acknowledge signal to the e-nose. The acquisition process will be repeated for every 30 minutes.

The system is using Digital Ocean Droplets cloud-based server, a Linux-based virtual machines (VMs) that run on top of virtualized hardware. The server is running on NodeJS, which is an open-source software that executes JavaScript code. The MySQL software is an open source relational database management system (RDBMS) based on Structured Query Language (SQL) is used to develop a database to store the receive data [14]. In the MySQL database server, node-RED software
was used to manage the data. Node JS and PHP were integrated to process the data. PHP standard mark-up language is open source general-purpose scripting language for the website and development which can be embedded into HTML [15]. HTML gives the establishment of the webpage. Desktop and portable programs web browser, such as google chrome and internet explorer are compatible with HTML. The web design is saved as PHP file (.php) and CSS file format for customisation. The HTML focus on how the file appears in the browser, while NodeJS focuses on how to represent them in a structured way. The data are transmitted by using TCP/IP protocol which both PHP file (.php) and java script being used. A dynamic table is created to display data stored in database server while java script is used to embed maps into the website. The database is created in PHP MyAdmin, then the table of database is created in the database. It also has to connect to the PHP file using query to display all of the acquired data. In the PHP file, there are commands to retrieve data from the database server.

**Figure 3. Data acquisition process.**

Data processing process flow chart is shown in Figure 4. The acquired raw data will be converted from digital values to Part Per Million (PPM) for standard gas measurement unit. Each e-nose’s sensor has different formula for gas sensor resistance, Rs and the value of sensor resistance in clean air, Ro according to the respective gas sensor. The data in unit concentration will be place in in graphic interface (table and maps format).

The retrieved data are classified using Neuro-Fuzzy to predict the location Air Pollution Index (API). The data were used to train the Neuro-Fuzzy model for its good adaptability property (learning, generalisation and noise tolerance) which is suitable for the non-linear data. The training will generate an API model which being test for prediction success rate. It is predicted the API based on air sample of each location.
Web Service consists of reusable components that can be published, discovered and invoked across the Web [16]. The system will build and manage a website to display real time API data as graphic representative that being update every 30 minutes. This mapping system will give the location points in the area with the desired API. The area safety parameter can be displayed and monitor by the website. The cloud-based system is also trained to recognize, hazard patterns and identify accidental patterns of the air pollutants.

3. Methodology
An experiment was conducted to verify the e-nose sensitivity and detection limit that correlate with the indoor air pollution concentration. The samples were collected from five laboratories at University Malaysia Perlis. The e-nose was placed at these five locations. The samplings process is illustrated in Figure 5.

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**Figure 4.** Data processing process.

**Figure 5.** The air sampling process.
The e-nose sampling process utilise Purge, Sniff and Hold technique. Initially the instruments will acquire fresh air sample as the baseline data. Then each e-nose that placed at specific location in the five laboratories will acquire data at 10-minute time interval between them. The duration of the instrument process cycles is based on the e-nose’s MOS sensor characteristics and trial and error. Then the instrument will send the acquire air sample wirelessly to the database server through GPRS/GSM module. The acquisition process will be repeated for every 30 minutes.

4. Results and Discussion

4.1. Sensing Layer

The website was successfully created using software HTML and NodeJS CSS software. HTML and PHP were used to design the interface of the webpage while database uses MySQL database server to store data acquired from e-noses. The e-nose’s sensor response raw data that being stored in the database based on time and e-nose ID is a multivariate time series of waveform profiles as shown in Figure 6. It’s shown that the sampling technique was correct because the acquired data were within the normal range. This indicated that the e-noses data acquisition data are functions accordingly to collect quality measurement. The acquired data were being pre-process by applying relative baseline manipulation technique. The used data are the difference between ambient (baseline data) and air sample data. This pre-process will increase the system sensitivity that will improve the API values prediction result.

![Figure 6. The e-nose sensor response.](image)

4.2. Cloud-based System

PHP file fetches data from MySQL database using Query language. Prior to that, logic programming in java script using NodeJS is used to convert the raw data to unit of concentration (PPM) as shown in Table 1.

The Neuro-Fuzzy classifier is used to predict the data unit concentration into API values. 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 2 shows the API colour coding.

The system website main page is shown in Figure 7. The embedded map API at each location will be arranged in graphic image representation for better illustration to users. The graphic image mapping will display the API from different locations at the same time and the table of data stored in database in descending order. The API location is represented by five different colour code that give different information about the pollutants in the area as shown by Table 2.
Table 1. Data Conversion to PPM.

| 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    |

Table 2. The API colour code.

| Colour     | Concentration Index | Condition         |
|------------|---------------------|-------------------|
| Green      | 0 – 0.20            | Very low - excellent |
| 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 - danger |

The webpage will display the air pollutants and API in rotational order for every 30 second interval. The webpage information will be automatically updated for every 30 minutes by simultaneously loading new API values into the PHP file. Based on the results shown in Figure 7, which show the system API data against time. The API reading is dependent on humidity and temperature which varies according to air pollutants concentration. Low humidity and high temperature make air pollutants move more rapidly, hence increasing the API values.

All of the results indicate that the API values correlate with air sample location as shown by Figure 8. The results show that the system was able to predict the API values according to their location. The system performs good data acquisition, effective transmission, good data processing and fast display the API values.

It is very useful technique in getting information or monitoring the indoor air pollutants i.e. university laboratories atmospheric environment based on accurate real time API values reading anywhere using the webpage system. The users interact and manage information related to the cloud system and will alert relevant authorities for any abnormal condition. They can use browsers i.e. IE or Mozilla Firefox or Google Chrome to connect to the Internet. A Windows Mobile device or smart phone, is used to providing a website to display the result since it is more convenient since people
spend more time on smart phones. The mobile device will enable user to obtain information fast and easily. This approach will provide an optimal approach to system management, access control, storage and retrieval of acquired data. The web page will create awareness to users to manage their laboratories schedule to avoid any possible health problem.

Figure 7. LABMON cloud-based website.

Figure 8. Graphic representation of gas concentrations.

5. Conclusion
A cloud-based system using e-noses integrate with cloud had been successfully implemented. The system was tested in UniMAP selected laboratories which air samples were acquired using e-noses and transmitted wirelessly to MySQL database server using GSM/GPRS communication module. The system for monitoring the laboratories atmospheric environment API was developed by using HTML, Node-RED and Node.js JavaScript programming language. The real time data collection is using e-noses and send to MySQL database server. The data were process and the API values was generate using Neuro-Fuzzy classification model. The API values of the air pollutants were displayed by the website. The environment temperature and humidity also being display. The system also able to send alert signal once the API values exceed the safety limit. Future work should consider the technique that tackle the uncertainties issue i.e. e-nose’s sensor drift and humidity interface in generating the API values. The system should include further development of the data processing, storage and retrieval methodology. It also should implement the usage of control alarm using web server certain areas with high risk of hazardous air pollution.
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