Design of E-nose as an Instrument Identification of Diseases Through the Respiratory Tract

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Abstract. The identification of a particular illness is usually done by microscopic check-up from the phlegm, urine, blood, Rontgen, and CT-scan. This technique needs a long period, high cost, and complicated procedure. As a result, society feels reluctant to check up on their health. Thus, research of an instrument that can define and diagnose the illness easily, efficiently, and accurately is needed. This research developed a prototype of an electronic nose that consists of a gas sensor that can respond quickly the element of volatile organic through the breathing air. Principal component analysis (PCA) method is the most appropriate method to classify the type of illness visually. Therefore, this research is needed to be applied in medical instrumentation.

Keyword: PCA, tract, e-nose, respiratory.

1. Introduction
Based on previous knowledge, doctors were able to diagnose diseases through respiratory air. But this technique not used anymore because it is considered inaccurate and it can only be done by doctors who are experienced in identifying diseases through the scent of breathing, other than that only a few diseases that have an advanced stage can be identified by human olfaction. Therefore an electronic nose system (E-nose) was developed which functions to diagnose diseases through respiratory air [1]. In the respiratory air consists of various mixtures such as nitrogen (N2), oxygen (O2), carbon dioxide (CO2), water vapor (H2O) and hundreds to thousands of volatile compounds or called Volatile Organic Compounds (VOC) with concentrations in order ppm to ppb. This VOC can be produced in the body (endogenous) and can also be absorbed as pollutants from the environment (exogenous)[2]. VOCs released by the body contained in respiratory air have a special pattern according to genetic or environmental factors such as age, body weight, gender, lifestyle, and food habits that affect the chemical composition in a person's breathing so that it can be used as a biomarker in diagnosing a disease that originating from the lungs, such as tuberculosis (TB), Asthma, and Chronic Obstructive Pulmonary Disease (COPD).

Electronic instruments that have been developed to qualitatively identify the aroma are called Electronic Nose (referred to as E-nose ). In general, E-nose is built on three main parts, namely the chemical sensor array (gas sensor), data acquisition system and pattern recognition system. The E-
nose system was built based on the functioning of the human nose[3]. When compared to the human nose, the three main parts in E-nose are related to the receptor layer (billions of olfactory cells), the reinforcing layer (olfactory vesicles) and decision makers by the brain [4] [5]. So that the E-Nose programming technique involves an Artificial Neural Network system. E-Nose has a multi-functional properties, so the programming can be adjusted according to needs and based on training data[6].

Based on the discussion of the previous problem it can be assumed that E-nose has a new non-invasive and low cost[7] in detecting disease by detecting real-time VOC patterns produced by breathing[8]. VOC patterns are used as biomarkers in classifying COPD, Astma, and TB disease. So that in this research will be discussed how to design an E-Nose being able to identify diseases through respiratory air using principal component analysis (PCA).

2. Method

There are two main methods in this research that will be used:

2.1. Design Stage

At this stage e-Nose design will be carried out which will be built and its function determined. At the design stage for this research there are two main designs namely Hardware and Software Design:

2.1.1. Hardware Design. The sensors used in the E-Nose in this research are the oxide semiconductor gas sensors from TGS namely TGS813, TGS822, TGS825, TGS826, TGS 2611, and TGS 2620. The sensors are arranged in such a way as an array of sensors connected to a microcontroller. These types of sensors are very sensitive to various complex gas gases that come from the air in the human body. The block diagram of the E-Nose system hardware is shown in Figure 1 below:

![Figure 1. Block diagram of the e-nose system hardware](image)

2.1.2 Software Design. Software design in this stage is needed, so as to facilitate the observer in observing and retrieving e-nose data through a Graphical User Interface (GUI) that can record sensor data in real time. The results of reading analog signals that were successfully recorded by the sensor in the form of changes in voltage every time caused by chemical reactions contained in human respiratory air.

2.2. Stage Taking Samples

The stages of sampling in this research were designed based on Figure 2 below:
Intake of sample in this research was carried out by instructing the patient to breathe normally on an e-nose device that had been designed using an oxygen mask. The duration of time needed for the patient to breathe is about five minutes. The output data from the reading results will then be recorded using the Data Logger User Interface (GUI) Data and data processing will be performed using PCA and Artificial Neural Networks to distinguish training data and testing data. Patients who will be taken air breathing are patients who have indications/diagnosis of COPD, Asthma, and tuberculosis.

3. Results and discussion
3.1. E-Nose Instrumentation
The e-nose consists of six gas sensors, a temperature sensor and a fan, and then the e-nose is connected to the computer. The analog signal that is read by the sensor is visualized in a 2D graph as shown in Figure 3. The visualization data that is formed is derived from quantitative data of the voltage on the sensor which is influenced by organic compounds contained in the respiratory air.
The quantitative signal is then processed using the following equation 1:

\[ \text{read bit} = \frac{\text{max bit}}{\text{Ref Voltage}} \times \text{Voltage} \quad (1) \]

The results of recording data stored on the computer will form the matrix N x M, where N is the number of data samplings, while M is the number of sensors used.

3.2. Data Sampling Analysis

The data analyzed at the beginning is zero data. Zero data is empty data from e-nose without breath sample. Zero data retrieval is needed to see the difference in sensor response without samples and with breath samples containing VOC compounds. The sampling time of each sample for all sensors is represented by a 120 x 6 matrix, this informs that each sensor gets 120 data points for each sample. Samples taken in the form of breath of patients diagnosed positive with asthma, COPD, and tuberculosis are presented in the radar plot in Figure 4 below:

From Figure 3 it can be seen that there are different patterns detected by sensors for each disease. The difference is caused by differences in the sensor's response to the different VOC compounds detected by the sensor to one sample. These patterns can also be used as a biomarker in the content of VOC compounds contained in respiratory air. VOC compounds contained in respiratory air which are used as biomarker are presented in table 1 below:
Table 1. Volatile Biomarker in humans

| No | Volatile Biomarker                                      | Disease | Referensi |
|----|---------------------------------------------------------|---------|-----------|
| 1  | Alkanes, short-chain HC, Isoprene, 8-Isoprostane, Leukotriene B4, Nitric oxide, Pentane | Asthma  | [9][8][2][10][11][12][13][14][15] |
| 2  | 8-Isoprostane, Leukotriene B4, Nitric oxide, Nitrotyrosine, PPOK |         | [8][16][17][18] |
| 3  | 2,2-dimethyl undecane, Methylated alkane | TBC     | [19][20] |

The results of the Principal Analyst Component Processing (PCA) are presented in Figure 5 below:

![Figure 5. PCA analysis](image)

From Figure 5. It can be seen that each disease identified by e-nose forms their respective patterns that do not intersect each other, this concludes that the gas sensor on e-nose is able to distinguish between COPD, Asthma, and TB so well. For the percentage of variation of the 1st Principal Component and 2nd Principal Component is 73% and all three samples of the disease are well dispersed. The identification of the sensor response to the VOC of respiratory air is shown in Figure 6.
From Figure 6 it can be confirmed that the VOC sample from the respiratory air to the three diseases tested can be responded to well by all sensors that account for the largest variable in identification, the largest identification variable is shown by the length of the vector from the base to the end of the vector, thus interpreting the response the best sensor.

4. Conclusion
Based on the results of the research Electronic nose (E-nose) is designed to be able to distinguish between COPD, Asthma and tuberculosis through the respiratory air. Electronic nose designed to be able to recognize these three diseases through volatile organic compounds (VOCs) contained in the breath of the patient. This can be seen from the ability of the six sensors on the electronic nose to be able to work optimally in identifying biomarkers contained in the respiratory air of patients suffering from tuberculosis, COPD, and Asthma. The accuracy in the classification of these three diseases is 73%.

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