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Design and Testing of Electronic Nose for Determining the Pattern of Bad Breath Classification in Patients with Diabetes Mellitus and Pulmonary Tuberculosis (TBC)

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Abstract. In this study, the electronic nose (E-Nose) is based on array gas sensor. This tool consists of 10 MQ gas sensors related to Volatile Organic Compound (VOC) gas components. The working principle of the tool is to imitate the biological system of the nose which is useful to smell both bad and pleasant smell. E-Nose will detect samples of breath or bad breath on Tuberculosis (TBC) and Diabetes Mellitus patients and healthy peopl*e*. Then, the data responses will be evaluated by using 2 patterns recognition methods called Principle Component Analysis (PCA) and Cluster Analysis (CA). The classification results can be explained by the value of the first 3 PCs from the score plot on the PCA of the data. PC1 accounts for 52.6% of the variance, while PC2 accounts for 17.8% of the variance, and PC3 accounts for 9.5% of the variance. The cumulative value of the first 3 PCs is 79.9%. The score plot graph shows a perfect classification of 3 data groups between healthy people, tuberculosis and diabetes mellitus patients. The results of this study indicate that the electronic nose (E-Nose). The instrument can identify the pattern of bad breath of healthy people and TBC and diabetes mellitus patients.

INTRODUCTION

Halitosis is a general term used to describe the odor that is disliked when air blows, regardless of whether the odor substance originates from the oral or non-oral origin. The oral cavity has a significant role in the occurrence of halitosis [1]. Bad breath is a clear indicator to analyze VOC, which is produced in the body. This substance is distributed throughout the body through the blood, then they can pass through the pulmonary alveolar interface and appear when exhaling. This VOC value can be measured in parts in per million volume (ppmv) and parts per billion volumes (ppbv) [2-3]. The analysis of VOC concentration in the breath can provide the indicator of metabolic status so it can distinguish between healthy and sick people. Thus, this technique has the potential to detect the disease in the first stage of the disease, non-invasive and painless [4-5].

Some of the causes of non-oral lousy breath can be caused by diseases such as kidney failure, tuberculosis, liver cirrhosis and diabetes mellitus. In addition, there are other metabolic involving enzymatic disorders and trimethylaminuria, which cause VOC production, which manifests as bad breath or halitosis [2,6-8]. Kidney

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disorders in the chronic kidney failure form are associated with increasing nitrogen urea levels and decreasing salivary production. Typical bad breath is the uremic odor in combination with a dry mouth.

Pancreas damage can also cause breath bad. Diabetic ketoacidosis can also cause a distinctive breath odor. Type 2 diabetes mellitus type 2 shows breath bad is sweet and has a distinctive fruit aroma. Patients with diabetes mellitus show an increase in the concentration of ketone bodies, acetone, acetoacetic acid, and beta-hydroxybutyric acid in blood and urine. Ketone bodies are produced by the liver during fatty acid metabolism and used as an energy source when glucose is not available [6-7,9].

Pulmonary tuberculosis can also cause typical breath terrible. This disease is an infectious disease caused by Mycobacterium tuberculosis. Analysis of breath bad can help in diagnosing pulmonary. Several potential biomarker compounds have been found by sampling breath bad, such as methyl phenylacetate, methyl p-anisate, methyl nicotinate, and o-phenylanisole [3,10-13].

In the modern development sensors, gas detection including VOC is performed with a gas sensor array method. This method is also called an electronic nose or E-nose. The working principle of this method imitated the working principle of the human nose. This method uses many sensors are used simultaneously in an instrument. Data will be obtained in parallel from each difference gas sensor. For data processing systems carried out using a multivariate analysis method. With this data processing technique, the information will be obtained in the form of patterns from identified gas source [14-16].

Determination of pattern recognition methods has a very important impact for accuracy and reliability of result analyze. Differences response from sensor array can be used to identify various types of gasses with data processing techniques using the appropriate classification method [17]. PCA and CA are methods that have been widely using recent research this is because the PCA and CA methods are perfect for graphical visualization. Of several types of the cluster and can also reduce the dimension of the data matrix [18].

From the various background above, we also developed an e-nose system to detect pulmonary TBC disease and diabetes mellitus. This research essential in Indonesia considering that there is no development detection system for some of those using e-nose.

Tools made using 10 different MG gas sensor are arrange and form a sensor array system that can response simultaneously and real-time the 10 gas sensors are connected to the Arduino mega analogue pin. Arduino microcontrollers are used interface and are connected with LabView as GUI (General Unit Interface) of the data acquisition system. The measurement data will be saved directly to the computer in excel format. Furthermore to recognize pattern based on the type of disease use PCA (principle component analysis) data processing.

EXPERIMENTAL DETAILS

Bad breath analysis research using the E-nose system with PCA and CA method has been done in 2 stages were the manufacture of gas array sensor devices, data retrieval and processing data. Determination of sample objects by identifying patients has done by looking for about patient data in a hospital, health center and health facilities at level I. Samples consisted of 25 healthy people, 25 people with pulmonary tuberculosis, and 25 people with diabetes mellitus: for pulmonary tuberculosis patients without clinical data on phlegm or chest X-ray. For people with diabetes mellitus, fasting blood sugar checks and random blood sugar checks are performed.

Measurement of breath odor is measured by E-Nose. Objects (samples) were asked to fast for 2 hours and gargle. Measurements were made with repetitions 5 times at that time, by blowing balloon objects (ample sites). Balloons containing sample breath were censored by an E-Nose device. Data sent to a computer was processed using 2 methods were PCA method. Data interpretation has done by validating the results of pattern measurements with the result of healthy laboratory clinical trials.

RESULT AND DISCUSSION

Before an electronic nose or E-Nose is used to measuring or detecting bad breath in tuberculosis sufferers, diabetic mellitus sufferers, and healthy people. We must test the instrument first. Its aim to know the device can work according to our expectations or not. The device works according to the principle of the human nose when it is acquiring data. There are two cycles, inhale and exhale on the human nose, collecting and purging on odor data acquisition system. Because there are collecting and purging cycles, the response of the gas sensor array that responds odor from sensor array chamber, there are two data that is obtained: collecting and purging. Below is the sensor array response when it responding odors in collecting and purging condition, see Fig 1.

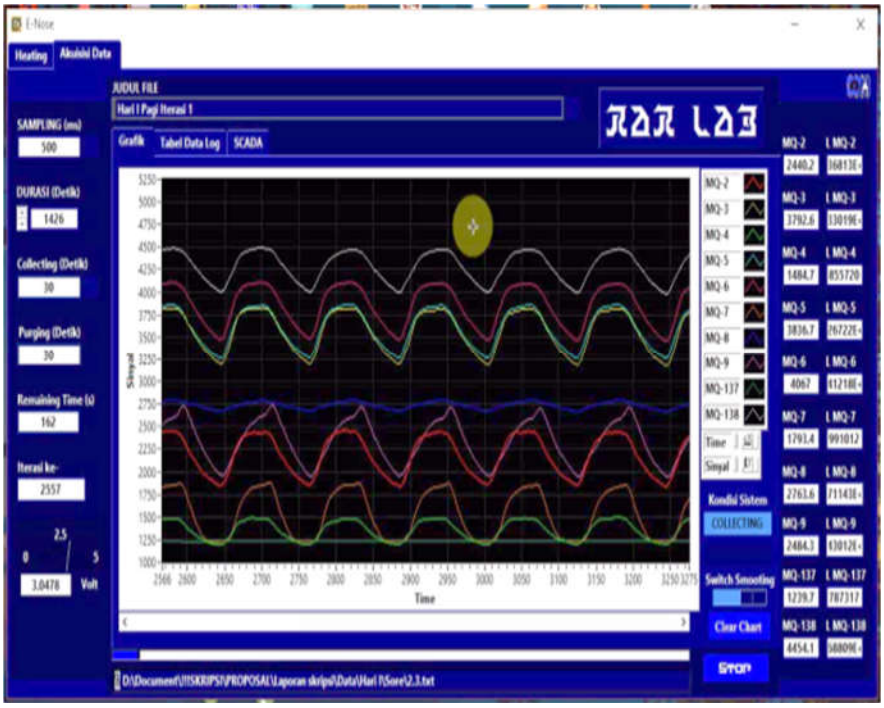

FIGURE 1. The Response of Gas Sensor Array to Odors

Every Gas sensor gives different respond to every sample. This problem will be difficult to analyze because there are too many response graphs that are obtained in this research. So, it needs to use a multivariate method to evaluate the ability of many responds on this electronic nose. To distinguish between different group varieties, the data were analyzed using three recognition technique, namely Principal Component Analysis (PCA).

This model was built using unattended pattern recognition methods. This method cam is used to reduce the dimensions of data, it can also help to visualize different categories. This research used 10 sensors, so in the classification process, it will produce 10 variable to be plotted. It is impossible to see the graph with 10 dimensions. The PCA method can reduce 10 variables in the graph to 2 or 3 data variables that represent all of the variables. This technique is perfect to use when there is an indication of significant correlation in data. In this research, the PCA method is used to classify data from 3 data groups from 60 data of bad breath. The 3 data groups are data groups of diabetic mellitus sufferers, tuberculosis sufferers, and healthy people.

Figure 2 shown score plots in PCA's data. Based on this image PC1 shown variation in large data, temporary result PC2 for the next large variation. PC1 donate 52.6% from variation, temporary PC2 donate 17.8% from variation, and PC3 donate 9.5% from variation. From Principal Component Analysis contribute 79.9% of variation can describe by the first three PC or if used 2 dimensions from contribution principal analysis so, 70.4% from variation can describe by the first two PC. Based on the score plot graphic showed measurement by an electronic nose with processing data by PCA method, the score plot obtained 3 groups data is good. Data groups red colour spots from the smell of the mouth of a healthy person, the green colour spots diabetes mellitus and the blue colour spots from bad breath pulmonary tuberculosis.

Figure 2 shows the PCA cannot classify the data group from the three types of data collections desired. Because while taking data, we are difficult to treat the patient's condition. For example, when patients will be taking data, must be teeth brush and do not eat before their lousy breath is taken. It's challenging for us, because of there some patients inattention with our device. This problem is possible to impact on some spots will cross into other data's groups. This spot is possibly caused by the censoring smell affected by the smell of food that has been eaten.

Another problem is the place ballon's sample. In our opinion, the place ballon's sample it has smell itself, which is not less powerful. It can be influenced by research results. Overall the results showed nice grouping. Moreover, it was already seen spots group from patient's diabetes mellitus, group of pulmonary tuberculosis and people healthy groups.

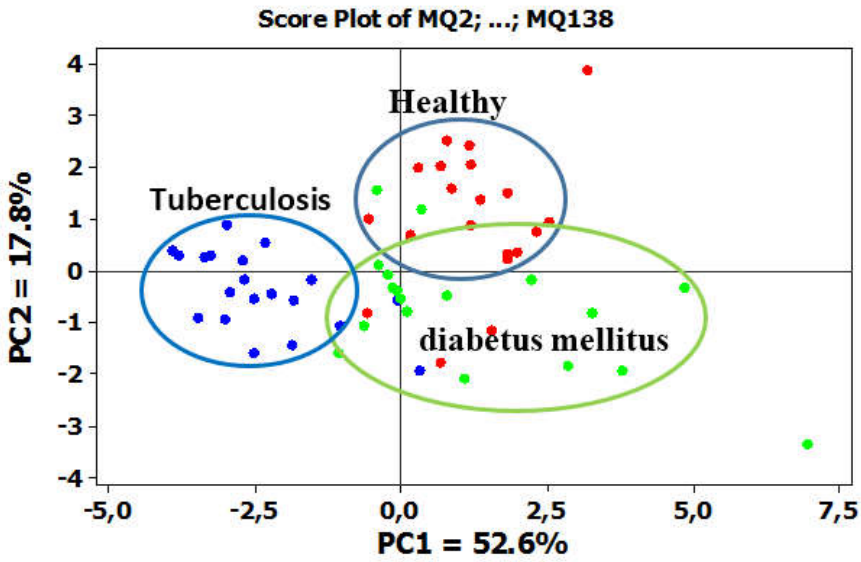

FIGURE 2. Score Plots of Data Groups

SUMMARY

The data acquisition system using E-Nose can be built from the MQ series gas sensor array at a relatively cheap cost. This sensor is found and sold freely. E-Nose data acquisition system built is a PC-based acquisition system. This data acquisition system measures the smell of gas and stores digital data on the computer properly. Data stored in digital format on a computer is processed and analyzed with numerical integrals and PCA multivariate statistics.

Based on the research data, it can be concluded that the score plot of each response showed a perfect classification between 3 groups of data, namely: the breath group of healthy people, diabetes mellitus breath group, and breath group of pulmonary TBC.

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