Identifying Tuberculosis through Exhaled Breath by Using Field Programmable Gate Array (FPGA) myRIO

Hendrick, Nadia Alfitri, and Andrizal
Electrical Engineering Department, State Polytechnic of Padang, Padang, Indonesia
Email: {hendrick, nadiaalfitri, andrizal}@polinpdg.ac.id

***Abstract*—In this research we purposed to detect tuberculosis by using electronic nose through breath air. Also in this research, we made use of field programmable gate array (FPGA) myRIO made by National Instrument. We used a set of array to detect TB placed in sensor room. What the subject needs to do is just exhale into the space of the array. Creating the pattern of TB, this equipment applies Fast Fourier Transform (FFT) method so that the form of TB data known as BTA+ will be produced. The result gained was good enough which can be seen through the change of magnitude occurring when processed with FFT. The subject who was involved in this research has got medical checked up before and has been diagnosed BTA+. For the purpose of clarifying, we made use of Learning Vector Quantization (LVQ). Through offline test result, TB is well classified as expected.**

***Index Terms*—tuberculosis, field programmable array, TB marker, fast fourier transform, learning vector quantization**

I. Introduction

Tuberculosis is a kind of infectious disease which is caused by bar shaped bacterium (basil) or Mycobacterium tuberculosis. Chemical substance of this bacterium is classified in volatile organic compound(VOC) [1]-[3].In addition, many studies suggest there are more or less 130 kids of VOC in breat air [4], but the ones most commonly found are nephthalene, 1-methyl-, 3-heptanone, methyl-4-(1-methyl)- and cyclohexane.1,4-dimethyl. [5]

The object of this research is generally detected through the sputum as well as breath air based on TB marker gained from patient [4], [6]. This TB marker is formed through the sensor array response by using signal processing. The form of TB marker is then used to determine whether the patience is categorized as suffering TBC (BTA+) or healthy person. The method to detect voc sputum is by applying electric nose and chromatography. Most of sensor applied to chromatography makes use of surface acoustic wave [7]. This TBC identification has ever been examined before to cow, but itwas through the frozen serum and by applying the Principal Component Analysis (PCA) in order to group the TB and non TB identified data [8]. The identification can also be done through exhaled breath of a patient [9]. This can be carried out by way patient exhales into air bag. The breath air is then flowed from the air bag to sensor space using pump. Generally identification through exhaled breath makes use of chromatography.Only little research by making use of patients' exhaled breath for thepurpose of identifying BTA patient has been carried out. The research being done makes use of hardware and software national instrument. The hardware being used is Field Proggrammable Gate Logic (FPGA) myRIO [11]-[12]. And the software used for programming myRIO is LabVIEW along with other supporting Libraries.

An e-nose comprises of sensor, embedded device and PC as signal processing. In this research field programmable gate array (FPGA) is used so that e-nose which is produced is portable. Besides that, this research applies Learning Vector Quantization (LVQ) method in order to do data grouping.

II. Material and Methods

A. Human Subjects

Breath air used as sample in this research was the patient's breath air which has been analyzed by the doctor. Medical examination stages included blood examination, X-ray (Rontgen) and sputum. These stages were carried out in laboratory. And then the result of the examination was analyzed by the doctor who made sure the patient suffered TBC well-known as BTA+. The patients whose breath air was taken for this research were those who had been diagnosed BTA+1 and BTA+3. The breath air of every patient was taken 5 times. And this was done by way he or she exhaled through mouth into sensor space equipped with gas sensor array

B. Sensor Characteristics

Electronic Nose (e-nose) used in this research is based on gas sensor (development). To detect tuberculosis mycobacterium, gas sensor used were TGS 821, TGS 822, TGS 825, TGS 826, TGS 2600, TGS 2602, TGS 2610

Manuscript received August 14, 2014; revised December 19, 2014.

doi: 10.12720/joace.3.6.470-474

and TGS 2620[10]. Whereas this research made use of sensor as follows (Table I).

TABLE I. SPECIFICATION OF METAL OXIDE SENSORS FOR USE IN THIS E-NOSE SYSTEM

No	Sensor	Figure	Target Gas
1	TGS 2600		Air contaminant
2	TGS 4161		Carbon dioxide
3	TGS 2610		LP Gas
4	TGS 2620		Solvent Vapor
5	TGS 822		Organic Solvent vapor
6	TGS 825		Hydrogen Sulfide

C. *Electronic Nose System*

Electronic Nose (e-nose) is a system comprising gas sensor array with different sensitivity, signal processing unit and pattern recognition. This research is particularly aimed at creating e-nose on Field Programmable Array (FPGA). This system making makes use of software LabVIEW National Instrument. To take breath air sample was directly conducted by way of exhaling into the sensor space. This research makes use of gas sensor array which is made by Figaro. Gas sensor output is resistance, so a signal conditioner is required. Signal conditioner has principle of voltage dividing circuit. Gas sensor circuit is in Fig. 1.

Signal processing unit used in the e-nose applies Fast Fourier Transform (FFT) which functions to do data conversion from time to frequency domain.

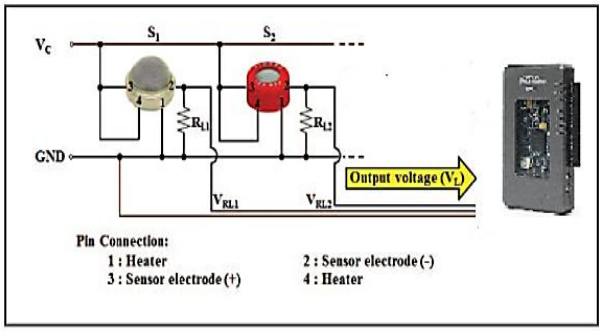

Figure 1. Sensor circuitry

LVQ with the architecture as seen in the Fig. 2 is made use in this research:

LVQ yang digunakanterdiri 24 node input dan 2 node output (2 class). Input node LVQ didapatkandarihasil proses pembuatanpola.

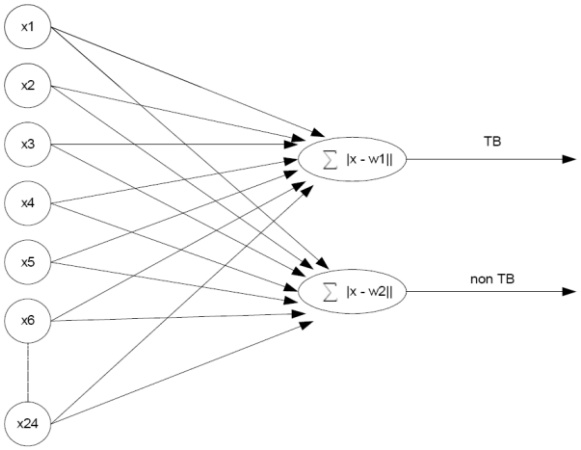

Figure 2. Arsitetur LVQ

III. RESULT

Data collecting is carried out by using sampling frequency as big as 1 kHz and 1024 points of FFT. Program which is applied for collecting gas sensor data is through channel analog input as seen in Fig. 3:

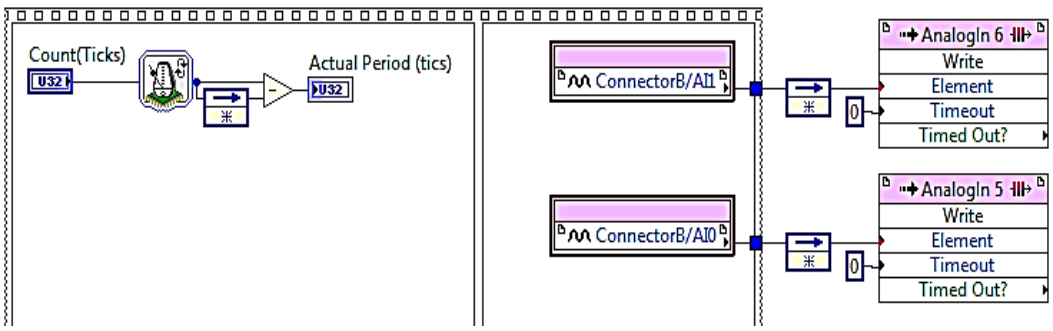

Figure 3. Analog read (Target)

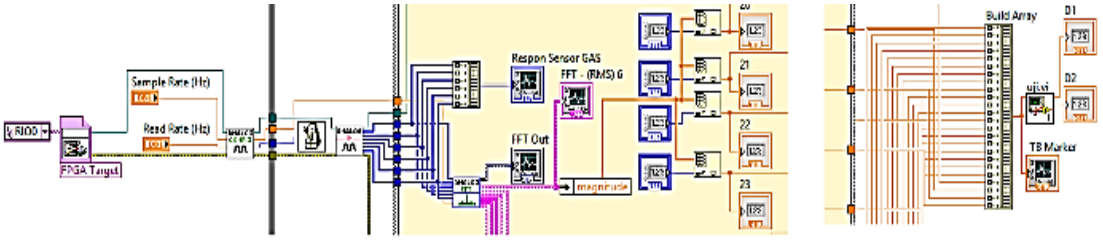

Figure 4. Program FPGA (Host)

Analog input consists of 6 channels.The data of signal conversion result is then saved into the memory. The above program is included in FPGA myRIO (target) whereas, the program used by the host is as seen in Fig. 4:

Listing program in the host normally comprises of several VIs, they are FPGA target, AnalogInConfig, AnalogIn, FFT, frequency selector andtest vi.Test VI it self consists ofprogram for LVQ training and LVQ identification. LVQ training program makes use ofmathscript as seen in Fig. 5:

```
%program lvq

s=[14.24, 177.91, 6.81, 0.08, 14.26, 178.05, 6.82, 0.06, 14.91, 209.68, 14.74, 2.08,
  15.69, 210.86, 14.12, 2.74, 15.79, 217.56, 16.26, 3.66, 15.78, 217.55, 16.27, 3.67,
  14.21, 173.79, 5.99, 0.18, 14.21, 173.88, 5.98, 0.16, 14.25, 174.22, 5.99, 0.19, 0.5
  15.87, 224, 18.03, 5.09, 15.82, 223.58, 17.98, 5.08, 15.72, 218.22, 16.24, 3.91, 8.
  15.89, 238.71, 23.33, 5.64, 15.89, 238.81, 23.38, 5.66, 15.99, 240.44, 23.96, 6.08,
  16.14, 252.79, 29.19, 9.51, 16.15, 252.92,29.19, 9.52, 16.11, 247.71, 26.65, 7.71,
  17.18, 259.55, 30.75, 8.98, 17.18, 259.65, 30.77, 9.01, 17.22, 260.20, 30.84, 9.04,
  15.96, 234.46, 23.01, 9.80, 15.91, 231.37, 21.31, 8.14, 15.92, 233.99, 22.93, 9.73,
st=[1 2 1 2 1 1 2 2];
alpha=0.6;
%initial weight matrix first two vectors of input patterns
w=[s(1,:);s(2,:)]';
disp('initial weight matrix');
disp(w);
%set remaining as input vector
x=[s(3,:);s(4,:);s(5,:);s(7,:);s(6,:);s(8,:)];
t=[st(3);st(4);st(5);st(7);st(6);st(8)];
con=1;
epoch=0;
while con
  for i=1:6
    for j=1:2
      D(j)=0;
      for k=1:24
        D(j)=D(j)+(x(i,k)-w(k,j))^2;
      end
    end
    for j=1:2
      if D(j)==min(D)
        J=j;
      end
    end
    if J==t(i)
      w(:,J)=w(:,J)+alpha*(x(i,:)'-w(:,J));
    else
      w(:,J)=w(:,J)-alpha*(x(i,:)'-w(:,J));
    end
```

Figure 5. Training LVQ using mathscript

The Output of LVQ training program is weight for BTA+ and healthy patient. The weight is applied into identification program as seen in Fig. 6:

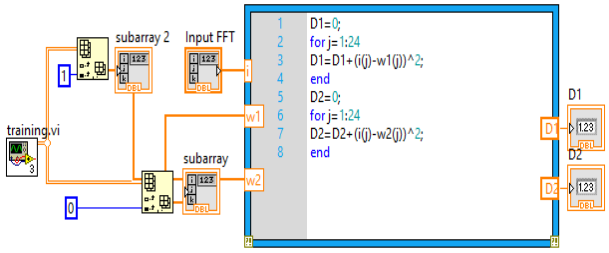

Figure 6. LVQ identification program

the identification program as seen in Fig. 6 owns two variable inputs; exhaled breath pattern and weight which is then processed by apllying mathscript as in above figure. The identification output is classified as D1 and D2. If the value of D1 is smaller than that of D2, then it will be grouped into BTA+. If D2 is smaller, then it will be grouped into healthy person. Fig. 7 shows the whole used in this research

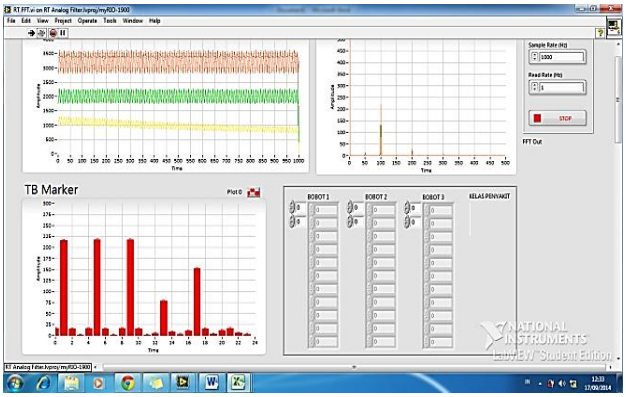

Figure 7. Front panel host program

A. *Sensors Response*

The gas sensor response to the breath air of the patient diagnosed as BTA + fluctuates. The response of Gas sensor array fluctuates due to the effect of the existing air within the sensor space. The response of sensor array is seen in Fig. 8. Each of sensor gas has different voltages. Sensor 1, for example is always at range of 1500mV. All of gas sensors give response to patient's breath air

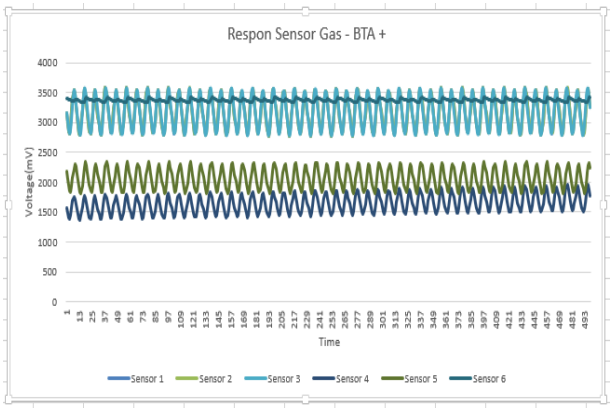

Figure 8. Response of gas of patient TB

Fig. 9 shows the response of gas sensor to breath air of healthy patient. Sensor 5 has the smallest voltage value at range 1000mV.

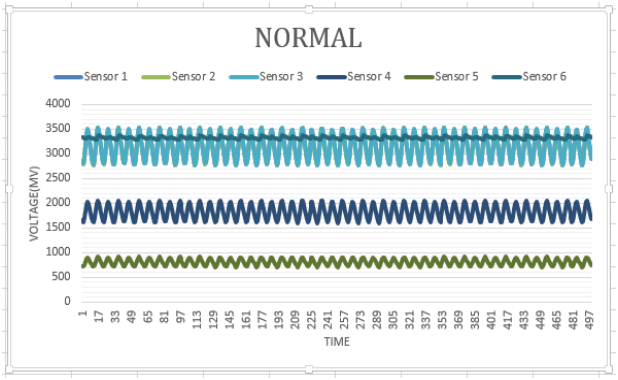

Figure 9. Response of gas of healthy patient

The graph resulting from gas sensors has frequency value for BTA patients and healthy persons. Therefore, FFT is used to see the frequency value in each of the sensor gas. This can be carried out by using FFT so that the sign which is previously in the time domain turns into the domain of frequency.

B. FFT Output

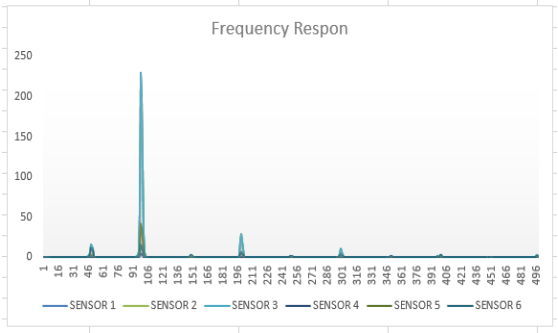

Figure 10. FFT output

TB marker was formed on the base of frequency of each gas sensor after FFT process was done. The form of FFT is seen in Fig. 10 which shows frequency in the signal with value 50Hz, 100Hz, 150Hz and 200Hz. magnitute is always gained at the frequency of 100Hz, while at other frequencies, the magnitute is always below 50. To make TB marker, some components of frequency which represent TB marker and non TB marker pattern were chosen. As the result, each sensor has 4 frequency components. After that, every data collecting as well as testing makes use of the frequency. TB marker is formed as seen in Fig. 10. The following is the composition of TB marker for each of used gas sensor.

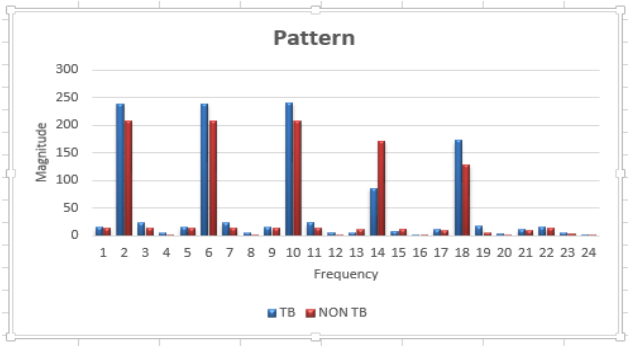

Figure 11. Comparison ofTB pation and Healthy Person exhaled breath

C. TB Marker

After several tests were conducted, ingeneral the same patterns were gained. After that normalization was carried out to get the graph as seen in figure 12BTA data pattern or TB marker is the red one and the data pattern of healthy person is the blue one.

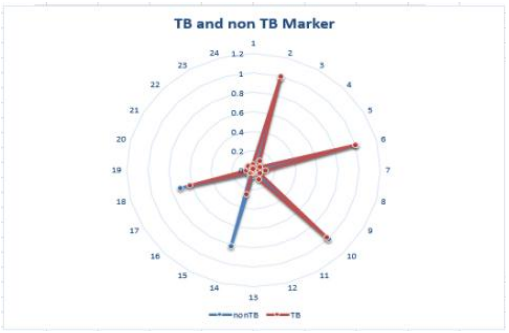

Figure 12. TB Marker

LVQ involved 24 inputs and 2 classes as TB and healthy person. From the LVQ training result, the quntity gained is in Table II. This weight was then used in identification process.

TABLE II. TB MARKER AS LVQ INPUTS

CLASS	1	2	3	4	5	6	7	8	9	10	11	12
BTA +	14.987	205.13	14.801	3.3688	14.992	205.24	14.807	3.3636	15.092	207.99	15.22	3.2767
Healthy patient	16.385	237.05	23.195	8.1196	16.347	235.7	22.453	7.3707	16.328	235.88	22.944	7.9422

13	14	15	16	17	18	19	20	21	22	23	24
2.3447	36.372	3.5497	0.92562	6.2874	94.045	8.7065	2.1254	10.782	14.839	4.3611	1.6216
6.6379	94.594	8.7364	2.8439	0.7982	6.6745	0.15075	0.25953	2.482	4.9946	2.0464	1.3692

D. Conclusion

The gas sensor response has certain frequency value for each of sensor. This is indicated by the response of gas sensor which is fluctuative. FFT has made it easy in making the pattern. It can be indicated by the change of magnitude value of sensor. The change of the magnitude can differentiate between breath of TB patient and healthy person. LVQ succeeded to classify data well. Hence it is automatically easy to be identified. The test of LVQ is still OFFLINE. For the future development, the test will be conducted ONLINE testing. We will add sensors to increase identification level and change the FPGA type. This is aimed at making this system portable. Hence all of the process is within the FPGA.

REFERENCES

[1] A. D. Wilson and M. Baietto. "Advances in electronic-nose technologies developed for biomedical applications," *Sensors*, pp. 1105-1176, 2011.

[2] A. Martinex-Romero, "Comparison of acid-fast bacilli smear and chromatographic immunoassay in patients with active tuberculosis," *African Journal of Microbiology Research,* vol. 6, no. 8, pp. 1690-1693, 2012.

[3] K. Clifford, "Development of a surface acoustic wave sensor for In-Situ monitoring of volatile organic compounds," *Sensors.*

[4] M. Philips, "Volatile biomarkers of pulmonary tuberculosis in breath," *Elseiver*, pp. 44-52, 2007.

[5] M. Philips, "Point of care test for Biomarkers of active pulmonary Tuberculosis," *Elseiver*, pp. 1-7, 2012.

[6] M. Philips, "Breath biomarkers of active pulmonary tubercolosis," *Elseiver*, pp. 1-7, 2010.

[7] S. Che, Y. C. Wang, and S. Cho, "Applications and technology of electronic nose for clinical diagnosis," *Open Journal of Applied Biosensor, Scientific Research*, pp. 39-50, 2013.

[8] P. Pasini and N. Powar. "Use of a gas-sensor array for detecting volatile organic compounds (VOC) in chemical induced cells," *Springer-Verlag*, 2003.

[9] T. Seesaard, C. Khunarak, and T. Kerdcharoen, "Development of an electronic nose for detection and discrimination of exhaled breath of hepatocellular carcinoma patients," in *Proc. IEEE International Conference on Systems, Man, and Cybernetics*, Seoul, Korea, Oct. 2012.

[10] D. M. Guo, "Automatic breath signal analysis and system design for medical Application," 2011.

[11] National Instruments, "NImyRIO Design Real Systems, Fast."

[12] National Instruments, "Getting Started With LabVIEW FPGA."

Mr. Hendrick was born in Padang, in 1977. He received the Bachelor's and Master's degree in Engineering Electronics from The Sepuluh November Institute of Technology, Surabaya, in 2003 and 2010, respectively. He is currently Lecturer of Electronics Department of Padang State Polytechnic, Sumatera Barat. His research interests Image Processing, Artificial Intelligent and Human Computer Interaction. He also did a project in electronic nose.

Mrs. Nadia Alfitri was born in Padang in 1976. She received her Bachelor's degree in Engineering Electronics from The Brawijaya University and Master's degree in Engineering Electronics from The Bandung Institute of Technology., in 2002 and 2007, respectively. She is currently Lecturer of Electronics Department of Padang State Polytechnic, Sumatera Barat. Her research interests Image processing and microcontroller.

Mr. Andrizal was born in Saruaso, Batusangkar, in 1968. He received his Bachelor's and Master's degree in Engineering Electronics from The Bandung Institute of Technology, in 2001 and 2005, respectively. He is currently Lecturer of Electronics Department of Padang State Polytechnic, Sumatera Barat. His research interest Image Processing and Real time system