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

myRIO

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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 breath 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 it was 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 the purpose 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 Programmable 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 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...
and TGS 2620[10]. Whereas this research made use of sensor as follows (Table I).

<table>
<thead>
<tr>
<th>No</th>
<th>Sensor</th>
<th>Figure</th>
<th>Target Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TGS 2600</td>
<td></td>
<td>Air contaminant</td>
</tr>
<tr>
<td>2</td>
<td>TGS 4161</td>
<td></td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>3</td>
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</tr>
<tr>
<td>4</td>
<td>TGS 2620</td>
<td></td>
<td>Solvent Vapor</td>
</tr>
<tr>
<td>5</td>
<td>TGS 822</td>
<td></td>
<td>Organic solvent</td>
</tr>
<tr>
<td>6</td>
<td>TGS 825</td>
<td></td>
<td>Hydrogen Sulfide</td>
</tr>
</tbody>
</table>

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.

![Sensor circuitry](image1)

**Figure 1.** Sensor circuitry

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

LVQ yang digunakan terdiri 24 node input dan 2 node output (2 class). Input node LVQ didapatkandari hasil proses pembuatan pola.

![Arsitetur LVQ](image2)

**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:

![Analog read (Target)](image3)

**Figure 3.** Analog read (Target)
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 and test VI. Test VI itself consists of program for LVQ training and LVQ identification. LVQ training program makes use of mathscript as seen in Fig. 5:

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:

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

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**

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. magnitude is always gained at the frequency of 100Hz, while at other frequencies, the magnitude 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, every 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.

**C. TB Marker**

After several tests were conducted, in general 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.

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

<table>
<thead>
<tr>
<th>CLASS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td>2.3447</td>
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<td>3.5497</td>
<td>0.92562</td>
<td>6.2874</td>
<td>94.045</td>
<td>8.7065</td>
<td>2.1254</td>
<td>10.782</td>
<td>14.839</td>
<td>4.3611</td>
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<tr>
<td>6.6379</td>
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<td>2.8439</td>
<td>0.7982</td>
<td>6.6745</td>
<td>0.15075</td>
<td>0.25953</td>
<td>2.482</td>
<td>4.9946</td>
<td>2.0464</td>
<td>1.3692</td>
<td></td>
</tr>
</tbody>
</table>
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


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