Construction of a Portable Modified Electronic Stethoscope (Hardware Design)

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***Abstract* – Stethoscope is one of the most common analog diagnostic instruments a medical practitioner uses in its field, especially for auscultation. Auscultation is the method used to listen to the sounds of the heart and lungs. Together with the advancement of the technology, this analog device is transformed into more advanced, digital user-friendly aid which is a big help for faster and more accurate readings of data. This study aims to develop and construct the best and efficient design of Electronic Stethoscope. It specifically aims to accomplish the following: (1) to determine the stethoscope that has the best material but not costly for the device's main body, (2) to acquire suitable and portable microphone with the ability to record clearer sounds, (3) to design a tube with the most effective way to connect the microphone with the analog stethoscope. The device is constructed using a Littman Stethoscope, a 5-mm diameter Lavalier condenser microphone and an audio jack that can be connected to any mobile devices that has the application to record and save sound files. The result of the construction and testing shows that the modified device is able to gather and record the lung sounds with a better quality and also, the cost-difference and accessibility of the device are visible compared to the electronic stethoscope available in the market.**

***Index Terms* – Auscultation, Advancement, Microphone, Stethoscope.**

I. INTRODUCTION

Respiratory sounds provide the basic segment of diagnosing and monitoring a patient's pulmonary ailment and is regarded as an important source of data for the trial of condition of the lung. These respiratory sounds can be classified as normal, for healthy people, and abnormal lung sounds, for people with sickness. The main categories of these abnormal lung sounds are: wheeze and crackles, also called rales. Wheeze is heard with a high-pitch whistling noise during inhalation or exhalation caused by narrowing of airways blocking the air flowing through them. It lasts up to more than 100 ms and dominant frequency is usually over 600 Hz. Patients with wheeze can be diagnosed with asthma, COPD, bronchitis or pneumonia. However, crackles or rales are series of short, and explosive sounds and can be heard mostly during inspiration but can also be heard during expiration. It si characterized by its dominant frequency of 2000 Hz and shorter than 100 ms duration. During breathing, rales indicate that the lung's air sacs are filled with fluid. Rales can be caused by pneumonia, heart disease, pulmonary fibrosis or lung infections. [1] These sounds can be acquired through a procedure called lung auscultation. Lung auscultation is performed for the purpose of examining respiratory system as the initial step in checking the patient's wellbeing. It is simple and non-invasive. Although, stethoscope, instrument used for auscultation, is still widely used tool today, the inevitable human error still occurs when conducting the auscultation test manually. As the time passes by, the booming of technology greatly helps in the field of medicine, and one of it is the enhancement of the classic stethoscope. [2] The aim of this study is to develop and a portable and efficient modified acoustic stethoscope, that records the lung sound of the patient, and produce a clearer and more distinct sound files by the simplest possible connection of microphone and stethoscope.

II. METHODOLOGY

The proponents tested different brands of stethoscope, microphone, and tube connectors to make the device come into reality. This approach provides simplified pattern that allows a clearer view on what things were considered with the construction of the project.

A. *Stethoscope*

For the main body of the device, the proponents are to determine the best stethoscope with the highest quality of material and of lowest cost. Different materials of stethoscope produce different quality of sound. It is composed of ear tips, tube, stem and chest-piece and all of this contributes as a factor of changes in the quality of sound. The cost, design, availability in the market, and ability to receive great sound quality were took into considerations.

1) Prestige Stethoscope

The cost for Prestige stethoscope ranges from 800 up to 2000 pesos. It is budget-friendly and can be easily found in the medical market. It has double-head chest-piece – a diaphragm for high frequency sound and a bell for low-to-medium frequency sound. The length of the stethoscope is 28 inches.

2) Baxtel Stethoscope

Its price ranges from 600 up to 1600 pesos. It has same attributes as the Prestige stethoscope, it has a chest-piece with two sides, diaphragm and bell, that allows listening for wider or narrower area and picks up higher or lower frequency.

3) Littman Stethoscope

Litmann is a very well-known brand when it comes to stethoscopes. The price ranges from 4000 up to 5000. It has a versatile adult and pediatric 2-sided chest-piece – a dual single-piece tunable diaphragms which are both pressure sensitive. It has also high acoustic sensitivity, and the tubing is modifiable.

B. Microphone

Major part of the device is the microphone. The microphone plays a big role in the project because the intensity and quality of the lung sounds to be used as a data depends on the receiving capability of it. It must be of high quality and has the ability to record the sounds loudly, distinctly and clearly. The proponents tested the recording using an electret microphone and a ready to use lapel, or condenser, microphone.

1) Electret Microphone

Fig. 1. Electret Microphone

Electret microphone is a small microphone, enough to fit in the tube of the stethoscope, without connecting wires. It is required to be connected to a 3.5mm jack for it to be used.

2) Lavalier Lapel Microphone

Lapel is also an electret microphone only that it has a built-in audio connector. This condenser microphone is highly sensitive and records sound loudly and clearly. It is mostly used for media and guaranteed to have a best quality.

C. Design for tube connection

The tubes are designed to connect the microphone and the stethoscope. Placing the microphone directly to the tube of the stethoscope doesn't guarantee the microphone for full reception of better-quality sounds from the chest-piece of the stethoscope. The path that sounds will travel can also be a factor with the quality of the recorded lung sounds. It may be heard noisily, like popping, when sound waves bounce back from chest-piece to microphone.

1) T-shaped tube

Fig. 2. T-shaped tube

This were the first design for the connection of the microphone and stethoscope. The hole is where the microphone will be placed. It is designed as microphone is placed horizontally to avoid bouncing of sound waves since the microphone are highly sensitive.

2) Y-shaped tube

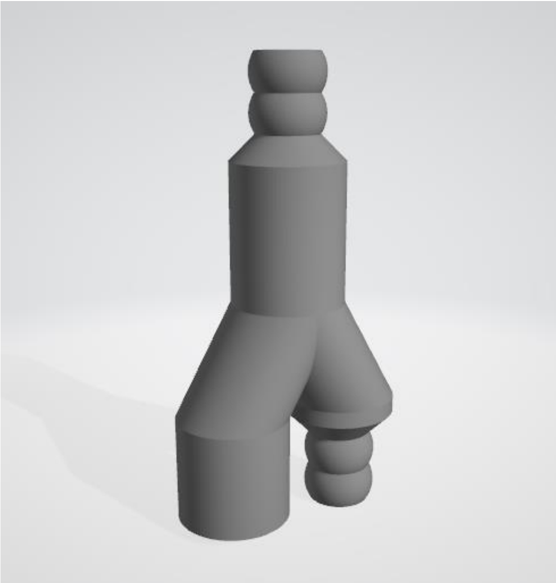

Fig. 3. Y-shaped tube

The other design is a Y-shaped tube. The dented surfaces are designed to give the tubing of stethoscope stronger grip and the hole is designed for the microphone. This design allowed splitting of the sound waves for the stethoscope's ear piece and microphone without directly travelling to the microphone which avoided the bounces of the sound waves creating a popping-like noise.

D. Pre-processing of data

Since the project aims to maintain the portability of the design, the proponents didn't depend on using microcontrollers for controlling of the gathered sound, instead pre-processing of the sound is conducted for the lessening of the environmental noise in the recorded lung sound by determining suitable filter. And create a representation using the features extracted from the lung sound, before and after the filtering. The parameters used is the Zero Crossing Rate and the Spectral Energy. The Zero Crossing rate determines the rate at which the signal changes from positive to negative, this determines the number of the signal's frequency. The decrease in Zero Crossing Rate proves that the signal is filtered. Spectral Energy describes how the energy of the signal is distributed with frequency.

III. RESULTS AND DISCUSSION

A. Selection of Stethoscope

Fig. 4. Littman Classic III Stethoscope

Technically, with specification of Prestige Stethoscope, it is suitable for the main body of the device, however, the chest piece cover is made of poor quality of plastic that sticks to the bare skin of the patients that causes additional unwanted sounds in the recording. On the other hand, the composition of Baxtel Stethoscope's tube is unable to fit the design of the project. The quality of the tubing is hard to modify and shows a sign of unreliability since the project will not be fixed in a specific location. And, for Littman Stethoscope, figure shown above, researchers invested to this brand since its technology is undoubtedly good compared to the first two brands. The covers of the chest-piece do not stick to the skin which helps the recording part to gather only the intended sounds of the project and the tubing is flexible and very reliable for auscultation.

B. Microphone Selection

Fig. 5. Lavalier Lapel Application

Electret Microphone needs hands-on connection of its wires which requires a precise soldering. Meticulous soldering is needed because being uncareful can damage the microphone and cold solder can cause static sound when it is in use. Exposition to heat for too long can damage it also. Even though its price is low, the proponents don't settle for it because it has low quality properties and for short term use only. While with the condenser microphone, shown in the figure above, it that gives assurance to the reliability of the electronic connections and quality of the sounds it receives. The available audio connector it has also helps the proponents for the simplification of its connection to the mobile device to be used.

C. Selection for suitable tube design

The connection T-shaped tube design fit so well only that it cannot support the weight of the microphone's connecting wire for a long time. It is not also very convenient to use since it is placed near the handle of the stethoscope. That's why the proponents come up to a new design, which is the Y-shaped tube, it designed to provide proper fitting that can also support the weight of the two parts, chest-piece and ear tips, and also it provides convenience to the user since it is small in size and doesn't block the hands of the users. This connecting tube allows the users to record the lung sounds while listening to it at the same time since it is design to have a special hole for the earpiece.

D. Overall Data Gathered Analysis

Each of the constructed models were tested to gather data-lung sounds, from the patients and checked the best quality it provides for the comparison and choosing the best modified model to be used. The models were constructed as best-to-best and least-to-least materials of all the components for the model.

1) Zero Crossing Rate

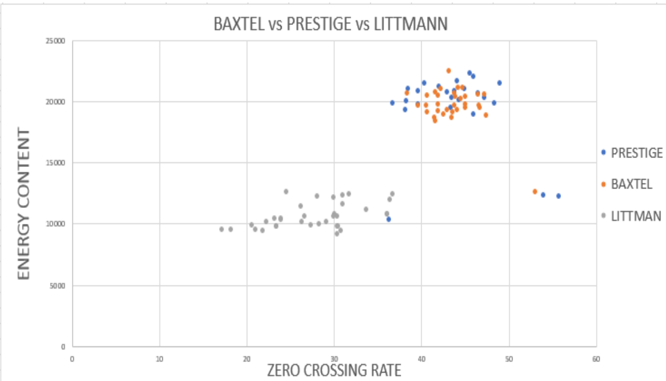

Fig. 6. Energy Content vs. Zero Crossing Rate

Zero Crossing rate determines the rate at which the signal changes from positive to negative, this determines the number of the signal's frequency. Low Zero Crossing Rate indicates lesser noise. Based on the result the scattered plot shows, Baxtel and Prestige has a high Zero-Crossing Rate compare to the Littman stethoscope. As it shows, Prestige's and Baxtel's recorded sound has lower audio and barely audible indicating that the higher the Zero Crossing Rate is the lower the amplitude.

2) Variance

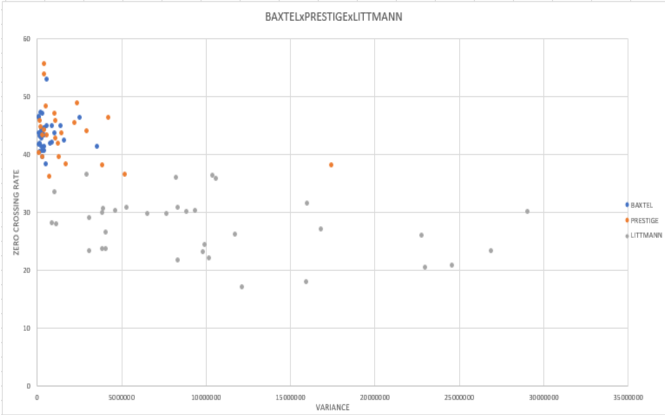

Fig. 7. Zero Crossing Rate vs. Variance

Variance is a time domain-based feature, it is defined as the measurement of the spread of a distribution, wherein in this study, this distribution is the amplitude. In this scattered plot, it is also shown that for Prestige and Baxtel Stethoscope the recorded sound is inaudible (lesser amplitude) resulting to smaller variance compared to the Littman Stethoscope.

E. Filtering

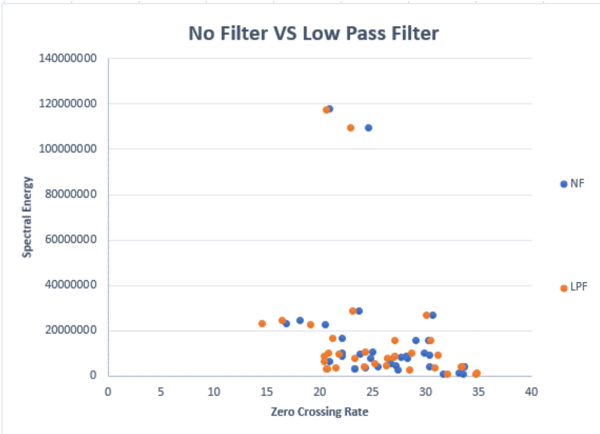

Fig. 8. Scattered Plot of Low Pass Filtering

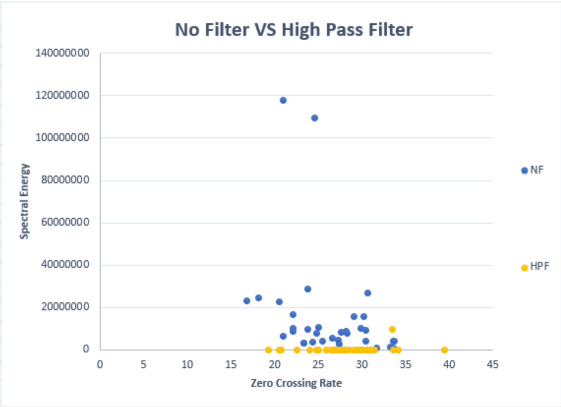

Fig. 9. Scattered Plot of High Pass Filtering

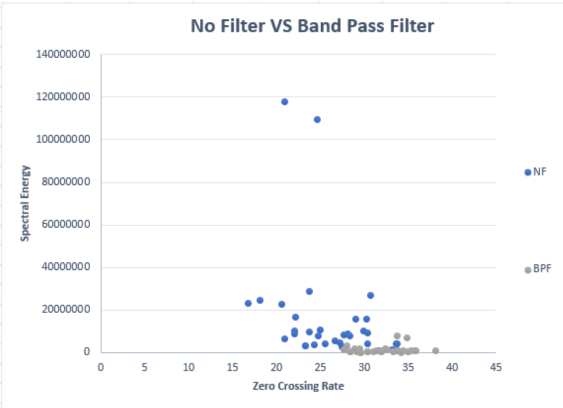

Fig. 10. Scattered Plot of Band Pass Filtering

Differences between the compression of the Zero Crossing Rates of each filter are visible through the three scattered plots shown above. Except with the manual hearing test, for whether the sound is enough filtered. The proponents made this representation to prove that graphically, Band Pass Filter is the suitable filter for the lung sound extraction. The compressed Zero Crossing Rate proves that the filtered sound sticks to the same rate of the its positive and negative cycle, cutting off the unwanted frequencies. For the Spectral Energy the limiting of frequency leads to the lessening of energy distribution. With the results, it is proven that Band Pass filter with the limit of 600Hz-2000Hz is suitable in the pre-processing part

IV. CONCLUSION

In conclusion, the modified stethoscope was constructed with best-to-best materials of the components and it was able to provide a reliable result with the great quality of lung sounds. Best-to-best materials are constructed using the Littman Stethoscope and Lavalier Lapel Microphone connected using the Y-shaped tube design. The model was tested, and it provided a loud and distinct quality of data with lesser environment noise and even static noise were also avoided. The device is designed portably which enables the user to record the lung sounds conveniently and listen to it at the same time. Overall, the modified stethoscope achieved and maintained the desired and original function as the hardware part of the Automatic Lung Sound Analyzer which is a great help as an aid for the patients in the remote areas that lacks doctors in doing the basic test such as the automation of auscultation, it is also a great help for the new medical practitioners who are a bit confused in the differentiating the lung sounds. This model is portable, accessible and very easy to use.

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