Design and Development of An Additive Tool to Increase the Accuracy in Detection of Cardiac Malfunctioning from Heart Sound

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***Abstract*— Throughout the world, a major prevalent threat to human being is cardiovascular diseases. The detection of Heart Sound has become a preliminary screening tool for a wide range of medical tests. It is a noninvasive assistive diagnostic tool which helps the physicians in predicting cardiovascular diseases. In this paper, we are presenting the work on the design and development of the additive tool which is based on heart sound signal acquisition and splitting with the computer-aided platform. These are mainly covering the major aspects like heart sound theories, relationship between 4 different heart sounds and cardiovascular diseases. The technologies used in the workflow are acquisition of the heart sound signals from indigenous kit, denoising the signal, processing, splitting and analysis of four different heart sound signals on different subject under various age groups and physical condition. It is a real time heart sound hearing, monitoring system with a visual display.**

Keywords:* *heart sound, cardiovascular disease, phonocardiograph, bio-signal

I. INTRODUCTION

Due to the turbulent flow of blood and the vibrating cardiovascular structures, heart sounds & murmurs are produced. Important information about cardiac diseases is obtained from the Phonocardiography (PCG) used together with the Electrocardiography. Though ultrasounds are used to acquire additional quantitative indices of the cardiovascular health, yet PCG is simple and sophisticated heart sounds investigations tool [1].

This is because they are non-invasive, economical, easier and accurate methods for assessing different pathologies of heart valve. The detection of third & fourth heart sound in adults is revealed as a simple method for systolic heart failure discovery [1].

The S1 & S2, first heart sound and second heart sound respectively as shown in Wiggers diagram are easily audible in nature. The time duration of them is around 150 ms and 120 ms respectively with a corresponding frequency ranges from 20 to 150 Hz. First heart sound is associated with the closure of the mitral-tricuspid valve and it occurs at the time of the iso-volumetric contraction of the ventricles. At the time of the iso-volumetric relaxation of the ventricles, second heart sound occurs and it is related to the aortic-pulmonary valve. And the remaining two (S3 & S4) i.e the third heart sound and fourth heart sound are very light with low frequency and almost inaudible in nature. S3 happens at the beginning of the diastole and is not originated from the valve, it is known as Proto diastolic sound. Because of blood flow in bulk into the left ventricles, there are vibrations in the valve. The fourth heart sound is not usually found in adults and is mainly found in the healthy children. Pathologically, it is called pre-systolic gallop when found in adult.

The healthy cardiac sound signals are the signals which have a clear sound of S1 (‘lub’) and S2 (‘dup’) and almost negligible sound of S3 and S4. [2,3]. Varying physiological conditions governs the intensity of the first heart sound (S1 or lub).

In persons with emphysema, obesity, pericardial effusion, myocardial disease or mitral regurgitation, decreased first heart sound is observed. The vigour of the ventricular systole has an effect in the alteration of intensity (increase) of first heart sound. Thus it leads to loud sounds in exercise, emotional states and in hyperthyroidism, anemia, mitral stenosis and hypertension. Many researchers have discussed the conditions giving rise to change in intensity of the first heart sound [4-7]. The relationship between ECG and PCG can be well understood from Wingger diagram.

The figure depicts that S1 occurs with low frequency vibrations approximately 0.05 second after the onset of QRS-complex of ECG signal. The starting time of S2 in ECG is approximately 0.03-0.05 second after the end on T wave. Again, S3 starts at 0.12-0.18 second after the onset of second heart sound (S2) and the fourth heart sound (S4) starts approximately 0.12-0.18 s after the onset of P wave of ECG signal.

Two major components are there for S1 & S2, they are M1 and T1, A2 and P2, respectively. M1 is due to the mitral closure and interruption in blood flowing in left atrial and systolic ventricular and T1 is for tricuspid closure. A2 starts before aortic valve closed, and P2 starts after pulmonary value closure, both are caused by intra-ventricular pressure dropping and blood returning in diastole. The delay time between M1 and T1 is the first split and that for A2 and P2 is the second split. Discrimination between the normal or pathological type is made on the measurement of the first and second split, lower or higher than 30 ms [8]. In case of abnormal auscultatory findings, often the test is followed by echocardiography. There is a need of developing a more practical, inexpensive, reliable and non-invasive approach to auscultation for continuous monitoring as there is a lack of reliability of ordinary auscultation and also it is expense and there is awkwardness of echocardiography. [9-12].

At present, there are about 290 million people suffering from cardiovascular diseases in many countries alone, so the prevention and treatment of cardiovascular diseases have become an urgent issue for health-conscious people. Heart sounds—the sounds made by the heart systole and diastole—are recorded as heart sound signals. It is also known as phonocardiography (PCG), whose acquisition system is noninvasive and easy Digital Subtraction Analysis of the heart murmurs signal using a custom computer program called Murmurgram is done for the detection and characterization [13-15]. Through PCG data processing and analyzing, the results can be used as an assistive diagnostic tool for the prediction of cardiovascular diseases. Because of the heart sounds' characteristics and the presence of noise in the environment, challenges are there in the detection of heart sound signals. On the one hand, the randomness and variability found in the cardiovascular disease symptoms is the reason for the complexity and diversity in the signal manifestation. On the other hand, heart sound signals are relatively weak, and the acquisition process of the original signals can be affected easily by various noises and interferences, resulting in noisy data collected. It can reduce the accuracy of related parameter extractions and increase the uncertainty of diagnosis.

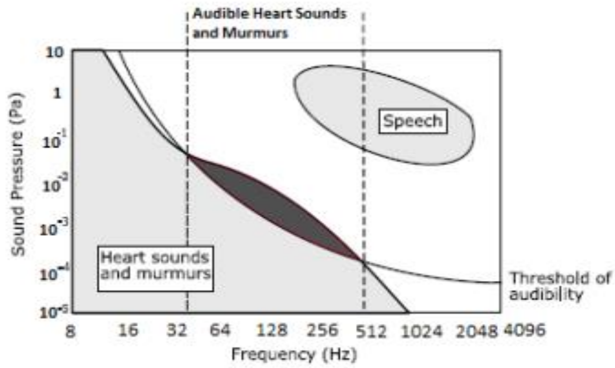

Figure 1: Relationship between the acoustic range of cardiac sounds and the threshold of audibility of sound pressure for human ear (figure redrawn from Leatham [16])

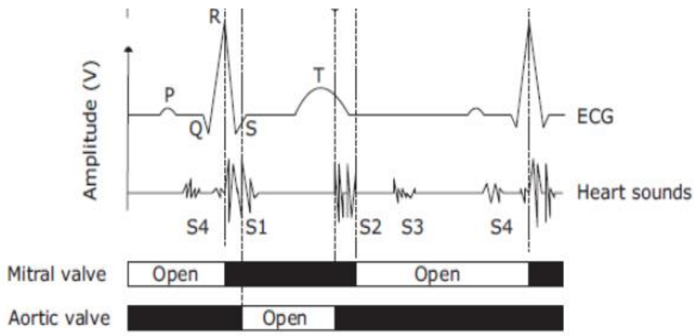

Figure 2: Wiggers diagram showing pressures and flows in the left side of the heart over one heart cycle and their relation to electrical (ECG) and mechanical (PCG) activity [17]

II. METHODOLOGY

Working methods of this project is subdivided into these following stages: • Signal Acquisition • Filtering Unit
• Digital Signal Processing unit • Display System

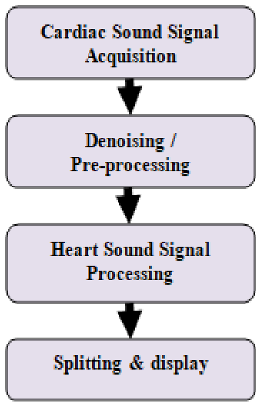

Figure 3: Flow Chart representing the methodology of work

Signal Acquisition: It's the initial part of the work. A condenser microphone containing digital chest piece is used to acquire the phonocardio-signal from the subject's heart.

Filtering Unit: Since the heart sound signal is type of bio-signal, so presence of noise will be there. Thus, in the next stage we did denoising of the signal. Filtering unit is composed of four band-pass filters that is the junction in between acquisition system and PC device. Band-pass filters can separate each of the heart sound in different frequency ranges. Then these signals were fed into the computer system through an analog to digital convertor. DAQ may be used too.

Digital Signal Processing Unit: In the computer system, the acquired signals were subjected to digital noise cancellation algorithms followed by the amplification of the heart sound signals.

Display System: The platform THINKLAB Phonocardiogram was used for splitting the heart sound signal into its four components i.e SplitS1, SplitS2, SplitS3 and SplitS4 and displaying the result.

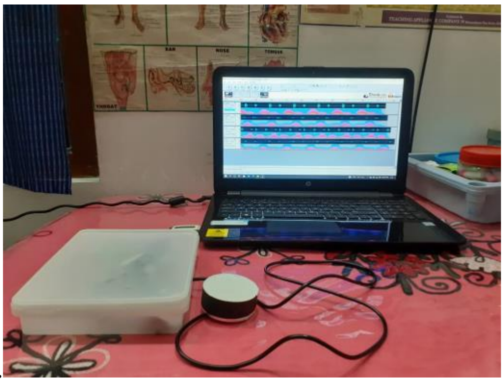

Figure 4: Set up for signal acquisition and processing

Figure 5: Sample photos of signal acquiring

III. RESULTS & DISCUSSION

The test was carried out on 20 different subjects within the age group of 20-65 years. Their heart sounds were recorded through the developed kit. 10 sets of reading were taken from the subjects in normal conditions and 10 sets were taken under different conditions like smoking, running, exercising and other physical activities etc.

In the testing phase it has been observed that in all these cases, we are able to get the wave forms for 4 distinct heart sounds.

The experimental results suggest that this system can capture both S1, S2 (fundamental heart sounds) and is also, capable of capturing S3 & S4 (abnormal heart sounds) without aliasing. It is a fast, efficient and economical tool which may be utilized for the acquisition and the analysis of heart sound signals quantitatively.

From the studies we correlate the key components in the PCG Signals. When it is compared with the monitoring sequence of the patients' physiological parameters with the tagged database, not only one can obtain more intuitive diagnostic results but also the potential cardiovascular disease may be further inferred by the experts with their clinical knowledge. [18,19]

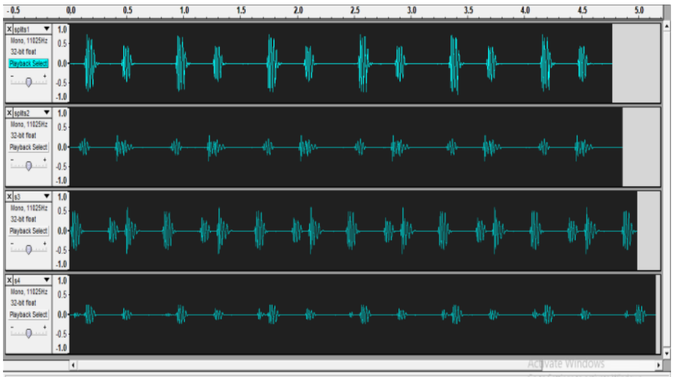

Figure 6: Waveform for four different heart sound separately

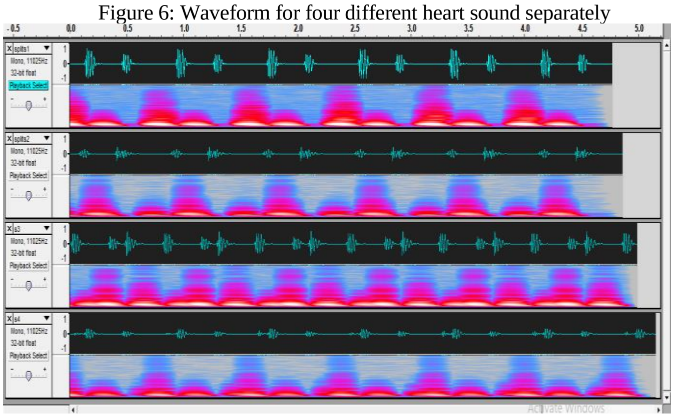

Figure 7: Frequency spectrum for four different heart sound separately

IV. CONCLUSION

It is a very low cost and useful additive tool. This device is unique because it can display with audio and frequency spectrum the 3rd and 4th Heart sound as well as 1st and 2nd Heart Sound. This unit can be used at home also since it doesn't require any prior training. It may be included as simple, low-cost, portable medical equipment in Emergency or ICU in Hospitals for clinical use. With further up-gradation in our work, the result will be easier to use in the field of cardiac research and also in Telemedicine.

From split S3 and split S4, we can interpret so many physiological informations, which may bring huge development in future medical technology. In this pandemic situation, the covid patients may use this product in home (as it is low in cost, easy to perform) as it can display all of their heart sounds. These signals provide the information about the acoustic activities relating to the sequence of the physiological signs that are present in the cardiac cycle. It suggests that the quantitative analysis of the heart sound may provide a new non-invasive technique for continuous cardiac health monitoring based on acoustic and improved detection of mechanical dysfunctions caused by cardiovascular and cardiopulmonary diseases.

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