# THE HEART AUSCULTATION. FROM SOUND TO GRAPHICAL

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### ABSTRACT

*Heart sounds and murmurs have very small amplitude and frequency signals thus make it so difficult to hear without the correct tools. In clinical practice currently, physicians listen to the patient heart sound and murmurs by using the traditional technique as an example mechanical stethoscope which having low accuracy and could lead to the false diagnosis. Moreover, conventional method has no ability to record the sound measured. Worst still it is totally depending on the physician's skills and experienced which this ability is decreased over time. This issue is highly important in early detection of heart sound abnormal. The stereo heart auscultation purposed in this research is to provide solutions rise from conventional technique. Furthermore, the sound signals produced from heart will be converted to the real-time graphically presented with time-frequency analysis, which provides more information about the heart conditions by sound produced. The system compromise hardware such as electrical transducer, electronic circuit, data-acquisition device, computer and also software for signal visualization or imaging. Database of heart sound and murmurs use to validate the developmental system replacing true patients. It has been demonstrated, in preliminary result, that heart sound classification according to on types of a valve problem such as aortic regurgitation, mitral regurgitation, tricuspid regurgitation, aortic stenosis and pulmonic stenosis could be differentiated using the development measurement system.*

*KEYWORDS: Heart sound; Transducer; Measurement system; Real-time graphical; Time- frequency analysis*

## 1.0    INTRODUCTION

In this chapter, the definition of auscultation, the heart sound signal, heart murmurs and issues on the conventional stethoscope and also relevant previous research are determining and presented.

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## 1.1    Ausculation

Auscultation is a method of listening to the sound of the body employing directly using ear or a stethoscope to determine or evaluate the duration, frequency, intensity and sometimes the quality in the sound produced by an internal body organ.

Auscultation of the heart could help physicians to diagnose many cardiac abnormalities using the stethoscope. The stethoscope can detect from low frequency to the high frequency of the heart sound. However, hearing the heart sound should be done in a quiet environment or low ambient noise to ensure that process attempt a possible disease (Karnath, B., & Thornton, W ., 2002).

## 1.2    Heart Sound

The activity of each cardiac cycle produced a sound which identified as heart sound or sometimes called as cardiac sound. This activity such as cardiac muscle contraction, blood flow and pressure and also opening and closing of heart valve, which generated a vibration that propagate through tissues up to the surface of the thorax, and it is measured as sound (Vikhe P.S., 2009, Zhongwei Jiang, Samjin Choi., 2006). This heart sound could be divided into four types, which are notified as first heart sound (S1), second heart sound (S2), third heart sound (S3), and fourth heart sound (S4).

Each sound has its own characteristics. S1 sound is longer than S2, which is shorter. The duration of S1 is around 0. 07s and frequency are between 10Hz to 140Hz. The S2 duration is 0. 04s and frequency are above 150Hz. S3 sound frequency is from 10 Hz to 50 Hz. The duration of this heart sound has between 0.07 to 0.12 seconds thus made it short and low pitched sound. The S4 sound duration is shorter, which is around 0. 02s. Because of these characteristics, many physicians having difficulties to capture S3 and S4. This sounds is important and determining a certain heart problem which sometimes leads to the fault diagnosis (Tseng, Y. L et al., 2012). Figure 1 shows the heart sound signal.
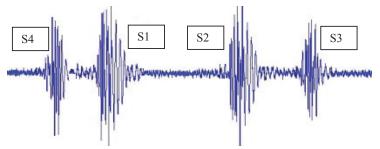
Figure 1. The illustration of heart sound signal

The "lub-dub" sound produced during closing major heart valve. The "lub" sound coming from tricuspid and mitral valve, which is S1 sound and "dub" sound associated with closing of semilunar valves (aortic and pulmonary) which is the S2 sound (Sharif, Z. et al.,2000). Moreover, the difference between these two sounds is intensity, and time occurs. S1 time is longer and softer sound compared to S2, which is shorter time but high energy. Meanwhile, S3 and S4 occurred after S2 and having a lower intensity or amplitude and very short time as we discussed in the previous paragraph.

### 1.3    Heart Murmur

Murmurs are identified as abnormal sound occurs, which may suggest the presence of a cardiac problem, especially on the heart valves. It caused by the turbulent blood flow in the heart system, and it is very important to verify the timing and pitch for diagnosis heart condition (Dokur, Z., & Ölmez, T.,2009). The heart murmurs hearing range could be a very low intensity to high intensity according to types of murmurs. However, not all heart murmurs occurred are harmless and not caused the heart problems. There are two classes of murmurs, systolic murmurs and diastolic murmurs. Aortic stenosis, Mitral and Tricuspid regurgitation occurs during systole and Mitral, and Tricuspid stenosis occurs during diastole. Figure 2 show example of normal and abnormal heart sound.
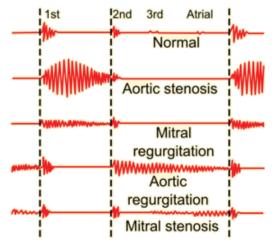
Figure 2. Normal and Abnormal Heart Sounds

## 1.4     The Auscultation

Usually, a doctor measure heart sound and murmurs by using traditional acoustic medical tools such as a stethoscope. Conventional stethoscope is not accurate. No immunity on environmental noise and detection are based on the physician's experience and hearing ability.  Moreover, low intensity and amplitude of heart sound almost impossible to detect clearly using conventional tools.

There is also much research develop an electronic stethoscope which amplified the heart sound. However, this tool still depending on the physician's hearing skill. (Kao, W. C. et al.,2011, Tourtier, J. P., et al 2011). Electronic stethoscope does not record or display the sound signal which is hard to determine the sound frequency component. Therefore, a digital signal processing with the help of a computer-based system is needed to help physicians to interpret in details the heart sound and murmurs in a graphical form for better identification of the heart problem.

## 2.0     METHODOLOGY

The system framework is shown In Figure 4. Basically, the system consists of hardware for signal acquisition and software for further signal processing and graphical presentation. The location of measurement and experimental work also presented.

## 2.1    Transducer

An electrical transducer from Multicomp, use in this system having a frequency response ranges from 15Hz to 15 KHz. The sensitivity of this transducer claimed by the manufacturer is -40±2dB at 1 KHz, super clarity and distortion-free features. This transducer also has a directivity of omnidirectional. The selection of a transducer is based on the heart sound frequency range and its amplitude. This transducer is embedded in the mechanical stethoscope diagram and connected to the designed conditional circuit.

## 2.2    Conditioning Circuit

The signal conditioning circuit consists of two elements, audio amplifier (LM386) and filtering circuit. The amplification of this circuit is set to be maximum of 5Vp with frequency filtering is set to 10Hz using an analog passive filter. The design circuit is simulated using Proteus Software to ensure the signal and frequency response should satisfy for heart sound and murmur's measurement. The circuit is constructed to a designed printed circuit board (PCB). Figure 3 shows the signal conditioning circuit
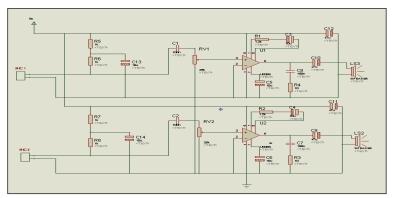


Figure 3. The signal conditioning circuit

## 2.3    Signal Acquisition

National Instrument DAQ model 6009 used to convert analog signal coming from the conditioning circuit into digital values to be fed to the computer for further processing. It has eight analog channel inputs, maximum 45K samples per second (S/s) and 14-bits of conversion. The sampling signal is set to be a minimum twice of the highest measurement frequency to ensure aliasing effects are minimized. The output from this DAQ will be connected through the computer using USB interfacing.

## 2.4 Software

LabVIEW software from National Instrument used to provide further signal processing such as digital filtering, data logging and also graphical user interface for controlling certain parameters.

There are two types of software filtering use of this system. Firstly, a Finite Impulse Response, Butterworth third-order band pass filter and signal smoothing technique. The frequency selected for Butterworth filter is between 10Hz to 300Hz, which falling between heart sound and murmur's frequency. Another technique for signal smoothing is used Wavelet denoising algorithm, which uses to enhance the measurement signal. The noise reduction for signals is using the discrete wavelet transform (DWT) instead of continuous wavelet transform (CWT) which providing fast processing and suitable for this real-time application.

The denoised signal then will be processed using Short Time Fourier transforms (STFT) technique. STFT is widely used in the non-stationary signal analysis which is suitable for analyzing heart sound frequency spectra. The STFT also presented in real-time graphical spectrogram providing more information on the frequency signals which could not provide by conventional auscultation technique.

## 2.5 Sensor Location

The first auscultation area is known as the aortic area. Aortic area is located at the second right intercostal space of the ribs. Second heart sound (S2) and semilunar valve sounds are best heard near this region. The second auscultation area is known as the pulmonic area. It is located at the second left intercostal space of the ribs. Second heart sound (S2) and the semilunar valve sound also is also best heard near this region. The third auscultation area is known as Erb's point.

Erb's point is located at third left intercostal space on the left lower sternal border of the ribs where an S2 heart sound is best auscultated. The fourth auscultation area is known as the tricuspid area. It is located at the fourth left intercostal space of the ribs and on the left lower sterna boarder. First heart sound (S1) and tricuspid valve sound are best heard near this region. Lastly, the fifth auscultation area is known as mitral area or apex area. It is located at the fifth left intercostal space of the ribs and in the middle of clavicular line. This is the area of apex beat. First heart sound (S1) and mitral valve sound are best heard near this region.
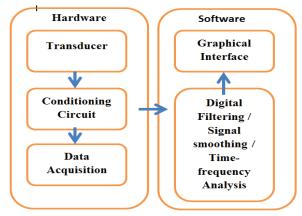
Figure 4. The System Framework

## 3.0    RESULT

The analysis of the abnormal heart sounds and murmurs are based on the sample data retrieved from the heart sound database in MP3 format. For normal healthy heart sound, three male volunteers are participating in the experiment.

Signal analysis is starting with normal heart sounds to auscultate on auscultation area at test subject's chest. Then, the abnormal heart sound and murmurs such as mitral regurgitation, pulmonic stenosis and aortic stenosis is tested. Both analyses are based on the waveform produced through a user interface.

## 3.1    Normal Heart Sound

Figure 5 shows normal heart sounds signals waveform that consists of S1 and S2 heart sounds.
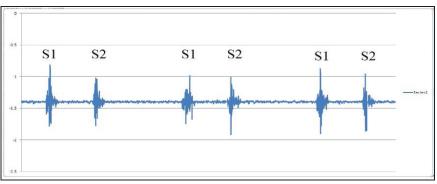


Figure 5. Normal heart sound waveform graph

Based on the observation, the heart sounds signals waveform (S1 and S2) does not contain any abnormal murmur's signals. This figure will be as reference for comparison of real test subject auscultation. Figure 6 shows the frequency visualization in spectrogram.
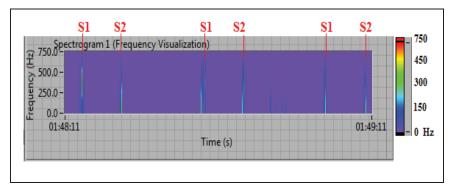


Figure 6. The spectrogram of normal heart sound

The spectrogram on Figure 6 shows that, S1 and S2 heart sounds show the maximum frequency around 180 Hz (light blue color) which identified in the range of normal frequency sound.

## 3.2    Abnormal Heart Sound With Murmur

Analysis of abnormal murmur's sample sounds consists of three types, which are mitral or tricuspid regurgitation, pulmonic stenosis and aortic stenosis.

### 3.2.1    *Aortic and Mitral regurgitation*

Aortic, mitral or tricuspid regurgitation is an abnormal condition where the aortic valve, mitral valve or tricuspid valve cannot close completely during contraction due to narrowing or scarring of the valves thus produces some murmurs. This murmurs are been classified as aortic regurgitation, mitral regurgitation or tricuspid regurgitation murmurs due to failure of that's valves. Figure 7 shows the signals waveform of heart sounds that contain murmurs because of mitral regurgitation disease.
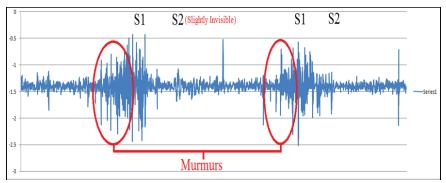
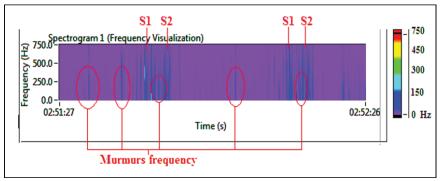Figure 7. Murmurs from the Mitral regurgitation problems



Figure 8. Spectrogram of Mitral regurgitation on sample murmur's sounds

Figure 8 shows the maximum frequency around 180 Hz (light blue color) for S1 and S2 heart sounds is around 130 Hz (dark blue color) lower than S1 heart sound. There are certain signals (murmurs) occur at the beginning of S1 heart sound and significantly occur between the heart sounds (S1 and S2) also show in the time-domain signal. The frequency of this murmurs signals is identified around 130 Hz (dark-blue blue color).

### 3.2.2  Pulmonic Stenosis

Difference with regurgitation that makes aortic, mitral or tricuspid valves cannot close completely. Stenosis disease makes either one of these valves cannot open to completely thus produce some murmurs that can be classified as stenosis murmurs according to each type of valve such as pulmonic stenosis or aortic stenosis murmurs. Figure 9 shows the pulmonic stenosis murmurs signal waveform occurred in the heart sounds.
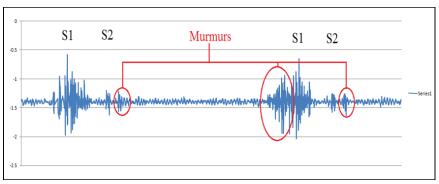
Figure 9. Murmurs from Pulmonic stenosis disease in heart sounds

From Figure 9, the additional sounds (murmurs) seem to occur at the beginning of S1 heart sound after S2 heart sound. These murmurs occur due to resistance of blood flow through the pulmonary valve thus causes the right ventricle failure to functioning as well. Right atria pressure may increase to the 'foraman ovale' (an opening in the septum between the left and right atria) to be opened. This condition may produce murmur's signals as shown in the red cycle. Figure 10 shows the spectrogram of mitral regurgitation sample murmur sounds.
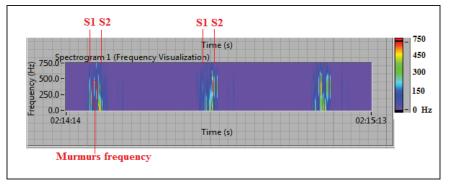


Figure 10. The spectrogram of pulmonic stenosis murmurs

Figure 10 shows S1 and S2 heart sounds were mixed together because of the additional of murmurs between these heart sounds. S1 and S2 heart sounds show the maximum frequency around 180 Hz (light blue color) while the maximum frequency of the murmurs' signal is up to 750 Hz (red color). The frequency of the murmurs after S2 heart sound is around 130 Hz (dark-Blue blue color).

### 3.2.3 *Aortic Stenosis*

Aortic stenosis occurs because the aortic valve cannot open completely during contraction of heart thus make the heart sound heard different from normal. Figure 11 shows the signals waveform of aortic stenosis murmurs.
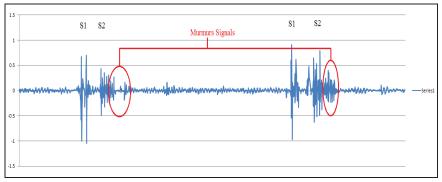


Figure 11. Murmurs from aortic stenosis

Figure 12 shows the murmurs occur at the end of S2 heart sound. The frequency of murmurs is higher than S2 signal.
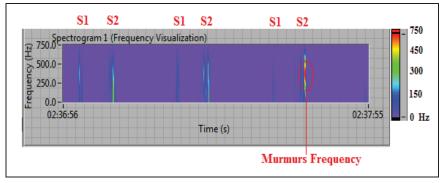


Figure 12. Spectrogram (Frequency Visualization) of Aortic Stenosis sample Murmurs

Based on the spectrogram in Figure 4.13, the frequency of S1 and S2 heart sounds is around 130 Hz (dark blue) until 180 Hz (light blue). However, there are certain murmurs occur after S2 heart sound. The frequency of these murmurs is from 300 Hz (green color) and up to 750 Hz (red color).

## 4.0    CONCLUSIONS

The heart sound signal which presents in a graphical form in this case using spectrogram provide details of amplitude and frequency value during measurement of heart sound compared to the conventional tools. However, in this system, the S3 ad S4 signals could no longer be presented because of the transducer sensitivity, and sampling value. This problem could be minimized using a higher sensitivity transducer and high sampling signals. A suitable filtering technique could be improved the signal measured. It is also suggested that this system could be automated in order to assist physicians to make early diagnosis by using intelligence signal classification techniques.

## 5.0    REFERENCES

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