Study and Analysis of Electronic Stethoscope Signal Using MATLAB & LabVIEW as Effective Tools

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Abstract. This paper trades effectively with the study and analysis of heart sound signal processing from Electronic Stethoscope by using the Matlab tool. Examination of heart sound signal includes generation and simulation of heart sound signal, acquisition of real-time heart sound data, heart sound signal filtering and processing, extraction of feature, comparison of different techniques for cardiac signal processing. Heart sound signal analysis used FFT and Wavelet transform, identification of normal heart sound, calculating Beat Per Minute (BPM), and so on using the most familiar and multipurpose Matlab functionality with user interface LabVIEW. The reasonable need for Matlab functions can contribute us to work in high accuracy and convenience with heart sound signals for processing and analyzing both in real-time and through simulation.

1. Introduction

The stethoscope is cheap, non-invasive, and widely used in clinical practice. As a hearing tool for heart sounds, it provides information about heart rhythm abnormalities and helps detect diseases. The stethoscope is a medical device that is quite simple to determine the patient’s condition by checking the sound in the body, like the sound of the heart and lungs. The weakness of conventional stethoscopes is environmental noise, low sensitivity, low amplitude and frequency, and a relatively similar sound pattern [1-2]. The stethoscope is also widely used to hear breathing sounds and to hear intestine and blood flow in arteries and veins. Besides, it is also used by mechanics to isolate certain sounds from the engine for diagnosis.

The results of a doctor’s diagnosis depend on the sensitivity of the ear and the experience concerned, so it tends to be very subjective. Because the heart sounds of the identified can never have saved, so they can't discuss it with other doctors. An electronic stethoscope can be the solution to the problem above. The sound of the heart or lung that is detected can be recorded, heard again, or if it needs to be processed to have heard with a specific frequency from that data. Signal processing is also needed to accurately identify signal patterns, determine complex data sets, and remove noise. Normal heart sounds can get divided into first heart sound (S1) and second heart sound (S2) that can have seen in Figure 1. The first heart sounds (S1) arise due to 2 causes, namely: closure of the atrioventricular valve (mitral and tricuspid valve) and contraction of the heart muscles. Heart sounds of second have caused by the closure of the semilunar valve (aortic and pulmonary valves). S1 has a lower frequency and a slightly longer time than S2. Whereas, the second heart sounds have a maximum intensity in the aorta region [3]. S1 typically consists of the 30-45 Hz frequency range, while S2: 50-70 Hz, S3: < 30 Hz, S4: < 20 Hz, and murmurs are of relatively low intensity and are within the frequency range of 100 to 1000 Hz [4-10]. Therefore, the role of instrumentation is vital; the high gain must have obtained with a high general mode rejection ratio (CMRR).
As a result, many publications experiments and studied here focus on research to manufacture and model electronic stethoscopes. Further testing with LabVIEW and Matlab had already carried out using a microcontroller, data acquisition, processing, and digital information. Signals were acquired using a NI USB acquisition platform. LabVIEW is a software application from National Instruments that is designed especially for easy and robust data acquisition purposes. Thus, LabVIEW software was used for data recording and visualization in real-time due to its known capabilities [11]. Therefore, Labview is appropriate for the user interface on the Heart BPM measurement system. Meanwhile, Matlab is used to test and adjust digital filters [12] in the process of obtaining accurate signals. This process is essential because the heart sound signal is very noisy, usually 50Hz noise.

2. Electronic Stethoscope System
The aim of Electronic Stethoscopes is to produce a distinctive heart sound waveform and as much as possible arrhythmias. This Electronic Stethoscope system is a Matlab based simulator, and LabVIEW can display normal and abnormal waveforms. Many advantages in simulating heart wave sound with a simulator, are saving time and eliminating the trouble of picking up real heart sound signals with invasive and non-invasive methods. The Electronic Stethoscope simulator system makes it possible to analyze and study normal and abnormal heart sound waveforms without actually using hardware. Significant features of heart sound waves shown in Figure. 1, where notable features of the waves are waves of S1, S2, S3, and S4, the duration of each wave, and specific time intervals such as S1-S2, S2 Interval -S3, and S3-S4. Periodic heart sound signal with a primary frequency determined by heart rate. Therefore FFT can be used to represent heart sound signals.

![Figure 1. Illustrates the Heart Sounds signal [13,14]](image1.png)

2.1 The stethoscope system
The stethoscope system detecting chest sounds has two main blocks, signal acquisition, and signal conditioning. The signal is sensed by the sensor and then pre-amplified, filtered, and then it is given to Matlab signal analysis. The signal from the mic electret sent to a preamplifier, which consists of an inverting amplifier of gain = 21. OPA2228 was used for opamp as it very low noise, high output drive capability, and high slew rate. Heart sounds mostly contained in frequencies of 20-200 Hz. A 4th order low pass filter of cutoff frequency of 200 Hz and a 4th order high pass filter of cutoff frequency of 20 Hz was used to remove noise frequency components, leading to following resistance and capacitance values for low pass filter (figure 2): $R_1 = 8.6 \, k\Omega$, $R_2 = 7.3 \, k\Omega$, $R_3 = 20.8 \, k\Omega$, $R_4 = 3.04 \, k\Omega$, $C_1 = 56 \, nF$, $C_2 = 330 \, nF$ and for high pass filter (figure 3): $R_1 = 13.6 \, k\Omega$, $R_2 = 17.6 \, k\Omega$, $R_3 = 5.4 \, k\Omega$, $R_4 = 7.5 \, k\Omega$, $C_1 = 1 \, \mu F$, $C_2 = 1 \, \mu F$.

![Figure 2. Low Pass Filter Circuit](image2.png)
2.2. Heart Sound Signal Processing

In general, recorded heart sound signals are disturbed by noise and artifacts that are in the same frequency range and signal patterns that are similar to heart signal patterns. To produce meaningful data from the noisy heart sound signals, we have to process the heart sound signals. Heart sound processing could be approximately split into two phases by features: pre-processing and extraction of characteristics.

The pre-processing phase eliminates or represses noise from the heart sound signal, and the extraction stage aggregates diagnostic data from the heart sound signal. With LabVIEW and related toolkits, signal processing programs can have easily developed for both phases, such as baseline wandering removal, noise cancelation, normal and abnormal signal detection, fetal heart rate extraction, and so on [3]. This segment describes standard methods of heart sound processing based on LabVIEW. The Hanning window function is useful for noise measurements where better frequency resolution than some of the other windows. Block diagram for Hanning windows shown in figure 4.

2.3. Feature Extraction of Heart Sound Signal

For diagnosis, we often need to extract features from the raw heart sound signal. The following section extracts some features for each recording and splits each recording into windows. It consists of 10 seconds of the heart sound. System trials also use online data from Physionet consisting of normal signals, pulmonary stenosis, mitral regurgitation, systolic murmurs, atrial septal defects, ventricular septal defects, continuous murmurs with the specifications in table 1 [15].

| Table 1. Abnormal Heart Sounds Data |
|-------------------------------------|
| Normal | Frequency resolution | Time resolution | Resolution of frequency grid | the resolution of the time grid |
|        | 21.5332 Hz | 0.09288 s | 2.6917 Hz | 0.02322 s |
| Pulmonary stenosis | 15.6484 Hz | 0.12781 s | 1.9561 Hz | 0.031952 s |
| Mitral regurgitation, systolic murmur | 21.5332 Hz | 0.09288 s | 2.6917 Hz | 0.02322 s |
| Atrial septal defect | 21.5332 Hz | 0.09288 s | 2.6917 Hz | 0.02322 s |
| Mitral regurgitation, Mid systolic click | 21.5332 Hz | 0.09288 s | 2.6917 Hz | 0.02322 s |
3. Heart Sound Signal Analysis

3.1 Heart Beat Calculation

Heart Sound Signals are analyzed using the BPM (Beat Per Minute) function to calculate heart rate (figure 5). The formula for BPM: beats per minute = 60 * (number of beats collected) / (time in seconds to measure the beat) [16-17]. The normal value of the heartbeat lies in the range of 60 to 100 beats/minute. Bradycardia (slow heart) has a slower rate of frequency. Instead, it is called tachycardia (fast heart) with a higher frequency rhythm [16]. An arrhythmia can have indicated if the cycles are not uneven.

![LabVIEW Block Diagrams to Display BPM Values](image)

Table 2. BPM Value Reading Test

| Respondent | Measured BPM | Manual BPM |
|------------|--------------|------------|
| Respondent 1 | 84           | 86         |
| Respondent 2 | 131          | 131        |
| Respondent 3 | 119          | 129        |
| Respondent 4 | 84           | 88         |
| Respondent 5 | 107          | 107        |
| Respondent 6 | 72           | 80         |
| Respondent 7 | 72           | 81         |
| Respondent 8 | 155          | 140        |
| Respondent 9 | 72           | 79         |
| Respondent 10 | 107         | 107        |

The LabVIEW interface program can already display BPM, based on the results of the BPM reading test on the LabVIEW interface program of 10 respondents age around 20-25 years, where BPM values in the range of 60-100 [16-17] (Table 2). The measured BPM in the program has a different value from manually calculating BPM. The BPM measurement program at LabVIEW still uses a simple calculation algorithm, so the reading results are still not accurate.

3.2. Normal and Abnormality Detection

Heart sounds characterized by a large variation in both time and frequency domains [18]; they are, therefore, classified as non-stationary signals [19]. Fast Fourier Transform (FFT) tool used to detect normal and abnormal heart sound signals [20]. The FFT analysis of the heart signal performed using Matlab and LabVIEW. The waveforms with normality and abnormalities shown in Fig. 6, 7, and 8, respectively.
Figure 6. Illustrates the FFT of the normal heart sound signal using Matlab and LabVIEW

Figure 7. Illustrates the FFT of the abnormal heart sound signal using Matlab and LabVIEW

Figure 8. Illustrates the normal (red) and abnormal (blue) heart sound using Matlab

Figure 9. Illustrates the power spectrum normal (red) and abnormal (blue) heart sound using Matlab

Though, by using the Matlab and LabVIEW tools get results that are not significantly different. LabVIEW is very powerful for a user interface that can be directly implemented in realtime to devices, whereas Matlab is mighty for further analyzing signals with big data.

4. Conclusion
This review shows that simulations from Matlab and LabVIEW can have constructed to analyze signals from the heart sound. Both MATLAB and LabVIEW have an immense effect on heart sound signal processing. They are so useful and handy that even one can monitor patient heart condition merely utilizing the power of Matlab and LabVIEW, and also, self-diagnosis is possible. All these examples and techniques that have discussed here can be beneficial for experimental purposes even we don’t have any heart sound data. We still can simulate and analyze it. Finally, computer simulations
are powerful tools to interpret the heart sound signals. These methods are becoming a powerful tool for medical advances, and their integration in clinical settings should help improve patient care.

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