Design of an Automated Diagnosis System for Chest Sounds Analysis

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Abstract: ***In this paper the chest sounds were recorded using an electronic stethoscope exclusively designed. The aim of study is to investigate the separationof chest sound into lung and heart sounds. Since the lung and the heart are the vital organ of human, therefore the needs of immediate preventive and curative actions are primarily important. The sound separation was partially achieved using FASTICA. Further a system for automated diagnosis of heart sounds was developed using MATLAB.***

Keywords: heart sounds, Lung sounds, automated diagnosis

1. Introduction

Cardiovascular diseases are a major public health concern in India, and contribute to roughly 40 million deaths annually. Furthermore on a global scale, cardiovascular diseases are the most common cause of death, 80% of which occur in low- and middle- income countries. A recent report indicated that non-communicable diseases, particularly cardiovascular disease (CVD), have replaced communicable diseases as the leading cause of death in developing nations. [1]

Usually the diagnosis tool with high accuracy requires a large investment, takes a long time for processing and is almost located in urban areas. Whilst, for the fast action, another diagnosis tool (the stethoscope) which can conduct rapid diagnosis test is the most commonly used tool, however it gives less accurate results due to its low sensitivity and specificity.

Hence an initial prototype of an automated diagnostic system [2] using the simplicity of the traditional diagnostic stethoscope with the capability to detect CVD was developed. In this investigation Independent Component Analysis (ICA) was applied on the acquired sounds and Heat sounds were separated and classified using MATLAB.

2. Design of Electronic Stethoscope

Construction

Electronic stethoscope was constructed by removing the stem of the stethoscope'schest piece from the tubing. A plastic tube was attached to the stem of the chest piece. A condenser microphone was inserted at the other end of the tube. A 3.5mm stereo plug was connected to the other end of the microphone [3].

Figure 1: Chest piece of stethoscope

Figure 2: Plastic tube

Figure 3: 3.5mm Jack pin

Recording of sounds

The diaphragm of the electronic stethoscope was placed over the chest, and the stereo plug of the electronic stethoscope was connected to the microphone input of a laptop installed with Think labs phonocardiography software. Sounds were recorded using this software.

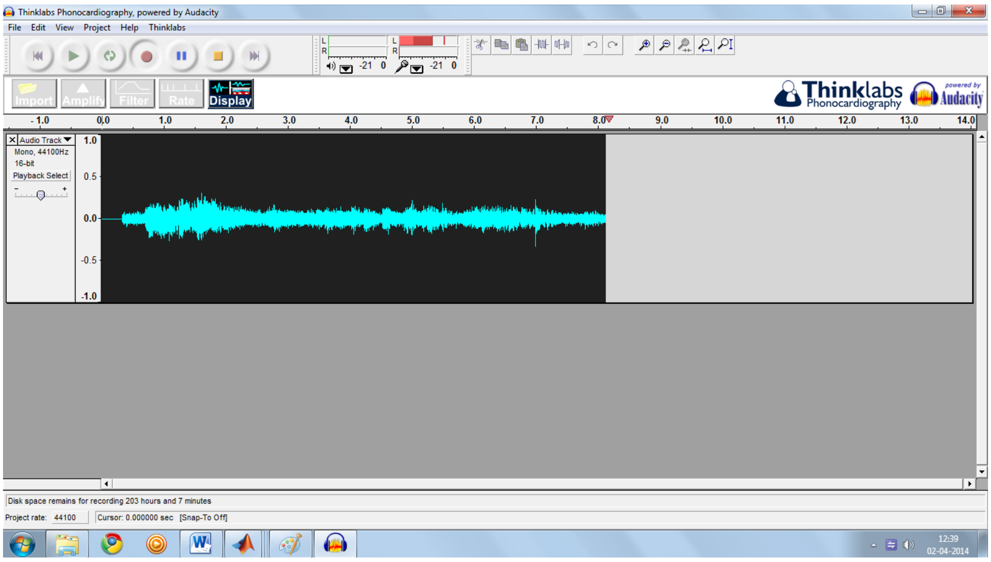

Figure 42: Recording in thinks lab phonocardiography software

A MATLAB GUI was also developed to aid recording the chest sounds, displaying the recorded sounds, its spectrum and heart rate.

3. Separation of Heart and lung Sounds from Chest Sound Recording

Acoustical analysis of lung sounds or heart sounds provides important and helpful information in the diagnosis and monitoring oflung or heart diseases.Lung sound and Heart sound signals were considered asindependent source signals. However, due to the delays andreflections of the lung tissues, the mixed signals recorded onthe skin were correlated and convoluted mixtures. A solution toseparate thesetype of mixed signals was to apply IndependentComponent Analysis (ICA) [4], [5]on the spectrograms of the recorded signals. Hence, the objective of this study was toinvestigate the application and feasibility of ICA on heart sound separation from lung sounds.This study addresses the problem of blind signal separation (BSS) using Fast independent component analysis (Fast ICA).

Algorithm

Step 1: **P**REPROCESS THE DATA:

The input vector data $\mathbf{X}$ needs to be centered and whitened before applying FASTICA.

*Step 2:*CENTERING THE DATA

The input data $\mathbf{X}$ was centered by computing the mean of each component of $\mathbf{X}$ and subtracting data from that mean. This had the effect of making each component have zero mean.

$$\mathbf{x} \leftarrow \mathbf{x} - E\{\mathbf{x}\}$$

Step 3: WHITENING THE DATA

Whitening the data involves linearly transformingthe data so that the new components are uncorrelated and have unity variance. If $\tilde{\mathbf{X}}$ is the whitened data, then the covariance matrixof the whitened data is the identity matrix:

$$E\{\tilde{\mathbf{x}}\tilde{\mathbf{x}}^T\} = \mathbf{I}$$

This can be done using eigen value decompositionof the covariance matrixof the data:

$$E\{\mathbf{x}\mathbf{x}^T\} = \mathbf{E}\mathbf{D}\mathbf{E}^T$$

where $\mathbf{E}$ is the matrix of eigenvectors and **D** is the diagonal matrix of eigen values. Once eigen value decomposition is done, the whitened data is:

$$\mathbf{x} \leftarrow \mathbf{E}\mathbf{D}^{-1/2}\mathbf{E}^T\mathbf{x}$$

Step 4: Apply FASTICA

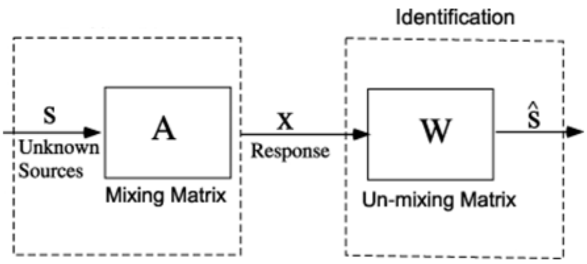

Figure 5: Block Diagram of ICA Algorithm

4. Heart sounds classification

Separated heart sounds from ICA were used to develop an automated diagnosis based on heart sounds classification. We have considered two common CVD's into consideration namely Aortic Stenosis and Aortic Regurgitation. In this procedure we have developed a method for determining the location of S1 and S2 sounds, distance between S1 & S2, width of S1, S2 and distance between consecutive S1 sounds.

The recorded signals were pre-processed before performing segmentation. In the first step the signals were down sampled and filtered. In the second step, segmentation was performed.

Pre-processing

The signal was smoothed, using 5 tap moving average filter. Further the signal was band filtered and squared, thereby highlighting the maximum peaks.

Peak finding

Peaks were identified using the PEAKDET command in MATLAB.Some modification in the existing function was developed to measure the different parameters of interest. Two thresholds were used in selecting the peaks of S1 & S2.

5. Investigation Result and Discussion

Figure 6 shows the MATLAB GUI developed to record breath signal using the electronic stethoscope. The GUI also option to view its spectrum and aid in heart rate calculation

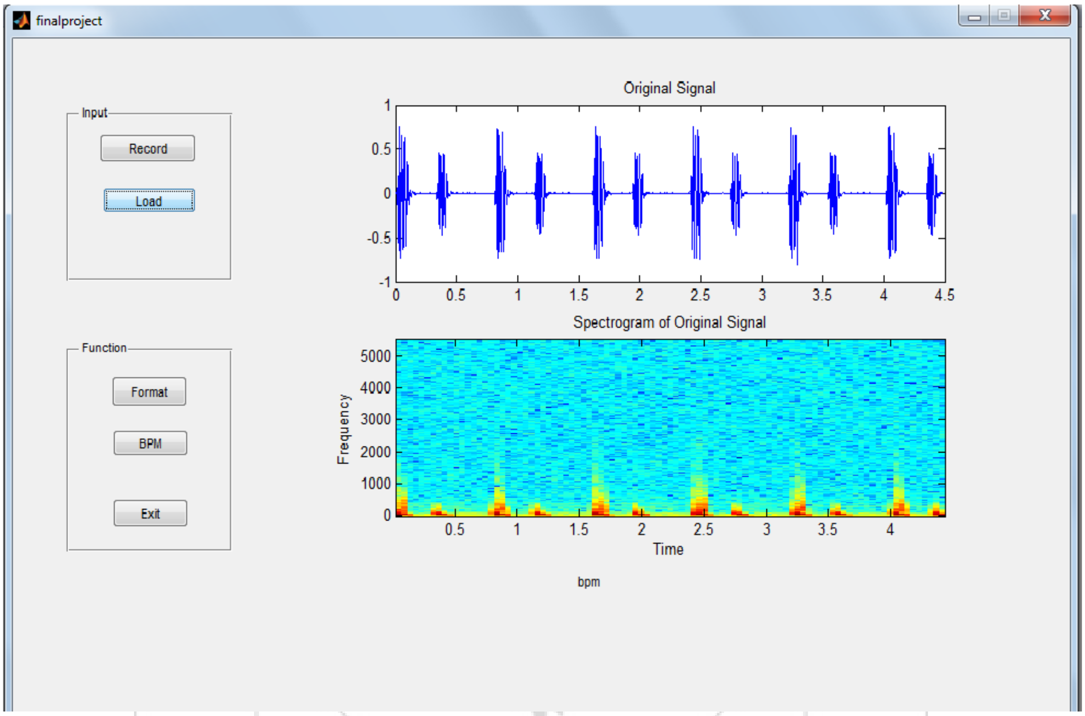

Figure 6: GUI Developed

Figure 7 shows the output after application of FASTICA on the recorded signal. For comparison purpose normal heart and lung sounds was downloaded from RALE's Repository. The produced lung sound signal (Figure 7)is different compared to the normal lung sounds (Figure 8), however the Heart Sounds segmented (Figure 7) from the algorithm looks similar to normal heart sounds (Figure 8). These problems are probably due to two reasons such as, sounds recorded over the mitral area, where the heart sounds were more dominant, simultaneous recordings were not employed. Hence this investigation requires redefinition and more improvement.

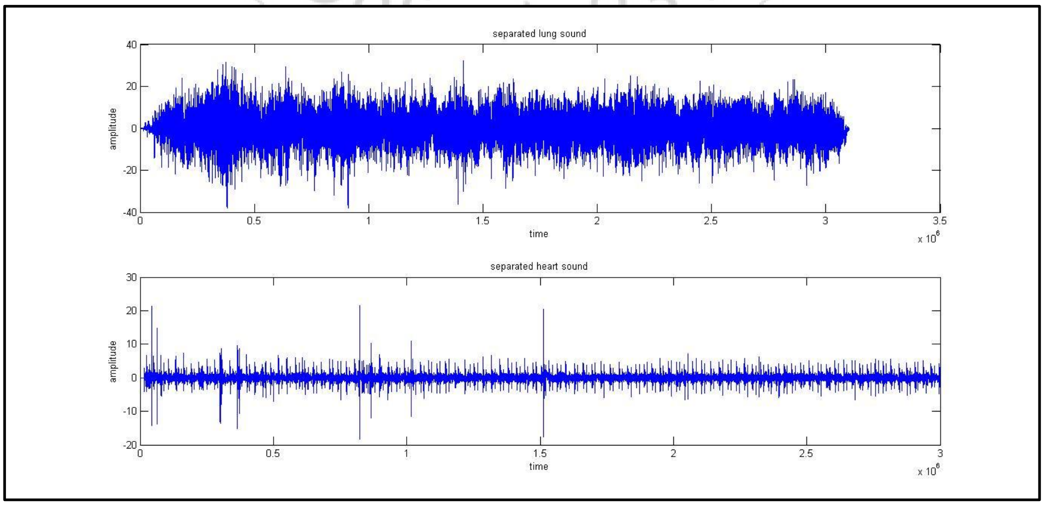

Figure 7: FASTICA on Recorded Signal

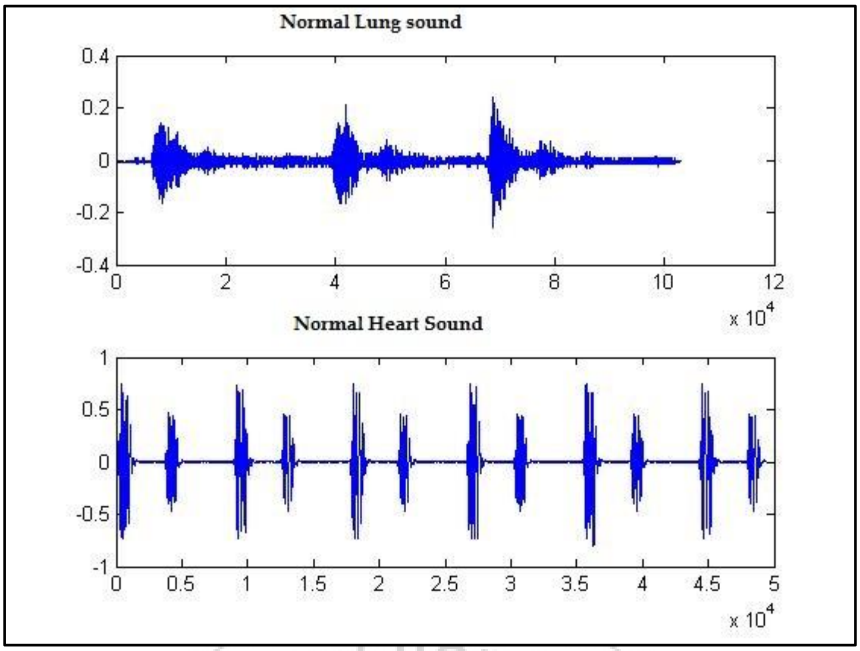

Figure 8: Normal Heart and Lung Sounds

Table 1 tabulates the different parameters calculated from the segmented heart sound signal. The values correlate well with values of normal heart sounds [6].

Table 1: Recorded Heart sounds parameters

Parameters	*Standard range(sec)*	*Output obtained(sec)*
Width of S1	0.9-0.16	0.11
Width of S2	0.09-0.14	0.09
S1-S1 distance	0.9-1.05	1.02

Furthermore the values of the parameters were calculated for diseased heart sounds Aortic stenosis and Aortic Regurgitation (obtained from RALE's repository). The values are tabulated in Table 2

Table 2: Parameters of Diseased hear sounds

Parameters	Aortic stenosis	Aortic regurgitation
Width of S1	0.68	0.38
Width of S2	0.139	0.331
S1-S1 distance	2.00	0.0154

Using these values a prototype of an automated diagnosis system was developed using MATLAB GUI shown in Figure 9. This system was developed only considering the width of S1, S2 and S1-S2 distance. This system has to be refined further considering the pitch, intensity of sounds and presence of added sounds.

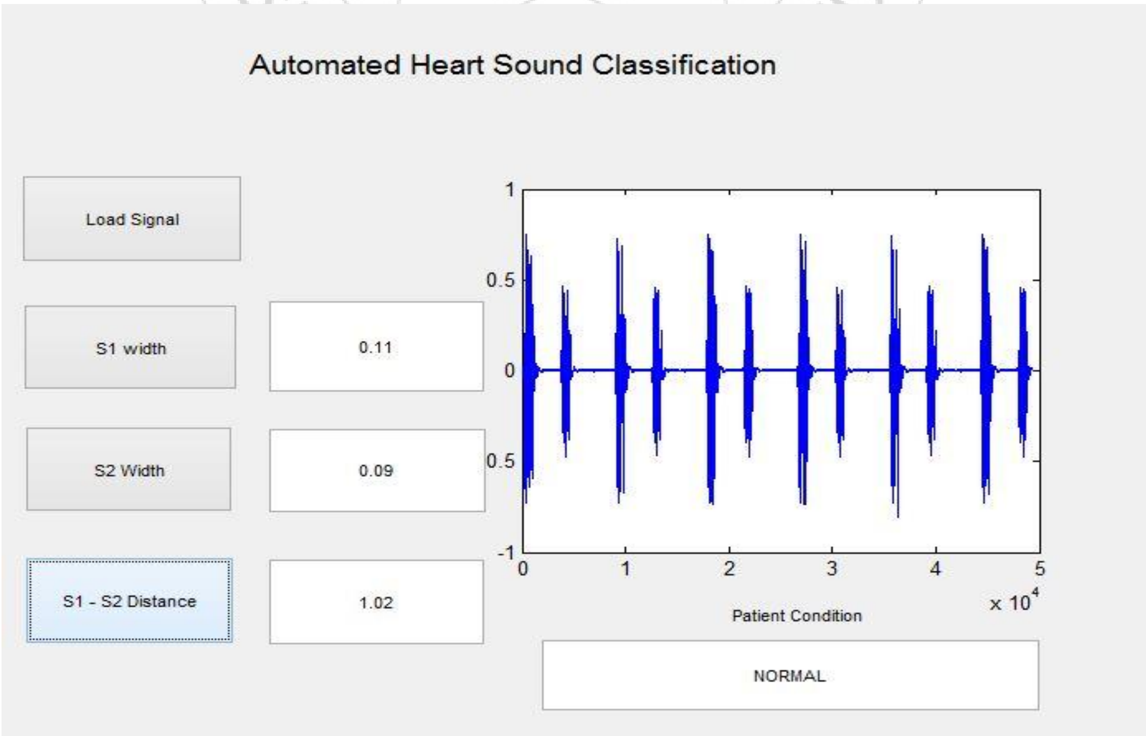

Figure 9: Automated Heart Sounds Classification GUI

6. Conclusion

The development of an automated diagnosis system for heart sounds was investigated based on time domain parameters of heart sound. The investigation was implemented using Matlab FASTICA for heart and lung sounds separation. From the investigation result, although the produced lung sound were not similar to normal lung sounds the algorithm can be further refined. Moreover heart sound signals were similar to the normal heart soundsand they were further classified to identify two diseased heart sounds namely Aortic Stenosis and Aortic Regurgitation.

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