Automatic Classification of Normal and Abnormal PCG recording Heart Sound Recording Using Fourier Transform

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Abstract: **Cardiovascular diseases are very common these days and there arises a need for regular diagnosis of humans. Phonocardiogram is an effective diagnostic tool for analysing the heart sound. It helps in providing better information regarding clinical condition of the heart. This paper proposes an algorithmic method for differentiating a normal heart sound from an abnormal one using the PCG sound data. Cepstrum analysis has been performed on both types of signals and features are extracted from the heart sound. The extracted features are trained and tested with the help of a support vector machine classifier. The proposed method has achieved an accuracy of 95% in correctly classifying a heart sound PCG signal as normal and abnormal.**

Keywords: Heart Sound, PCG, Signal Processing, Feature extraction, SVM

I. INTRODUCTION

In this modern world a large number of persons are suffering from cardiovascular related diseases. Despite remarkable advancement in medical filed, the diagnosis of the heart related problem at an early stage, is still a problem. Phonocardiogram analysis helps the physicians in providing better information regarding the heart sound. Slight variations from normal conditions in heart sound can be easily detected by experienced and trained physicians. However, the availability of trained trainer is not possible in each and every part of the country. Under such conditions, there arises a need for a diagnostic tool which can provide the information regarding the condition of the heart. On the basis of the post diagnostic information, one can consult the physician at the proper time.

G. Redlarski et al.[1] proposed a new methodology for heart sound classification. They combine linear prediction coding coefficient with support vector machine and modified cuckoo search algorithm to improved the performance of the diagnostic system. F. Meziani et. al [2] performed an analysis of the phonocardiogram signal with the help of the wavelet transform. The diagnosis is done to detect first and second sound of the heart sound. S.W. Deng and J. Q. Han [3] proposed framework to classify the heart sound without segmentation. It is done on the based of the autocorrelation features and diffusion maps. S Yuenyog et al [4] developed an algorithm to calculate the cardiac length using auto correlation of envelope signals and classification is performed using neural network bagging predictors. W. C. Kao and C.C. Wei [5] developed a methodology for complete heart sound analysis by segmentation of the beat cycles. L. Huiying et al [6] analysed the heart sound signals which are recorded using PCG using wavelet decomposition.

All these algorithms have encouraged the researchers to work in this area and provide some automated solutions as they are convenient, improves the creditability and helps in estimation of diseases. A proper diagnostic tool is required which may help the physician in analysing the heart sound and diagnose its condition at the earlier stage of the disease.

The main contribution of this algorithm lies in the use of the fourier transform and the cepstrum analysis for efficient classification of the normal and abnormal heart sound heart. The statistical features of the Fourier transformed signal are calculated. It helps in characterizing the signals correctly. Another significant contribution lies in the use of band pass filter. The filter helps in removing artefacts and noises that corrupt the heart sound recording. It will also increase the credibility of the developed algorithm and help in better classification of the heart sound from the PCG signal.

Structure of the remaining of the paper is as follows: Section II discusses about signal processing techniques which are performed in this proposed work for the pre-processing of the recorded PCG signal and extraction of features from the processed signal. Section III concludes results obtained from experiment after applying the developed methodology to available PCG recorded signal database. Finally, Section IV presents some concluding remarks obtained from the results of the proposed algorithm.

II. PROPOSED METHODOLOGY

Heart murmurs are an effective way to analyse the condition of a human heart. Each and every individual has different heart sound. Experienced physicians can easily trace out any aberrations in the heart murmur during auscultation process. At the time of recording heart signals, many other noises may add up making it difficult to analyse the signal properly. Keeping these things in mind, a band pass filter has been used in this paper which is capable enough of rejecting the noise and classify a heart sound as normal or abnormal based on some statistical features which have been extracted from the input data.

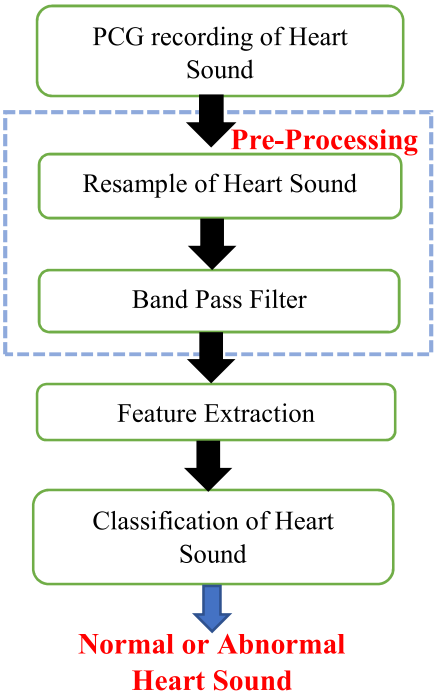

Fig.1. Block Diagram of the Proposed Methodology for Classification of Heart Sound.

Fig. 1 shows the block diagram of the proposed work for classification of a signal as normal or abnormal heart sound, from the PCG recorded samples. For accurate classification of the input signal, the signal is first resampled to make the algorithm faster and computationally efficient. Then the resampled signal is filtered using a band pass filter to remove the noise from the signals. The discriminatory features are extracted from the processed signal, which are fed to a support vector machine classifier for classification.

Fig. 2(a) shows the normal PCG recording of normal heart sound of a healthy person. This sound is recorded at sampling frequency of 2000Hz while Fig. 2(b) shows the unhealthy PCG recording belonging to abnormal class. From both figures, it can be observed that there is a difference between both classes of heart sound. So, an effective algorithm has been developed to extract the useful information from them which can help in better classification of available database of heart signals.

The approach can be divided into following categories:

- Pre-processing of the recorded signals
- Extraction of features from pre-processed data
- Classification of the normal and abnormal signals using supervised classifier.

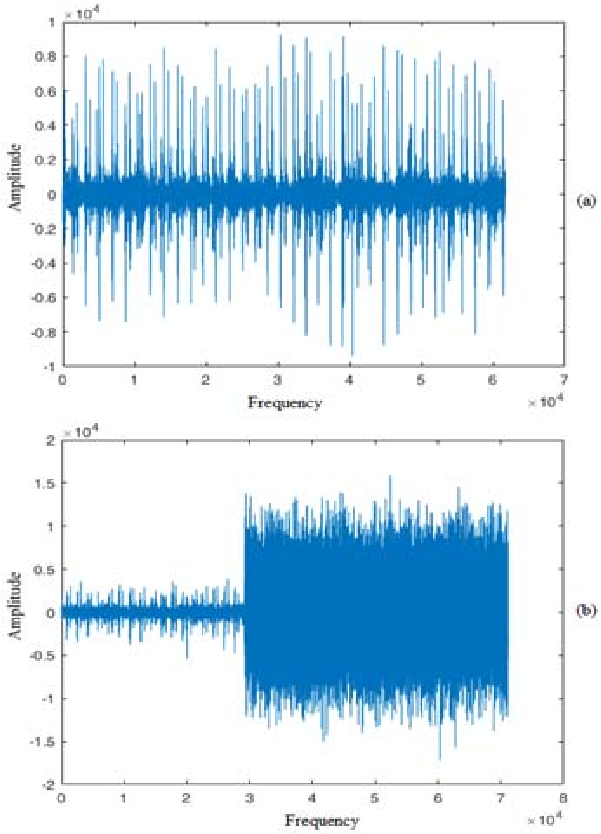

Fig.2. (a) PCG recording of the normal heart sound (b) PCG recording of the Abnormal heart sound

A. Pre-processing of the PCG signal

The heart sound samples used in the proposed work have a sampling frequency of 2000Hz. For faster analysis of the heart sound, the recorded signals are down-sampled to 1000 Hz. This helps in conserving the processing time. Fig. 3 shows the down sampling of the recorded heart sound. Fig. 3(a) shows the original heart sound recording which has sampling frequency of 2000Hz and Fig. 3(b) show the down-sampled signal whose frequency is down-sampled by a factor of two to a value of 1000Hz.

As the recordings of the signals are done in natural conditions, so there are chances that the recorded signals may contain some unwanted signals along with the actual heart beat signal. These unwanted signals are considered as noise. In order to remove these unwanted noisy signals, the resampled signal has been filtered using a band pass filter. The range of this filter is defined from 20 Hz to 450 Hz. The lower cut off frequency is mentioned in the given database. The band pass filter retains only the values corresponding to the frequency range defined above. All the frequencies outside this range are eliminated with the help of band pass filter.

Fig. 4(a) presents the down-sampled signal which is given as input to the band pass filter. Fig 4(b) shows the resultant filtered signal obtained after filtering process. The band pass filter is used to reduce the effect of the noise that occurs outside a particular range of frequency which are present during recording of the signal.

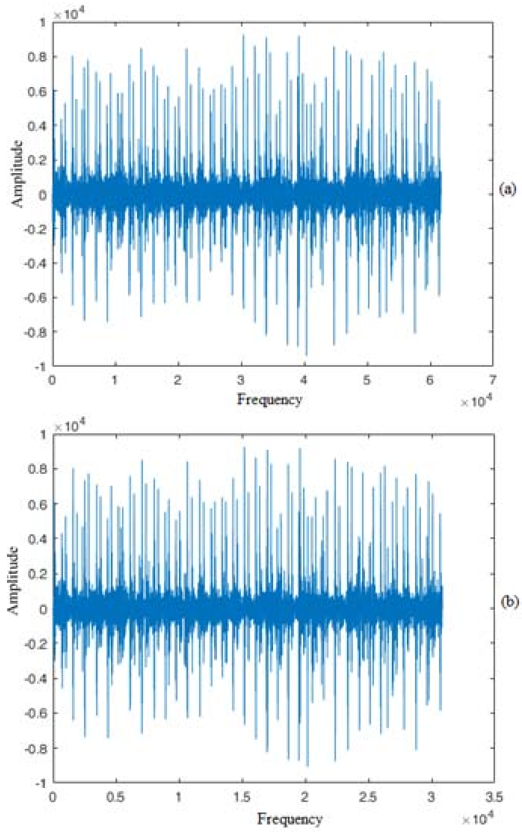

Fig.3. (a) Original recorded sound (b) Resampled heart sound

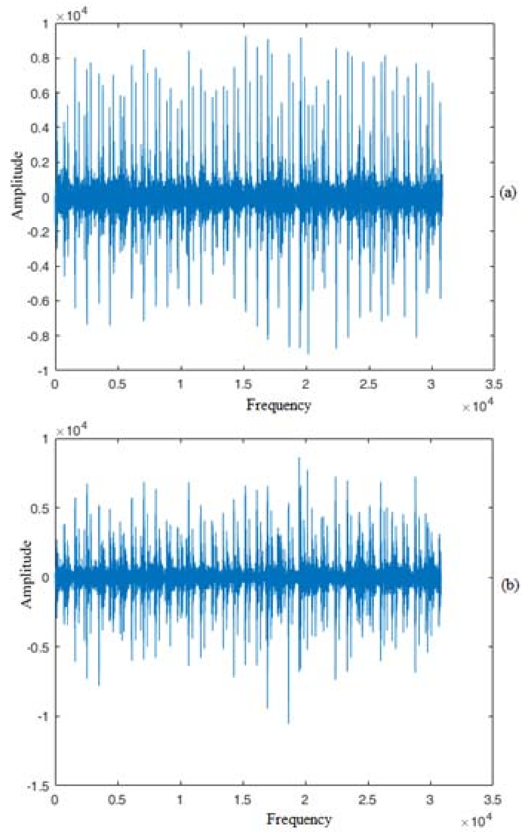

Fig. 4. (a) Resampled Signal (b) Filtered signal

B. Features Extraction

The next step is to extract the discriminatory features from the band pass filtered signal. For this purpose, Fourier transform and Cepstrum analysis is performed to extract the following features from the processed heart sound signals.

1) **Fourier:** Fourier transform is performed to analyse the frequency domain information contained in the signal [7]. It is performed by taking inner product of the signal with a window. The window used in the proposed work is “rectwin”. After using different available windows, it has been found that the best differentiable results were obtained using ‘rectwin’ window.

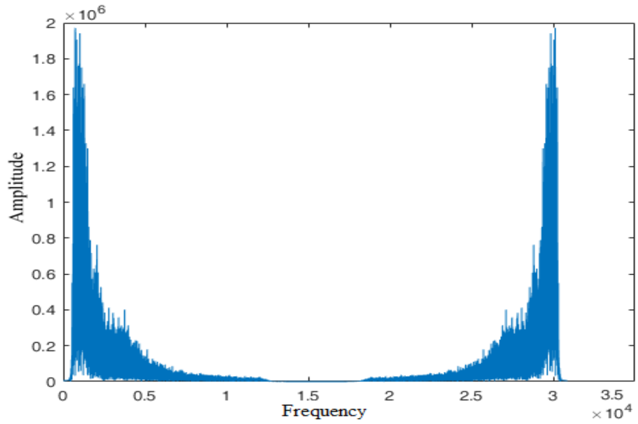

Fig.5. Fourier Transform of the normal heart sound.

Fig.5. shows the fourier transform of the normal heart sound. From this fourier transform signal, maximum value is calculated. Then mean value of the Fourier transformed signal is determined. It has been empirically analysed, that the ratio of the mean value of Fourier transformed signal to its maximum value, had shown proper discrimination between the normal and abnormal PCG signals. This ratio of average to max value of the transformed signal is calculated using following formula:

$$M_F = \frac{Mean(FT)}{\max(FT)} \qquad \text{i)}$$

Where, M_F is calculated value of the ratio

Mean(FT) is the mean of the Fourier transformed signal

max(FT) is the maximum value of the Fourier transformed signal

There is a gap in the feature values of both classes, i.e. normal and abnormal. This is demonstrated in Fig. 5. The feature values of the Fourier Transformed signal of the normal and abnormal heart sound are shown in red and green colour, respectively. There is considerable difference in the feature values of the two classes of the heart sound.

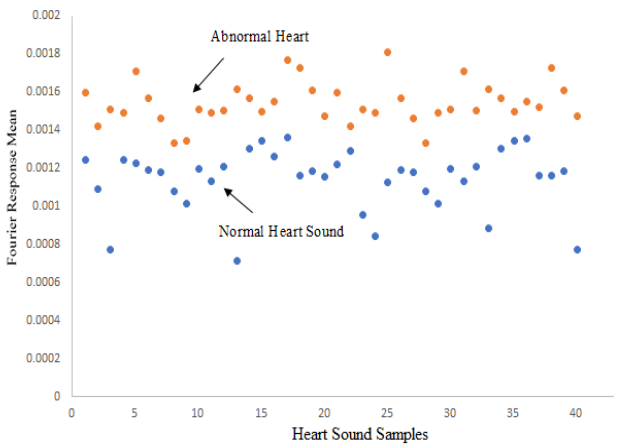

Fig. 5. Graph plot of the normal and abnormal heart sound. The normal and abnormal heart sound are shown in red and green colour respectively

2) **Cepstrum Analysis**: Cepstrum is an method where deconvolution is performed in order to obtained the cepstrum by calculating the inverse fourier transform of the logarithm of [8]. It is often used as tools for signal analysis [9] [10] It is computed using Auto-Regressive power spectral analysis [11]. The cepstrum coefficient is extracted from the band pass filtered input heart sound. Statistical feature, i.e. mean, is calculated from the extracted coefficients of heart sound sample. It has been observed that the average value of the cepstrum of the normal heart sound is higher as compared to that of the abnormal heart sound.

Fig 6. shows the graphical representation of the mean values of the Cepstrum coefficients extracted from the input test signal. It is clearly visible that there is an acceptable difference between the mean values of the Cepstrum coefficient of the normal and abnormal heart sound.

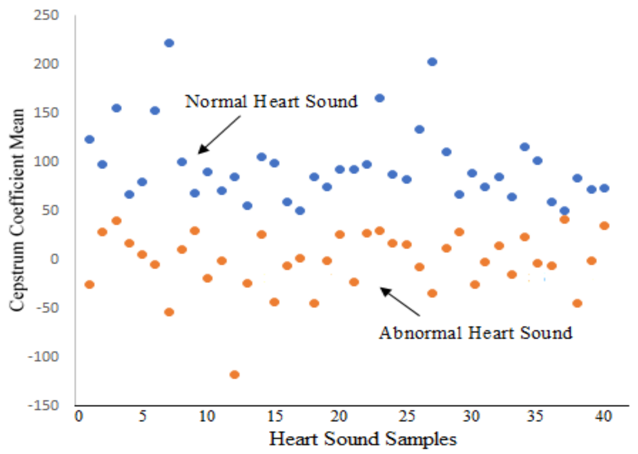

Fig.6. Graph of mean value of Cepstrum Coefficient of the normal heart sound and abnormal heart sound

The above-mentioned features, namely, means of Fourier Transformed and Cepstrum analysed signals, are used in the proposed work for classification of a test signal as normal or abnormal heart sound. The feature values are represented in form of box plots in Fig. 7. From the figure, it is clear that there exists a distinction between the values of the two classes. This distinction in feature values justifies the use of average values of Fourier transformed and cepstrum coefficients for analysis of heart sound signals.

C. Classification:

The main purpose of the proposed algorithm is to correctly classify an input test heart sound signal as normal or abnormal. The accuracy and precision of the proposed method have been improved by using two different features. These features have been discussed in the previous section. In this proposed work, a supervised classification approach is used and the classifier used to employ such environment is Support Vector Machine.

SVM is a linear classifier which generate a hyperplane separating two datasets [12]. In a supervised learning approach, the dataset is divided into two parts: training set and testing. The classifier is trained using features of training set while its prediction is checked for the testing set. SVM classifier is a binary classifier used to classify an input signal into either normal or abnormal class.

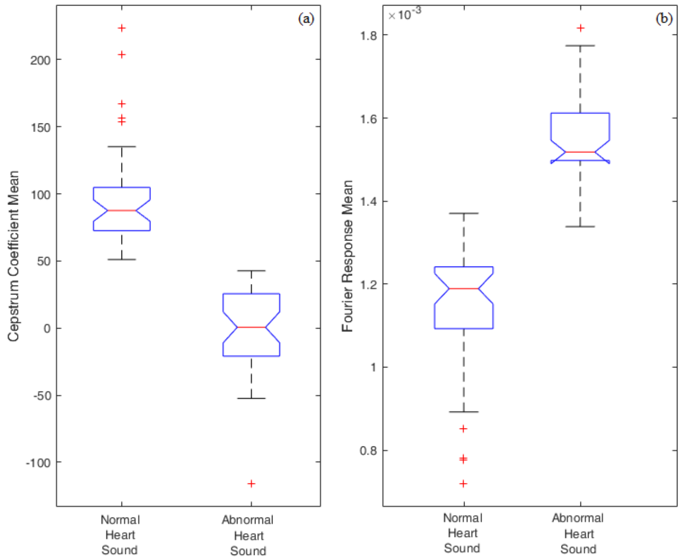

Fig. 7. Box Plot of the Extracted Features (a) Mean of the Cepstrum Coefficient (b) Fourier transform

III. EXPERIMENTAL RESULTS

For validation purpose, the 2016 PhysioNet/CinC Challenge database [13] has been considered in the proposed work. This comprehensive database consists of normal and abnormal heart sound signals which are recorded using phonocardiogram.

In the proposed work, a database consisting of a total of 100 heartbeat signals has been used. The dataset is divided into two classes, namely X and Y. Class X consist of 50 normal and class Y consists of 50 abnormal heart beat signals. The available database is categorized into training and testing set. From each classes of heart beat signal 40 samples are taken for training purpose and 10 samples for testing purpose. The performance of the algorithm is analysed using parameters like accuracy, sensitivity and specificity.

The computations of the proposed work are performed on a computing device which has Windows10 operating system installed and has a clock speed of 2.5 GHz. The tool used for the computation is MATLAB tool, version R2016b. The average computational time to remove noise and extract features from the input heart signal using the proposed algorithm is found out to be 0.5603 $\pm$ 0.326 seconds. Table I shows the features extraction of the heart sound. The first 10 samples belong to the normal class while the next 10 samples belong to the abnormal class.

TABLE I: FEATURE VALUES FOR NORMAL AND ABNORMAL HEART SOUND SAMPLES

Features Extraction			
Sl. No		**Cepstrum Mean**	**Fourier Transform**
Normal Sound	1	75.36886	0.001137
	2	85.7153	0.001472
	3	41.1894	0.000142
	4	117.0646	0.001309
	5	102.6446	0.00135
	6	61.13856	0.001366
	7	51.1385	0.00117
	8	85.36458	0.001168
	9	73.75775	0.001193
	10	74.21461	0.000782
Abnormal Sound	11	-24.1301	0.001607
	12	29.88941	0.001425
	13	41.12252	0.001518
	14	18.63557	0.0015
	15	6.395267	0.001718
	16	-3.6389	0.001577
	17	-52.4207	0.001468
	18	11.351	0.001338
	19	30.53631	0.00135
	20	-20.525	0.001515

Table II shows that the developed algorithm has achieved an overall accuracy of 95% for classification of the heart sound. It is observed that out of 10 PCG signal of the normal heart sound, 9 samples have been correctly classification except for one. This implies that the developed methodology can work efficiently for classification of the heart sound. The performance parameters used in the proposed work are calculated as follows:

$$\text{Sensitivity} = \frac{TP}{TP+FN} \quad \text{ii)}$$

$$\text{Specificity} = \frac{TN}{FP+TN} \quad \text{iii)}$$

$$\text{Accuracy} = \frac{TP+TN}{H+Ab} \quad \text{iv)}$$

Where H represent number of Normal Heart beat sound samples and Ab represent number of Abnormal heart beat sound samples. TP is defined as True Positive which can be described as number of abnormal heart sound samples that have been classified properly by the classifier. FN is defined as False Negative which can be described as abnormal heart sound samples that have been classified as normal by the classifier. TN is defined as True Negative which can be simplified as number of normal heart sound that have been classified as normal by the classifier using the given set of features. FP is defined as False Positive which can be defined as number of normal heart sound that have been classified as abnormal by the classifier using the given set of features.

TABLE II: RESULTS OBTAINED FROM CLASSIFICATION

CLASSIFICATION RESULT		**PERFORMANCE RESULT**	
True-Positives	10	Accuracy	95%
False-Negatives	0	Sensitivity	100%
True-Negatives	9	Specificity	90%
False-Positives	1		

IV. CONCLUSION

The proposed work presents an automatic approach for proper classification of phonocardiogram (PCG) signals as normal or abnormal. PCG signals are recorded at the sampling frequency of 2KHz. The input signal is down-sampled to 1KHz and then subjected to a band pass filtering operation. The filtered signal is analysed using Cepstrum analysis and Fourier Transformation. The mean value of the Cepstrum analysed and Fourier Transformed signal is determined and fed to an SVM classifier for classification. The algorithm has achieved an accuracy of 95% with a sensitivity value of 100%. The computational time for feature extraction is very low and encourages to implement such computational efficient techniques into real time application for assisting in clinical decision.

Future work could be concentrated on exploring some more efficient pre-processing methods to make the developed algorithm immune to noise signals. Further, the algorithm can be tuned for diagnosis of different types of diseases.

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