Categorization of Normal and Abnormal Heart Rhythms from Phonocardiogram Signals

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***Abstract*— A Phonocardiogram (PCG) is a graphic record of heart sound is an important first step in evaluating the cardiovascular system. In this study, a phonocardiogram signal has been decomposed into S1, S2 and S4 waves and average power and dominant frequency has been computed from segmented bursts of these signals. A Bayes classifier has been used for categorizing normal and abnormal heart sounds. The results show that this simple approach is significant to determine some abnormalities in the heart rhythm.**

Keywords — phonocardiogram; heart sound; burst segmentation; classification.

I. INTRODUCTION

In general, since PCG signal is a record of sound, audio and speech processing methods are adopted for analyzing it [1]. This study diverges from the previous in this regard. The algorithm is summarized as follows. The details of each step is given in the following. [2] [3]

II. MATERIALS AND METHOD

A. Materials

The challenge 2016 data obtained from the physio-net physiological signal resource [4] has been employed. The database includes recordings taken from subjects, heart sounds collected from both healthy people and patients with a variety of conditions [5]. It consists of five groups of data; A, B, C, D, E, and, F. The group A and B have only been analyzed since C, D and E contains insufficient number of trials and F has unbalanced data (number of normal and abnormal records are quite different) The group A consists of 117 normal and 292 abnormal type PCG recordings, B contains 386 normal and 104 abnormal number of trials.

B. Method

The method consists of four main steps. 1. Sample reduction 2. Decomposition of S1, S2, S4 bands, 3. Feature extraction and Classification.

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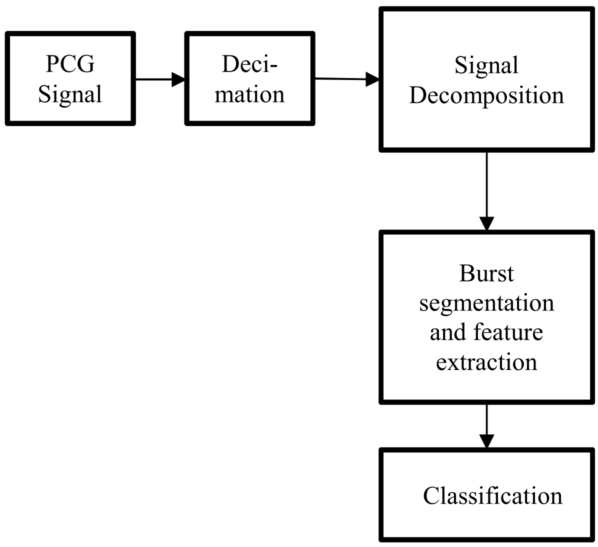

Figure 1: Block Diagram of Algorithm

1. Sample Reduction

The sampling frequency of the PCG data is Fs = 2000 Hz. PCG signals have bandwidths of 0-70 Hz. 2000 Hz is a very high sampling frequency for this frequency band. Sampling rate was deceased to reduce computation cost. This is done by employing three-stage decimator with a low-pass filter follow which eliminates designing a relatively narrow band low pass filter. The filters in the stages are equivalent and are fifth-order low-pass Butterworth filters with relative bandwidth of 0.35 (35% of the full band). The resultant signal frequency range is limited to frequency band [0, 87.5] Hz.

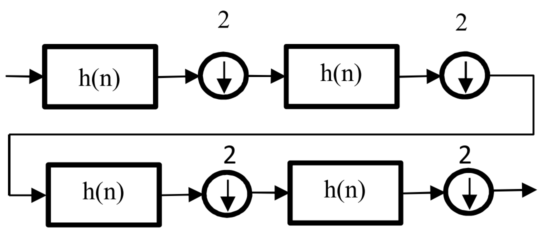

Figure 2: Sampling rate reduction

2. Decomposition of S1, S2, S4 waves

Decomposition of S1, S2, S4 waves. After the sampling rate has been reduced, the signal is divided into 3 basic frequency bands; [0, 20], [25, 45] and [50, 70], which are called S1, S2 and S4 waves First the discrete Fourier transform is computed at number of points twice the length of the signal. The frequency bands are separated in the frequency domain by multiplying the transform coefficients with the hamming window centered at mid-points of these bands and then computing the inverse Fourier transform. This approach is illustrated in Figure 3.

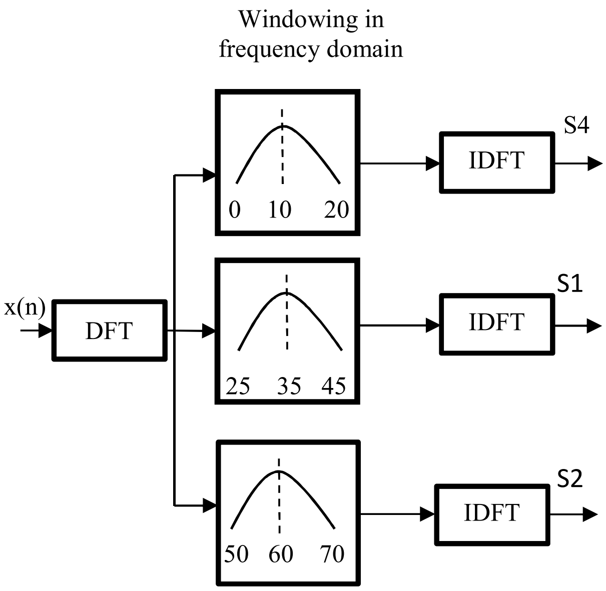

Figure 3: Decomposition of S1, S2 and S4 waves.

3. Feature Extraction and Classification

Feature Extraction and Classification. As a next features from each sub-bands are extracted. The bursts in each wave are detected and are segmented. The method used to determine a burst is summarized in the following. The root-mean square (RMS) and the dominant frequency in each burst are computed. The averages of the RMS and dominant frequency in each wave are concatenated and serves as feature vector. The natural logarithm of attributes of the feature vector are computed to improve the categorization performance.

Algorithm 1. Algorithm to segment bursts

$\hat{y}_1(n) = H\big(x(n)\big)$, where H is the Hilbert transform [6] operator.

$$\hat{y}_2(n) = H\big(-x(n)\big)$$

$$z_1(n) = \sqrt{\hat{y}_1^2(n) + x^2(n)}$$

$$z_2(n) = \sqrt{\hat{y}_2^2(n) + x^2(n)}$$

$$z\,(n) = \frac{z_1(n) + z_2(n)}{2}$$

$b\,(n) = z(n) > t$, where threshold $t = \frac{1}{m}\sum_{n=1}^{m} z\,(n)$

In here, $b\,(n)$ specify burst regions. The value *0* stands for no burst and *1* indicates position of burst sample.

To compute dominant frequency of each burst the Eigen method of subspace frequency estimation techniques has been preferred [7]. The pseudo power spectrum has been obtained assuming that the signal has two complex conjugate frequencies. The dominant frequency corresponds to the position of a peak of the spectrum. As it is widely known that the RMS of i-th burst $x\_i\;(n)$ is $\sqrt{\frac{1}{L}\sum_{n=1}^{L} x_i^2\,(n)}$, where L is total number of samples of the burst signal [8] (see Figure 4).

The number trial for group A has been chosen to 88 normal and 88 abnormal type samples and the number of training records has been 29 normal and 29 abnormal type samples. Similarly, for group B, the number of trials has been taken to be 78 normal and 78 abnormal class samples and the number of training records has been 26 normal and 29 abnormal type samples. The training and testing data has been chosen randomly and the classification process has been repeated 250 times. The Linear Bayes Classifier [9] has been used as classifier. This classifier is a simple and the most widely known classifier.

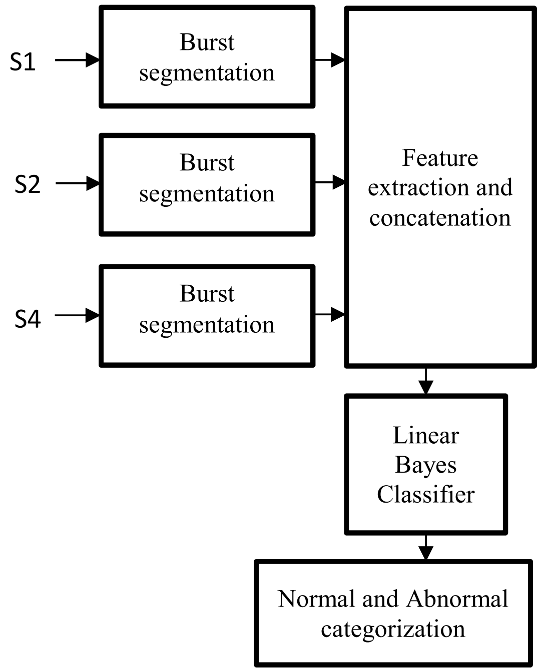

Figure 4. Feature extraction and classification.

III. RESULTS AND DISCUSSIONS

For a sample normal PCG signal of group A, the detected S1, S2 and S4 waves are shown in Figure 5 and Figure 6 demonstrate segmented bursts of the waves. The success selectivity and sensitivity rates of groups A, B are shown in Table 1. It is observed that the method fails for group B. However, the results for A are promising. The reason for bad accuracy for group B may be that the features used do not represent the categories sufficiently

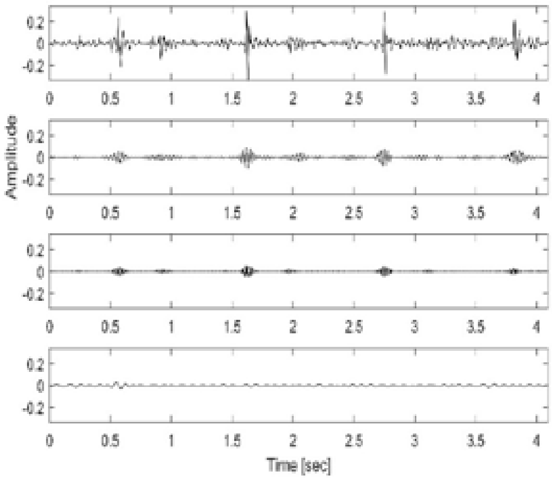

Figure 5: Original PCG signal and its S1, S2, and S4 waves.

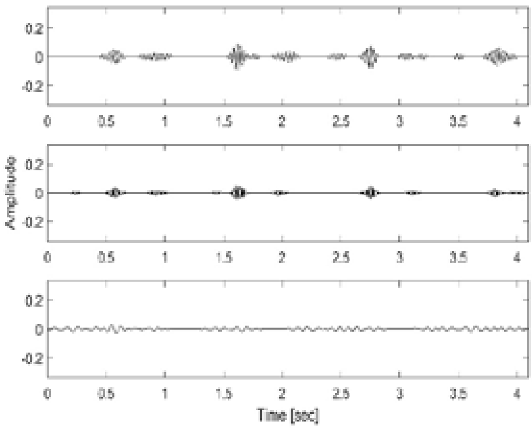

Figure 6: Segmentation. S1, S2, S4

TABLE 1: THE AVERAGE RESULTS OF 250 TİMES CATEGORİZATİON ATTEMPT

	Accuracy	Specificity	Sensitivity
A	61%	60%	61%
B	48%	49%	48%

IV. CONCLUSION

In this study, cardiac sound recordings collected from clinical or non-clinical settings were correctly classified as normal or abnormal and the algorithm was developed. The data obtained from the groups A, and B were categorized and average performances was obtained. The results of the study for group A suggest that it might support physicians to segment and determine normal and abnormal in phonocardiogram data if it is improved. However the algorithm fails for type of abnormality in group B.

In order to make a more accurate judgment, more PCG data should be used and the method should be tested. This method can also be adapted to identify certain heart diseases.

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