International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 3 No. 1 May 2013, pp. 145-150
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http://www.issr-journals.org/ijias/

Detection of Heart Diseases by Mathematical Artificial Intelligence Algorithm Using Phonocardiogram Signals

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ABSTRACT: An artificial intelligence (AI) algorithm has been developed using Mathematical formula to diagnose heart disease from Phonocardiogram (PCG) signals. Auscultation, the technique of listening to heart sounds with a stethoscope can be used as a primary detection technique for detecting heart disorders for the past years. But now the Phonocardiogram, the digital recording of heart sounds is becoming very popular technique as it is relatively inexpensive. Four amplitude parameters of the PCG signal are extracted by using filter technique and are used as input. PCG signals for three types of heart diseases such as Tachycardia, Bradycardia and Atrial fibrillation were used in this paper to test the accuracy. These disease types that affect the electrical system of heart are known as arrhythmias, cause the heart to beat very fast (Tachycardia) or very slow (Bradycardia), or unexpectedly (Atrial fibrillation). After the signals are filtered and the parameters are extracted, the parameters are fed to the AI algorithm. Classifications of heart diseases are carried using the AI algorithm by comparing the extracted parameters. Here comparison is done using Min Max method. The developed mathematical artificial intelligence algorithm is implemented in MATLab using Simulink and the simulation results proved that the developed algorithm has been shown to be a powerful technique in detection of heart diseases using PCG signals.

KEYWORDS: Artificial intelligence, Atrial fibrillation, Bradycardia, Heart, MATLab, Phonocardiogram signals, Tachycardia.

1 INTRODUCTION

Cardiac auscultation is the foremost basic analysis tool used to evaluate the function of the heart [1]. Electrocardiography (ECG) test is varied if the heart sound from the Phonocardiogram (PCG) shows any abnormalities. Heart sounds has the advantage of being heard and seen on the screen, which gives a higher level of the accuracy of the basic diagnosis. Even, because of noise and human misinterpretation, diagnosis may not be as accurate as we desired. Diagnosis accuracy can be substantially improved if an artificial intelligence machine is used to provide potential diagnoses using some parameters of the heart sound signals. Such process is expected to reduce mortality rate and cost of care [2].

There are a number of papers that propose different techniques for the extraction of parameters from the heart sounds and classify those using different techniques. In the late 1980 Mohamed and Raafat implemented a mathematical model to the heart sounds and murmurs by a finite number of parameters [3]. In this case, parameters were derived based on the linear prediction of the cardiac cycle frames, where classification was carried out based on the minimum distance between the parameters of the measured pattern and the reference patterns. Patil and Kumaraswamy presented an intelligent technique for heart attack based on Data Mining and Artificial Neural Network [4]. In this method, the parameters that are important to the heart attack are computed by K-means clustering algorithm.

A novel method of separating the heart sounds using homomorphic filtering and parameter extraction from wavelet coefficients are classified using GAL (Grow and Learn) algorithm [5].

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Reed et al. [5] analyze the heart sounds for symptom detection, where heart sounds were separated and transformed using wavelet decomposition. [6].

Yaghouby et al. presented Heart rate variability (HRV) based classification of arrhythmia. This is based on both the General Discriminant Analysis (GDA) and the Multi-Layer Perceptron (MLP) method [7].

In this paper, a new AI mathematical algorithm is developed and the input parameters to the algorithm are extracted from the PCG signals. PCG signals from many human subjects are collected and the diseases are classified using a comparison algorithm to assess the diagnosis predictability. Among these subjects, few are diagnosed with tachycardia (disease-1), remaining is diagnosed with bradycardia (disease-2) and Atrial fibrillation (disease-3).

2 MECHANISMS FOR HEART SOUND PRODUCTION

The human heart has four chambers, two upper chambers are called atrial and two lower chambers are called ventricles as shown in Fig. 1.

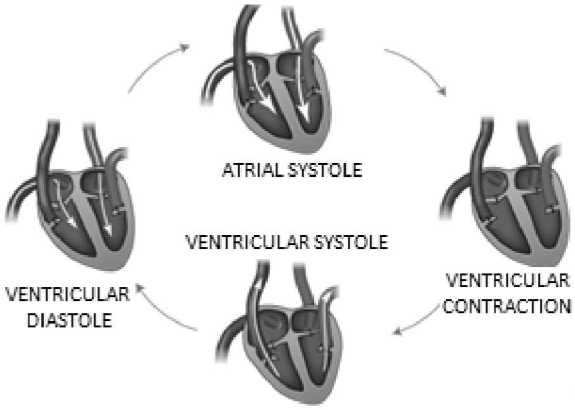

Fig. 1. Mechanism of creation of heart sound

There are valves located between the atrial and ventricles of a heart, and also between the ventricles and the major arteries. These valves open and close periodically to permit blood flow in only one direction. Two sounds are normally produced due to blood flow through the heart valves during each cardiac cycle as shown in Fig. 2.The sound S1 called “lubb” and S2 called “dupp”.

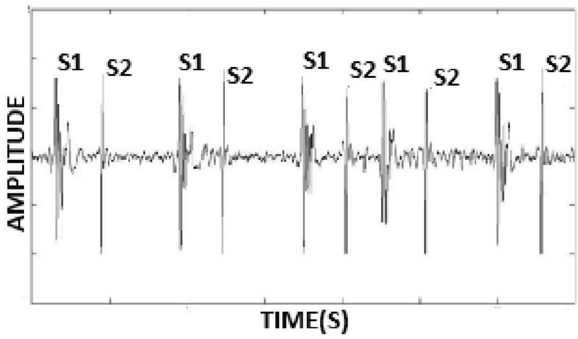

Fig. 2. Waveform of S1 heart sound lubb and S2 heart sound dupp

3 PHONOCARDIOGRAPHY

Diagnostic technique that creates a graphic record called Phonocardiogram (PCG) of the sounds and murmurs produced by the heart as shown in Fig. 3 [8].

The heart sounds are produced by mechanical events, as follows:

A. Valvular events - Vibrations caused mostly by closing of valves and a lesser intensity vibration is produced by opening of the heart valves [8].

B. Muscular events - Vibrations of the myocardium due to contraction of valves

C. Vascular events - The sudden distension of the arterial walls causes vibration due to ejection of blood [8].

D. Acceleration/Deceleration of the blood flow in the heart produces vibration [8].

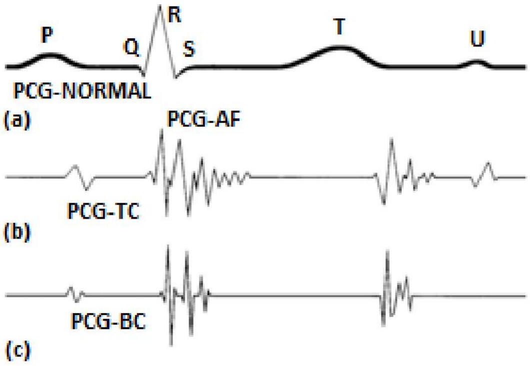

Fig. 3. (a) The PCG Signals for normal human (b) The PCG Signals for Tachycardia and Atrial Fibrillation disease (c) The PCG Signals for Bradycardia disease

4 Heart Diseases

The term "Heart Diseases" refers to diseases occurred in the heart and also in the blood flow system within the heart. There are more than 50 different types, the most common type that affects the electrical system is known as arrhythmias. They can cause the heart to beat very fast (Tachycardia) or very slow (Bradycardia), or unexpectedly (Atrial fibrillation) as shown in Fig. 3. These kinds of heart disease include the following types:

- Tachycardia
- Bradycardia
- Atrial Fibrillation
- Premature Atrial Contractions (PAC), also called as premature atrial complexes
- Atrial flutter etc. [9].

4.1 Tachycardia

Heart rate that exceeds the normal beat range is called tachycardia. A heart rate exceeds 100 beats per minute is usually accepted as tachycardia as shown in Fig.4.

Fig. 4. ECG showing tachycardia with a heart rate of 100 beats per minute

Even though, tachycardia can be dangerous depending on the heart rate speed and type of rhythm. Tachycardia derived from the Greek words tachys (accelerated or rapid) and kardia (of the heart).

4.2 Bradycardia

The resting heart rate of fewer than 60 beats per minute is called bradycardia, even though it is no symptomatic until the rate drops below 50 beats per minute as shown in Fig.5. It may produce cardiac arrest in some cases; because those have bradycardia may be not able to pump required oxygen to their hearts. It sometimes results in lacking of strength, briefness of breath, and if severe cause death.

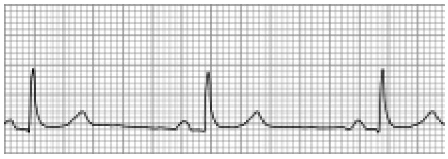

Fig. 5. Fig. 5. ECG showing bradycardia with a heart rate of about 50 beats per minute

4.3 Atrial Fibrillation

Atrial fibrillation or flutter is a one type of unexpected heart beat rate in which the heart sounds is very fast and irregular.

5 Simulation Using Matlab

In this paper, a new mathematical AI algorithm was developed using MATLab, where new parameters are extracted from the PCG signals and are used as input to the algorithms.

5.1 Parameters Considered

The P,Q,R,S amplitude values from the PCG signal are considered as input parameters as shown in Fig. 3.

5.2 Parameter Extraction

The parameters are extracted from PCG signal using Butterworth filter and many signal processing elements. The PCG signal is processed by filter and peak values of the signal are detected by MinMax Mask.

5.3 Atrial Fibrillation Detection Algorithm

Since an irregular rhythm of the QRS complexes is the major parameter of AF. The R–R interval (RRI), defined as the interval of neighboring QRS complexes, is an ideal parameter to identify AF. This paper uses two different algorithms for AF detection.

5.3.1 Algorithm I

Step 1: Detection of R waves and marking of R peaks.

Step 2: Calculation of RRI (the duration of adjoined Rpeaks).

Step 3: Calculation of the variation of consecutive RRI (ΔRRI).

Step 4: Activation of the alarm system when ΔRRI >150 ms occurs twice within each 6 s of computation.

5.3.2 Algorithm II

Step 1: Detection of R waves and marking of R peaks.

Step 2: Calculation of RRI (the duration of adjoined R peaks).

Step 3: Calculation of the variation of consecutive RRI (ΔRRI).

Step 4: Calculation of the SD of RRI (RRIstd) in each 6-s recording.

Step 5: Activation of the alarm system when ΔRRI >150 ms occurs twice and RRIstd > 60 ms within 6 s of computation.

The simulation for atrial fibrillation was shown in Fig. 6.

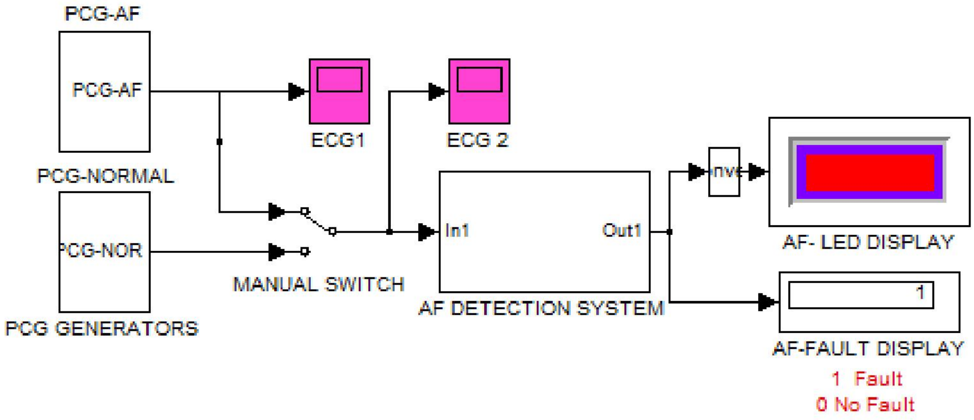

Fig. 6. Simulation of Atrial Fibrillation (AF) heart disease detection

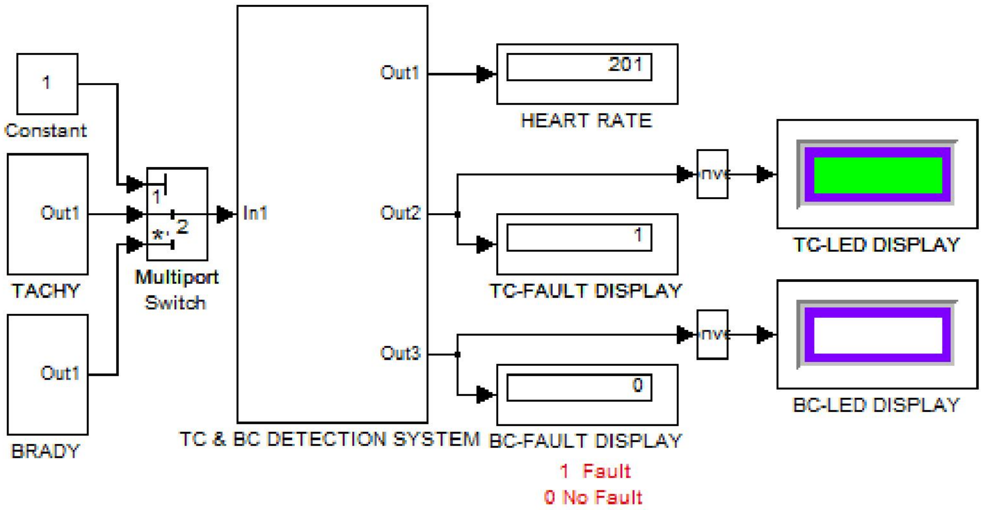

Fig. 7. Simulation of Tachycardia(TC) and Bradycardia(BC) heart disease detection

5.4 Tachycardia Detection

For this disease the AF detection algorithm was used by considering only the peak value without considering the time phenomenon ,that find tachycardia when the heart beats goes too fast. The simulation for tachycardia was shown in Fig. 7.

5.5 Bradycardia Detection

For this disease the AF detection algorithm was used by considering only the peak value without considering the time phenomenon, that find bradycardia when the heart beats goes too slowly. The simulation for bradycardia was shown in Fig. 7.

6 Results

The three different colours in the simulation a result indicates three different diseases occurred in the heart and white colour indicate normal condition of heart as shown in the Table 1.

Table 1. Simulation Results

S. No.	Disease	Fault Display Value	LED Display Colour
1	Tachycardia	0 (Normal Condition)	Green
		1 (Disease)	White
2	Bradycardia	0 (Normal Condition)	Blue
		1 (Disease)	White
3	Atrial Fibrillation	0 (Normal Condition)	Red
		1 (Disease)	White

7 CONCLUSION

This paper proposes the preprocessing of heart sound signal from many human objects with disease in simulation. Among these human objects, few are diagnosed with tachycardia (disease-1), remaining is diagnosed with bradycardia (disease-2) and Atrial fibrillation (disease-3). Four independent parameters related to the PCG signals are extracted. These parameters are fed as inputs to AI algorithm. The result shows that the new AI algorithm finds the diseases perfectly and simulation also verifies the same.

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