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Feature Extraction from an ECG Signal of Various Cardiac Patients Using Daubechies Decomposition Technique

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Abstract: ***Electrocardiograms (ECG) are cardiac signals formed by the cyclical electrical activity of the heart muscles. The signal is very important for cardiovascular disease assessment. The objective of the work can be laid down as ECG beat detection and Various Feature Extractions which includes P- height, Q- height, R- height, S- height, T- height, QRS width. The QRS complex is one of the most important characteristics and identification of R peaks makes the detection of other characteristic peaks efficient and easy. Using first derivative of ECG signal by computing sample to sample differentiation, position of R-peak can easily be detected. After detection of R-peak, corresponding Q-peak, S-peak, P-wave, T-wave were identified by Daubechies Wavelet Decomposition technique. From the designed algorithm we retrieved data sets for different data entered. We have tested the algorithm with different signals of different cardiac diseases and obtained datasets of the various features and plotted it in a graph to obtain the probable ranges for various features of various diseases. For this work we have used short duration ECG data from the physionet MIT-db database. The beats were segmented based on foot detection and the fiducial points were extracted. Based on the fiducial points, beat wise features were extracted which were fed to the designed algorithm.***

Keywords: Daubechies, derivative matrix, ECG, fiducial points, Single lead array

1. Introduction

Today, heart disease is one of the prominent cause of death worldwide. . To prevent heart attack from becoming severe, early diagnosis is of utmost importance. One of the diagnostic techniques is Electrocardiogram (ECG). ECG devices record electrical signal from cardiac muscle to predict the abnormality present in the heart. [1]

Electrocardiography is the process of producing an **electrocardiogram**, a recording - a graph of voltage versus time - of the electrical activity of the heart by using electrodes placed on the skin. These electrodes detect the minute electrical changes that are a result of cardiac muscle depolarization followed by repolarization during each cardiac cycle [2]. Fig.1 shows the general structure of an ECG signal and each of the fiducial points like P-wave, QRS-complex and T-wave represents each particular segment of cardiac cycle. Changes in the normal ECG pattern occur in numerous cardiac disorders, including cardiac rhythm disturbances, inadequate coronary artery blood flow and electrolyte disturbances. Since the signal analysis does not need any introduction of instruments in the body, hence it is considered the most efficient method of diagnosing cardiac conditions.

Table 1: Table based on the functions of segments extracted from ECG Signal

Segments	Function	Duration
P-R Segment	It is basically a measure of the time taken by an impulse to travel from atria excitation and through atria and remaining fibers of the conduction system.	120 ms to 200 ms long
S-T Segment	It is the measure of the time during which the ventricles of the heart are completely depolarizing and contracting	300 ms to 350 ms long
Q-T Segment	It is the measure of time duration from the period when then ventricles have completely depolarized to the point when they get re-polarized back to their resting potentials	About 400ms long

A lot of information on the normal and pathological physiology of heart can be obtained in the form of ECG. [3]

The detection and measurement of these characteristic waves are related to the detection of various cardiac diseases. For example QRS complex is used to determine heart rate whereas ST segment is related to Myocardial Infarction.

The basic function of this project is to work with various ECG signals, extract the features (P wave, QRS complex, T wave) form the signals and based of the various readings obtained we categorize the various diseases falling under the particular monitoring.

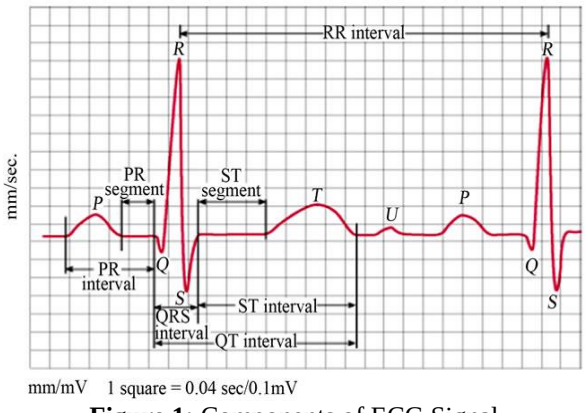

Figure 1: Components of ECG Signal

2. Methodology

2.1 Data Aquisition

For this study, short duration ECG data from the physionet MIT-db database were used. The beats were segmented based on foot detection and the fiducial points were extracted. Based on the fiducial points, beat wise features were extracted which were fed to the designed algorithm.

2.2 R Peak detection

Using the derivative based approach; the R-peaks were detected in this thesis work. Here only lead V5 was used to detect R-peaks because, in lead V5, the QRS-domains are more prominent than in the other leads. It is to be noted that in all the leads, positions of R-peaks are same. The algorithm or R-peak detection is mentioned below.

To detect the position of R-peaks, MITDB databases were used, available in "www.physionet.org". The R-peak detection algorithm undergoes four steps. These are,

a) Formation of single lead array from MITDB data.
b) Formation of first derivative matrix of from lead matrix.
c) Estimation of amplitude and duration of R-R interval.
d) Final detection of position of R-peaks.

1) Formation of lead matrix from MITDB data of ECG

Each MITDB data (available in "www.physionet.org"), consists of three columns. The first column denotes the sampling time (in second) and rest of two consist of ECG data, recorded from lead II and lead III. The first two rows represent the unit of the data of corresponding column, that means, for first column, it is 'sec' and for other columns, it is 'mill volt or mV in short'. Hence, these rows are simply ignored for computation. Now, the primary aim was to create a lead array using the data of lead II. For this reason, the second column of MITDB data was imported into MATLAB and stored in an array 'M'. From this array, R-peaks were detected.

2) Formation of first derivative matrix from lead array:

To perform first derivative, sample to sample difference is taken from array 'X'. The algorithm steps are given below, Y = originating an array that consists of first derivative of data of array X

i = 1;
1. Y (i) = X(i+1) – X(i);
2. i = i +1;
3. if i ≤ (n-1) , go to step 1
4. first derivative matrix 'Y' is created.

3) Estimation of amplitude and duration of R-R interval

In this step, taking first 1000 sample from array Y, an average of four maximum values amongst them, is calculated. Then, using this average value, R-R interval is to be calculated in an adaptive way.

4) Final detection of position of R-peaks

A. Beat Extraction from ECG Data:

From the detected R-peaks the corresponding beats were extracted by determining the beat boundary point between two successive ECG beats.

1) For the first R-peak

The beat starts from the first sample to 2/3rd of the distance between the first and second peak, measured from first peak.

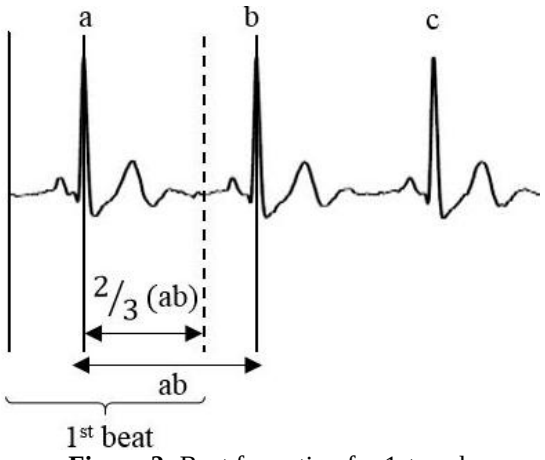

Figure 2: Beat formation for 1st peak

2) For the last R-peak

The beat was created from the 1/3rd of distance between the last and its previous peak, measured from last peak, to the last sample.

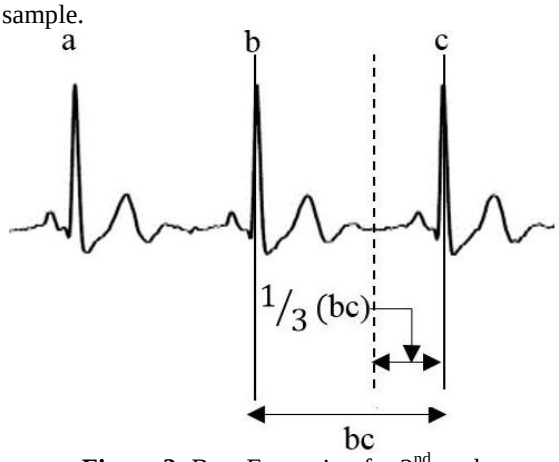

Figure 3: Beat Formation for 2nd peak

3) For other R peaks

The beat was created from the 1/3rd of distance between that peak and its previous one, measured from that peak, to the 2/3rd of distance between that peak and its next one, measured from that peak.

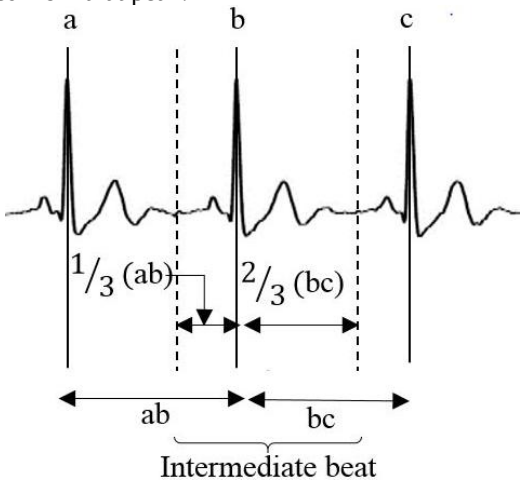

Figure 4: Beat formation for intermediate peaks

D. Designing the Algorithm

1) For finding R, we used the derivative method for the signal. First, we have made a derivative of the points in the signal and then graphed it. And the values of the highest peak were found and hence it was plotted and R-peak was found.

Let us assume, we have a signal 'Y' which has 'n' number of sample. Now the first derivative of this signal can be defined as,
X(m)= Y(m+1)-Y(m) where m=1,2,3,…….n-1
Similarly the second derivative can be computed as,
Z(m)= X(m+1)-X(m) where m=1,2,3,…….n-2
Now in QRS region, amplitude in signal X or Z is higher with respect to other part, within a beat. Thus QRS region can be easily detected by derivative method.

2) Beats were found out by taking the near about 1/3 of the R-R width before the of the R-peak instance to 2/3 of the R-R width after the R-peak instance.
3) The beat was used as window by which the Daubechies Wavelet algorithm was used to decompose and to find the points with better accuracy.
4) After finding R-peak, we take the time range of 10ms-15ms before R-peak instance the local minima was to get the Q-troughs. And by taking 10ms-15ms after the R-peak instance the local minima was taken to find the instance of S-troughs. After the instance was found the corresponding amplitude was plot from the array.
5) In a similar method, the S and T, the local maxima were taken 20ms-30ms before and 25ms-45ms respectively to find the points.
6) The QRS-complex width is taken by subtracting the instance of S from Q.

3. Result and Discussions

For this study, short duration ECG data from the physionet Mitdb database were used. The beats were segmented based on foot detection and the fiducial points were extracted. Based on the fiducial points, beat wise features were extracted which were fed to the designed algorithm.

Here, we have considered 6 cardiac diseases namely

- CARDIOMYOPATHY
- BUNDLE BRANCH BLOCK
- MIANTERIOR
- MI-INFEROLATERAL
- MIOCARDIAL
- MIOCARDITIS

For each disease we have initially tested for 3 datasets and the graphs were obtained indicating various features which are to be extracted from our designed algorithm, namely:

- P- Height.
- Q- Height.
- R- Height.
- S- Height.
- T- Height.
- QRS width.

1) Cardiomyopathy

Cardiomyopathies are a group of genetically heterogeneous myocardial diseases. In primary cardiomyopathies, hypertrophic cardiomyopathy (HCM) and dilated cardiomyopathy (DCM) are usually autosomal dominant inherited. [4]. The dataset mentioned in table 2 produced the following result.

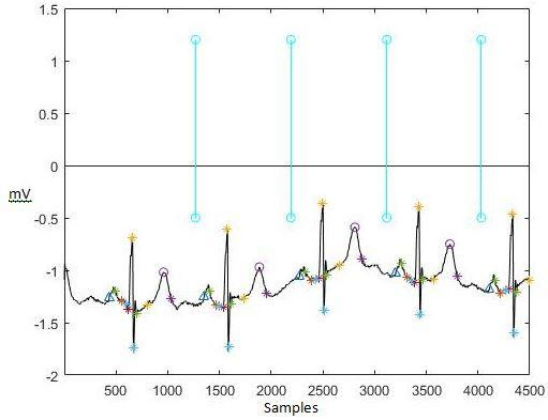

Figure 5: ECG showing feature of Cardiomyopathy

2) Bundle Branch Block

Bundle Branch Block (BBB) is a cardiac disorder, occurs due to blockage in the flow of electrical impulses of the heart. This irregularity can be observed on the ECG. [5] It sometimes makes it harder for your heart to pump blood efficiently through your body. The delay or blockage can occur on the pathway that sends electrical impulses either to the left or the right side of the bottom chambers (ventricles) of your heart. Bundle branch block might not need treatment. When it does, treatment involves managing the health condition, such as heart disease, that caused bundle branch block. The dataset mentioned in table 2 produced the following result.

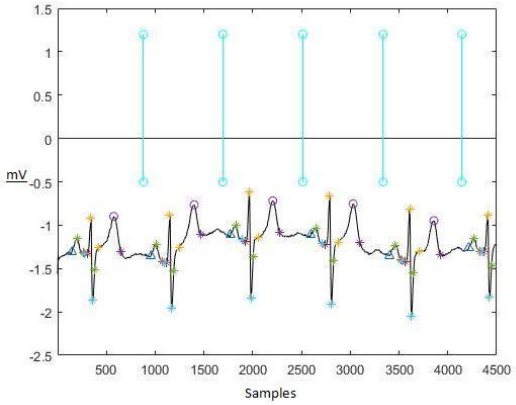

Figure 6: ECG showing feature of Bundle Branch Block

3) MI Anterior

An anterior wall myocardial infarction — also known as anterior wall MI, or AWMI, or anterior ST segment elevation MI, or anterior STEMI — occurs when anterior myocardial tissue usually supplied by the left anterior descending coronary artery suffers injury due to lack of blood supply. When an AWMI extends to the septal and lateral regions as well, the culprit lesion is usually more proximal in the LAD or even in the left main coronary artery. This large anterior myocardial infarction is termed an extensive anterior. The dataset mentioned in table 2 produced the following result.

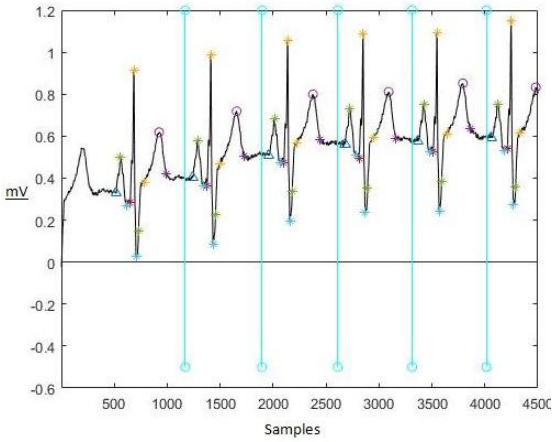

Figure 7: ECG showing feature of MI Anterior

4) MI Inferolateral

The dataset mentioned in table 2 produced the following result.

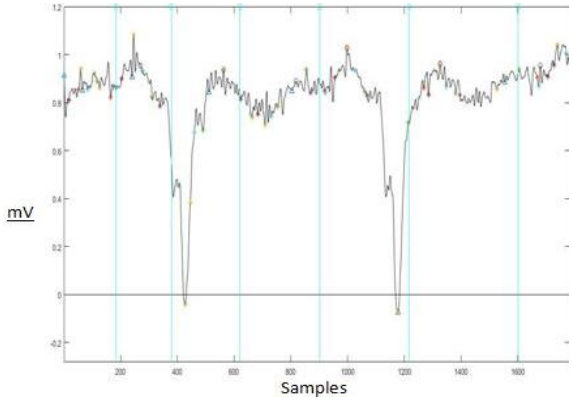

Figure 8: ECG showing feature of MI Inferolateral

5) Myocardial

Myocardial infarction (MI), commonly known as a heart attack occurs when blood flow decreases or stops to a part of the heart, causing damage to the heart muscle. If the patient is not treated early, it may lead to irreversible damage and even death since the cardiac tissues are damaged heavily [6].The dataset mentioned in table 2 produced the following result.

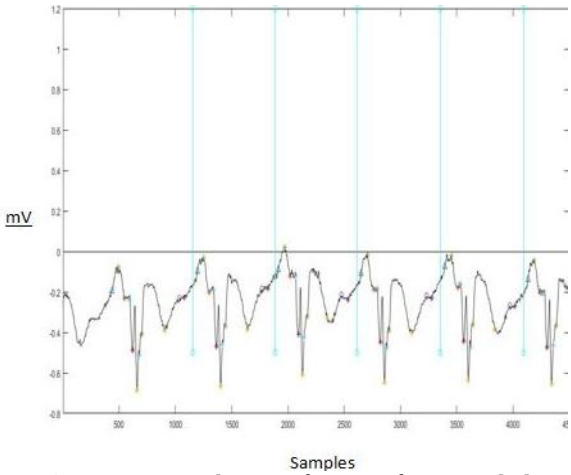

Figure 9: ECG showing feature of Myocardial

6) Myocarditis

One major public health problem in Latin America is Chagas disease. This is caused by infection with Trypanosoma Cruzi. In the chronic phase, infected patients develop chagasic myocarditis, ultimately resulting in arrhythmic death. Myocarditis can affect our heart muscle and our heart's electrical system, reducing heart's ability to pump and causing rapid or abnormal heart rhythms (arrhythmias). [7]

The dataset mentioned in table 2 produced the following result

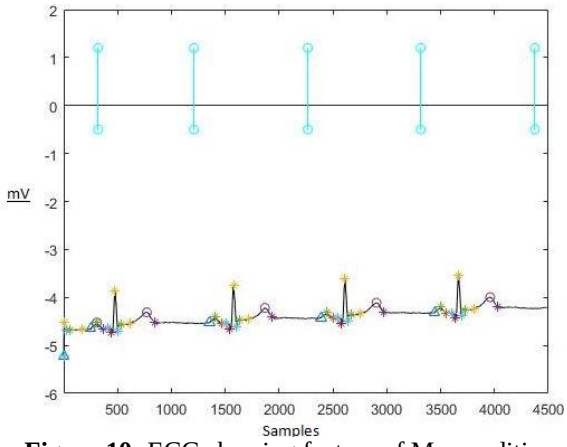

Figure 10: ECG showing feature of Myocarditis

Table 2: Table showing various features of 6 different cardiac diseases

Diseases	P(mV)	Q(mV)	R(mV)	S(mV)	T(mV)	QRS(ms)
Cardiomyopathy	0.086498	0.22857	0.8405	-0.21374	0.30756	0.111
Bundle Branch Block	0.14821	0.061099	0.40564	-0.72947	0.39851	0.1085
MI Anterior	0.20014	0.19175	0.57196	-0.30744	0.22424	0.1111
MI Inferolateral	0.13015	0.099635	0.059674	0.042417	0.2773	0.1152
Myocardial	0.12524	0.22755	-0.40243	-0.21476	0.08097	0.1097
Myocarditis	0.089341	0.15875	0.81191	0.03501	0.20001	0.1156

4. Conclusion

All algorithms, mentioned in this paper, was computed in same environment (MATLAB, i3 CPU, 3.19 GHz processor) with same number of multilead ECG data samples with one minute duration of PTB database. The total number of samples used in each record is 60000 per lead. Hence for computation, total (8×60000) samples were taken. As the records in PTB database are sampled in 1 KHz frequency level, they contain almost 60-120 heart beats. The proposed algorithm was implemented for 6 kind of cardiac diseases and 3 datasets for each disease were taken into consideration. As per the designed algorithm, all the features were extracted from the databases and the features were plotted on the graph.

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