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ECG Based Cardiac Abnormality Detection Using Crosswavelet Transform

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Abstract: ECG or EKG (Electrocardiography) records the electrical activity of the heart in a graphical format. This efficiently reproduces the action of the heart which helps to identify the hidden pathology. This underlying pathology is the sign of some abnormality. . The ECG is detected by electrodes attached to the outer surface of the skin and recorded by a device external to the body. ECG signal plays an important role in the preliminary diagnosis, prognosis and survival analysis of heart diseases. Here Cross Wavelet Transform (XWT) uses to analyse the ECG signal so that the pathology can be easily detected. The cross-correlation between two time domain signals gives a measure of similarity between two waveforms. The application of the continuous wavelet transform to two time series and the cross examination reveal localized similarities in time and frequency. The proposed algorithm analyses ECG data utilizing XWT and explores the resulting spectral differences. A normal beat ensemble is selected as the absolute normal ECG pattern template, and the coherence between various other normal and abnormal subjects is computed.

Keywords: Component; ECG, XWT, Myocardial infraction, Daubechies, MRA.

I. INTRODUCTION

Cardiac disease is one among the main causes of death in most countries of the world. Therefore, the identification of cardiovascular diseases and its anticipation is a very important issue in the medical career. Electrocardiography (ECG or EKG) is the graphical display of the heart, which records its activity over a period of time. The ECG is sensed by electrodes attached to the outer surface of the skin and recorded by a device external to the body [1]. ECG signal plays a significant role in the primary diagnosis, prediction and existence analysis of heart diseases. Electrocardiogram (ECG) is universally used for diagnosing many cardiac diseases, which are one of the prime causes of death all over the world. The beginning of ECG is the electrical stimulation of heart muscle cell causing series of depolarization and repolarization of its membrane. The electrical pulses produced due to this electrical activation are propagated along the cell fiber and transferred to adjoining cells. The result is generation of electrical impulses, which travels through the cardiac surface. These electrical impulses can be detected by surface electrodes amplified and displayed as the ECG. From electrical point of view, the heart is positioned at the center of the electrical field it generates. The intensity of its electric field reduces with the distance from its origin. Usually a 12-lead electrode system is used for recording ECG, discovering a general view of the electrical activity of heart. The recorded ECG waveform Consists of five different component waves, namely P, Q, R, S and T wave followed by a conditional U wave. Since cardiac disease is one of the dominant health anxieties all over the world. The analysis of individual ECG beats characteristic shape, morphological features, and spectral properties can give better result for the analysis procedure. However, automated classification of ECG beats is a challenging problem because the morphological and temporal characteristics of ECG signals show major variation for different patients under different physical conditions. An EKG shows:

- How fast your heart is beating
- Whether the rhythm of your heartbeat is steady or irregular

- The strength and timing of electrical signals as they pass through each part of your hea

This wave represents a flow of electricity that can be detected by electrodes placed on the surface of the body. Once depolarization is completed the cardiac cells are restored to their resting potential, a process called repolarization. This flow of energy takes in the form of ECG wave and is composed of P wave followed by QRS complex followed by T wave followed by U wave per cardiac cycle As stated due to the high mortality rate cardiac disease is been focused as one of the greatest threat to mankind. The unhealthy life style and lack of exercise is the main reason behind heart disease, the vessels get accumulated with fat and cholesterol which initially lead to the formation of an infract. The figure below shows the ECG signal and corresponding intervals.

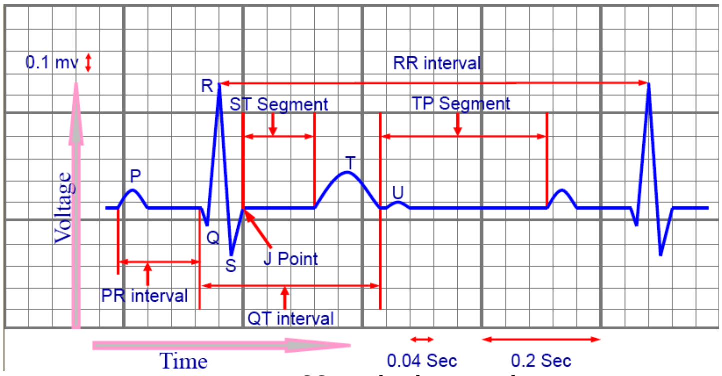

Figure 1.1 ECG signal and its intervals

II. Related Works

ECG records is mainly used to detect the different cardiac abnormality, the previous method used for the detection is also considered in this study. In the preprocessing stage of ECG the method followed is same as that of previous work, a real-time algorithm for detection of the QRS complexes of ECG signals was propose by Jiapu Pan and Willis J. Tompkin. It reliably recognizes QRS complexes based upon digital analyses of slope, amplitude, and width. A special digital bandpass filter reduces false detections caused by the various types of interference present in ECG signals. This filtering permits use of low thresholds, thereby increasing detection sensitivity. The algorithm automatically adjusts thresholds and parameters periodically to adapt to such ECG changes as QRS morphology and heart rate. Earlier the denoising procedure was done using filtering method, but now the denoising method is propagated through the use of Wavelet Transform. This method is being considered in the present work.

In the previous method denoising was done using filtering method and also the detection of the QRS complex is being done using different methods as [10] this particular method has been chosen as one of the pioneer method in that of ECG analysis,mainly known as Pan&Tompkins QRS detection algorithm. Now the wavelet based method is mainly used,for the denoising procedure as well as further detection also.Wavelet based ECG analysis is being done[3]. Then in the further procedures the signal is analysed and then feature extraction is carried out as in[6][8] which are some of the procedure carried out previously.

III. Proposed Methodology

The proposed method deals with the abnormality detection, in the present work the abnormality focused on is the Myocardial infraction. [5]Myocardial infarction, infarction means a block, which together says myocardial infarction, the infract which occur on the inferior myocardial wall leads to inferior myocardial infarction. Myocardial infarction (from Latin: Infarctus myocardii,MI) or acute myocardial infarction (AMI) is the medical term for an event commonly known as a heart attack. It happens when blood stops flowing properly to part of the heart and the heart muscle is injured due to not receiving enough oxygen. Usually this is because one of the coronary arteries that supplies blood to the heart develops a blockage due to an unstable buildup of white blood cells, cholesterol and fat. In this work, for the analysis of ECG there are certain steps that should be involved in the flow of work.These steps are shown in the flow chart given below. The flow chart below describes about the different steps that should be involved in every ECG analysis, here in the present work wavelet based method is being chosen for the preprocessing stages and as well as in the further steps. [8]

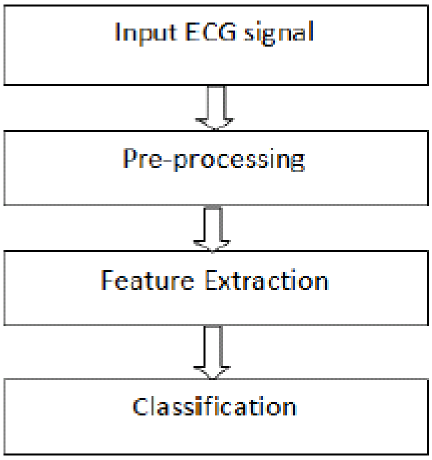

Figure 3.1 flow chart

A. Wavelet Transform

Most of the biomedical signals like ECG are non-stationary. Wavelet Transform was found to be the efficient solution for processing a non-stationary signal. For best performance in many applications, transforms require filters that provide a number of desirable properties such as orthogonality, compact Support, regularity and symmetry. Wavelet Transform possesses these properties, making them the best choice in analyzing signals. [7]The Multi Resolution Analysis (MRA) using wavelet transform is found to be an extremely useful method in extracting ECG features.[3] Wavelet mean small wave. So wavelet analysis is about analyzing signal with short duration finite energy functions. They transform the signal under investigation into another representation which presents the signal in a more useful form. This transformation of the signal is called wavelet transform. Unlike Fourier transform, we have a variety of wavelets that are used for signal analysis. Choice of a particular wavelet depends on the type of application in hand. Wavelet transform is a linear transform, which decomposes a signal into components that appears at different scales (or resolution).Time localization of spectral components can be obtained by multiresolution wavelet analysis, as this provides the time-frequency representation of the signal.[3] A Wavelet Transform, at high frequencies, gives good time resolution and poor frequency resolution, while at low frequencies the Wavelet Transform gives good frequency resolution and poor time resolutions. Based on a discretization manner of the time-scale plane and characteristics of wavelets, the WT can be branched by continuous wavelet transform (CWT) and discrete wavelet transform (DWT). [3]Recently, the WT have been applied to various topics in the wind engineering, and their applications still are evolving. The continuous wavelet transform involves decomposing a signal f(t), into a number of translated and dilated wavelets. The main idea behind this is to take a mother wavelet $\Psi(t)$, translate and dilate it, convolve it with the function of interest, and map out the coefficients in wavelet space, spanned by translation and dilation. Periodic behavior, then shows up as a pattern spanning all translations at a given dilation, and this redundancy in the wavelet space makes detection of periodic behavior rather easy. The wavelet transform preserves temporal locality which is an advantage over Fourier analysis.[4]

In the present work Daubechies wavelet db4 is chosen. This is due to its similarity with the ECG signal. Although the Daubechies algorithm is conceptually more complex and has slightly complicated computations, this algorithm picks up minute details that are missed by other wavelet algorithms, like Haar wavelet algorithm. The Daubechies wavelets, based on the work of Ingrid Daubechies, are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments. They are extremely asymmetric and under magnification, show characteristic jagged wiggles. This complexity means that there is no simple formula for this wavelet. But this fact can beautifully turn into a practical tool, easily programmed and used with minimum mathematical training. [2]A general Daubechies wavelet is shown below.

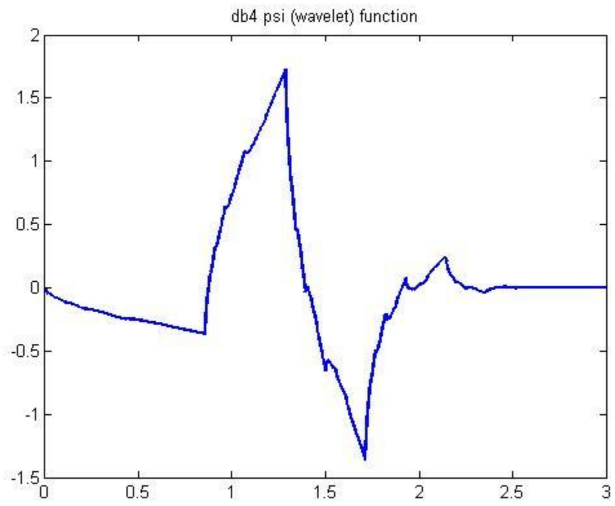

Figure 3.2 Daubechies wavelet

Here in the present work the wavelet chosen is db4, then in the first step is the denoising in this the signal is denoised by wavelet transform approach.

B. Denoising

The signal is first decomposed using Discrete Wavelet Transform, DWT Here the signal is decomposed to 10 level. The decomposition of the signal lead to Approximation and detail coefficients And then the denoising is done by removing certain approximation and detail coefficients

Electrosurgical noise and muscle contraction noise are high frequency noise. Electrosurgical noise completely destroys the ECG and without its removal an accurate feature extraction cannot be accomplished. The frequency content of this noise is 100 kHz10 MHz. Since the sampling frequency of the data is 1 kHz an aliased version gets added to the ECG. The muscle contraction noise has a frequency range from dc-10 kHz.[6] These two noises are eliminated by discarding the detail coefficients D1, D2. After removal of these noises the remaining ECG signal ranges from 0 to 125 Hz. The drift of the baseline is caused due to respiration and is likely to be as a nearly sinusoidal component and the frequency of respiration gets added to the ECG during its acquisition. The baseline variation frequency is 0.15 to 0.8 Hz. Motion artifacts are transient baseline changes caused by change in the electrode skin impedance with electrode motion. The baseline disturbances caused by motion artifact can be assumed as a signal resembling one cycle of a sine wave and is within the frequency range of baseline drift. These two type of noises stated above can be eliminated by removal of the lowest frequency component, after decomposition of the ECG signal.coefficient A10 contains this frequency along with the DC component of the ECG. Discarding A10 frequency band and reconstructing the signal eliminates these two noises.

Power line interference contains a 60 Hz noise inter-twined with the ECG. In India the power line frequency is 50 Hz. In this work, ptb-db data files under Physionet are used for evaluation of the proposed method, where the power line frequency is 60 Hz. Electrode contact noise is transient interference caused by loss of contact caused by the electrode and skin. During this time short duration power line interference corrupts the ECG. These two noises can be eliminated by the dyadic scale DWT technique by identification of the frequency band containing the frequency range of 59.5 to 60.5 Hz. [12][6]

The signal output is in the frequency band 0 to 125 Hz . On further decomposing the signal, the low pass component (A5) will have 0 to 62.5 Hz and high pass component (D5) will have 62.5 to 125 Hz. The noise is in the low pass component, so it is decomposed .The next level decomposition yields 0 to 32.25 Hz signal component (say D5a) and 32.5 to 62.5 Hz signal (say D5b). Now the high pass component D5b (containing the 60 Hz noise) is decomposed. The signal component D5b containing the noise frequency is continuously decomposed until the frequency band of 59.5 to 60.5 Hz is obtained. This component is rejected and the signal from the rest of the decomposed components is reconstructed. This reconstructed signal is the noise free signal.

C. QRS complex band selection and R peak detection

In this stage the objective is to find out the QRS region from the detail coefficients of the DWT decomposition and mapping of this zone in the denoised array the QRS complex regions are more prominent in details at scale D3 to D5, among which the most of the energy of the QRS complex is concentrated. For signals with high noise content the components D4 and D5 are to be considered.An array is formed by addition of components D4 and D5.To find out the QRS complexes from an empirically determined threshold value is set which is equal to the 15 percentage of the mean amplitude value of array. To detect the R peaks accurately, the indexes which exceed the threshold level are marked in the array.Since the maximum width of the QRS complex for any patient is not more than 160 ms, a fixed window of same width is searched in that array to detect the indexes where the threshold condition is satisfied. Between two consecutive searches a blanking period of 200 ms is offered. The R peaks are the maximum amplitude values within that array , the actual R peaks can be obtained by searching the local maximum (minimum) value ,the amplitude of each R index is again checked If this is positive (negative), an R peak (an elongated or pathological Q or S) is identified. So, by this method all the peaks of the QRS complex are identified.[12]

D. Cross Wavelet Transform(XWT)

The continuous wavelet transform is effective for examining how a time series varies in time and scale, but fails to include how it varies over a range of scales when assigning a period that best characterizes it. After identifying that a periodic pattern exists in what can be potentially noisy and poorly sampled data, one finds the dilation which characterizes the period from the time-averaged data (i.e., the wavelet power spectrum), and from that dilation the period is calculated. For a quasiperiodic signal there is no unique dilation; there is a need for a method of directly measuring a characteristic time scale, or scales, that includes information on how a source varies in dilation, and for this we shall go for Crosswavelet Transform.A Quasi-periodic signal is a periodic signal with period and amplitude variations.The Electrocardiogram(ECG) and several physiological signals can be treated as quasi periodic. The study of interrelation between pairs of time-domain signals can be performed by the application of XWT. The XWT of two time series X and Y is defined as [4]

$$W_{xy} = W_x W_y^{*}$$

Where * denotes complex conjugation. The cross-wavelet spectrum is complex, and hence one can define the cross-wavelet power as

$$|W_{xy(s)}|$$

the wavelet cross spectrum is denoted as (WCS) Another useful measure is how coherent the XWT is in timefrequency space. The Wavelet coherence spectrum (WCOH) of two time series is defined as

$$R_n^2(s) = \frac{\left|S(s^{-1} W_n^{XY}(s)\right|^2}{S\left(s^{-1}\left|W_n^X(s)\right|^2\right) \cdot S\left(s^{-1}\left|W_n^Y(s)\right|^2\right)}$$

Where S is a smoothing operator and s is the scale. WCOH can be thought of as a localized correlation coefficient in the time frequency space.[5]

Here in this work cross wavelet transform is mainly used as an analysis tool for the comparision of the signal, the databases is being chosen from PTB. Which contain records subjected to Myocardial Infraction, then as a part of the analysis as we are using the scope of XWT as this transform is chosen as an analysis tool in the present study, a normal beat is kept as a reference signal or a standard normal template is used A cardiac beat from a 25 year-old pathologically normal nonsmoking male subject with a heart rate of 72 beats/min is considered as the normal template for analysis. A beat ensemble from patient id: ptbdb/patient150/s0287lre is considered as the normal template. This normal template is validated using standard textbooks and also by visual inspection by doctors.

Then after the Pre-processing stage both the signals ie the normal signal or the Template signal and the signal to be analysed is being subjected to Continuous wavelet transform first and in this computation the mother wavelet used through out the analysis is db4 as it has the similar shape as that of the ECG signal. So after the computation of CWT, the CWT transformed signal is again subjected to XWT as a part of comparison of the signal. The cross correlation is the measure of similarity between two waveforms. The application of CWT to two time series and the cross examination of the two decompositions reveals localized similarities in time and scale (scale being inverse of frequency). The XWT and WC are used for cross examination[4] of a single normal and abnormal beat with that of a standard normal template beat. Because of the morphological similarity with that of the QRS complex db4 is selected as the mother wavelet for analysis.

E. Flowchart

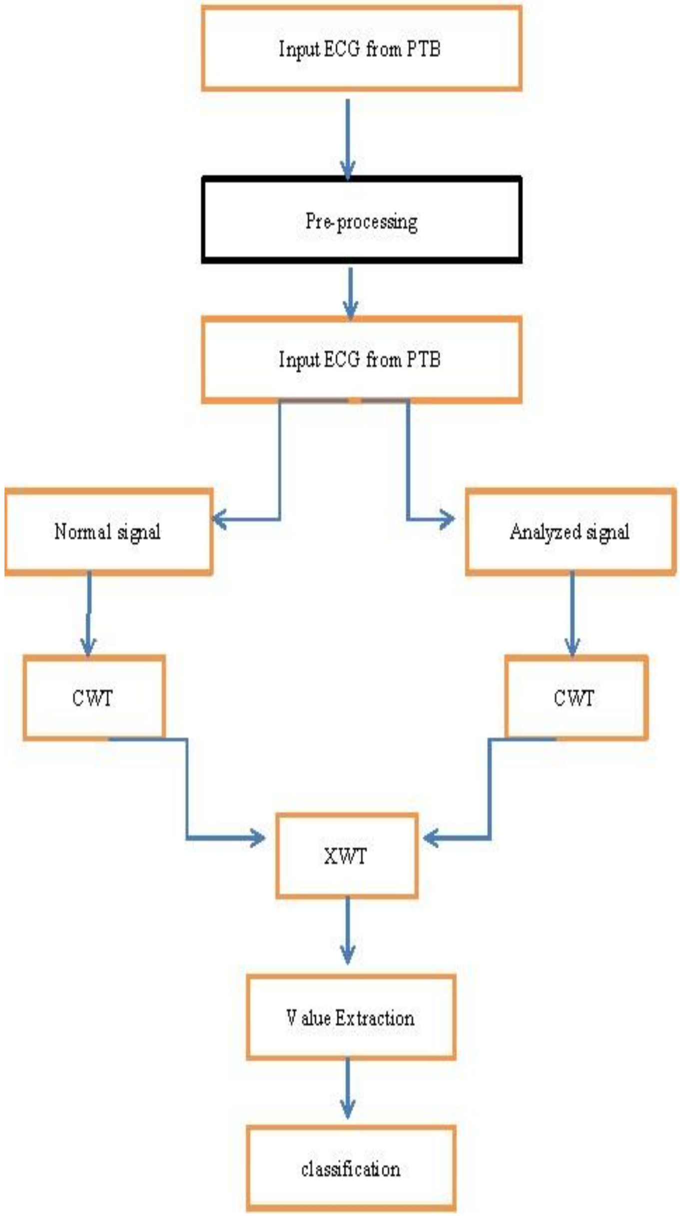

Figure 3.3 Detailed Flow chart

The figure shows the flow chart in which the detailed methodology is being scheduled the signal to be analysed and the normal signal is subjected to XWT.and after the computation of XWT the value is calculated the maximum correlated value and the average value and then the signal is being passed on to next section.

F. Classification

After the calculation of values the Classification Procedure is done in this classification a certain threshold value is being set which can be set by observing it on to different database samples and by observing different samples the threshold value is set. Here for the classification a simple threshold based classifier is proposed, here after the observation of different values a particular threshold value is set and the normal and abnormal margin is calculated. So that it can classify the signal in to normal and abnormal. The classification mainly depends on the extracted value.Here the classification is done based on single lead ECG data. The abnormality focused here is Myocardial Infraction.

G. EXPERIMENTAL RESULT

The input ECG signal is obtained from the ptbdb database of PhysioNet Library. The plot of Normal ECG signal before processing is shown in figure

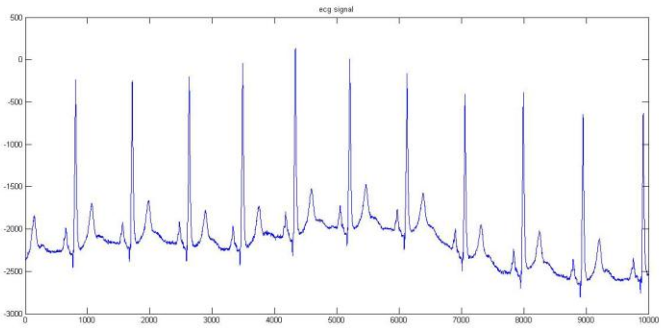

Figure 3.4 ECG signal with noise

The selected ECG signal is first denoised using the concepts of DWT, by eliminating specified coefficients D2,D1 and A10 and then reconstructing the signal. The denoised signal is shown below.

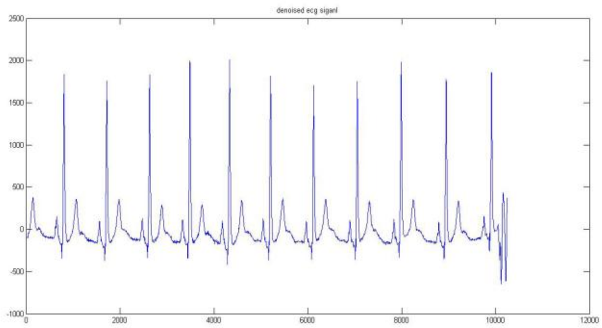

Figure 3.5 Denoised ECG

Here a threshold based classifier is proposed so, so for that a threshold value is find out from the parameters obtained as a prior to classification and based on that value the ECG signals are classified into normal and abnormal class,which produces good efficiency in the classification. Here the data base is chosen from PTB.And the result is being tested in different data bases. The wavelet used for the analysis is Db4.

IV. CONCLUSION

A system which classifies the ECG signal into Normal and Abnormal is implemented .And the it is being tested in two different databases; a threshold based classification is used here. The threshold value is being generalized by observing different samples. So it can be also tested using different classifier. Here this system is tested with different data bases.

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