AN ACCURATE ECG FEATURE EXTRACTION METHOD FOR DETECTING MULTIPLE CARDIOVASCULAR DISEASES

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Abstract—Biomedical signals are studied frequently to diagnose possible diseases in human body.In recent years,computer-assisted ECG interpretation has been playing an increasing role in assisting doctors in the diagnosis and treatment of heart anomalies.The burden of cardiovascular diseases among the people of different countries has been increasing and therefore ,it is necessary to detect the different cardiovascular diseases in the patients at an early stage.Many people may suffer from multiple cardivascular diseases.Hence,a system needs to be proposed for simutaneous monitoring of different diseases.ECG Feature Extraction plays a significant role in diagnosing most of the cardiac diseases.In this thesis, a comprehensive review has been made for feature extraction of ECG signal and classification methods which have been proposed during the last decade exhibiting its own advantages and disadvantages.As a result of the survey conducted,the main parameters used for performance evaluation of ECG feature extraction methods are accuracy,positive predictivity,sensitivity and detection error rate.The main objective of the thesis is developing methods to analyse and detect small changes in ECG waves and complexes that indicate cardiac diseases and disorders.The contribution of this thesis are in the specific context of detecting different cardiovascular diseases like arrhythmia,sinus tachycarida,3rd degree atrioventricular block,right bundle brach block,left bundle branch block,sinus bradycardia ,dilated cardiomyopathy,Artial Fibrillation, Flutter, Supraventricular Tachycardia (SVT) and myocardial infarction.Wavelet Transform is a very powerful technique for feature extraction and can be used along with neural network structures to build computationally efficient models for diagnosis of Biosignals (ECG in this case).In this paper,biorthogonal wavelet transform technique for ECG feature extraction and classification for simultaneous detection of multi-ple cardiovascular diseases is proposed.The simulation results of biorthogonal wavelet transform is validated on MIT-BIH arrhythmia database in terms of performance metrics.

I. Introduction

Electrocardiogram (ECG) is a diagnosis tool that report the electrical activity of heart recorded by skin electrode.The morphology and heart rate reflects the cardiac health of human heart beat.It is a noninvasive technique,that means this signal is measured on the surface of human body, which is used in identification of the heart diseases.Any disorder of heart rate or rhythm, or change in the morphological pattern, is an indication of cardiac diseases, which could be detected by the analysis of the recorded ECG waveform.The amplitude and duration of the P-QRS-T wave contains useful information about the nature of disease affecting the heart.At present,the burden of cardiovascular disease (CVD) in the world is enormous and is increasing at an alarming rate.It is estimated that by 2020, CVD will become the leading cause of the global health burden, accounting for 73 % of total global mortality and 56 % of total morbidity[4].Therefore the predic-tion of cardiovascular disease diagnosis and prevention is an important significance.To ensure accuracy and efficiency, ECG signals are used with digital signal processing for decrypting and feature extracting[6].ECG Feature Extraction and their classification of various features plays a significant role in diagnosing most of the cardiac diseases.

The objective of ECG signal processing comprises of:[2] 1. The improvement of measurement accuracy and repro-ducibility of the ECG signal for diagnosing different cardio-vascular diseases .

2. Noise reduction represents an important objective of ECG signal processing

- In many situations, the ECG is recorded during ambulatory or strenuous conditions such that the signal is corrupted by differ-ent types of noise, sometimes originating from another physio-logical process of the body. Electromagnetic fields caused by a power line represent a common noise source in the ECG that is characterized by 50 or 60 Hz sinusoidal interference, possibly accompanied by a number of harmonic.Among the noises plaguing the ECG are the power-line interference: 50/60 Hz pickup and harmonics from the power cord; electrode contact noise: baseline drift due to variable contact between the electrode and the skin; motion artifacts: shifts in the baseline caused by changes in the electrode-skin impedance; muscle contraction: electromyogram -type signals (EMG); respiration causing drift in the baseline; and electromagnetic interference and noise coupled from other electronic devices.For meaning-ful and accurate detection of ECG signal, steps have to be taken to filter out or discard all these noise sources.

3. Data compression represents yet another objective of ECG signal processing

–Electrocardiograph signals may be recorded on a long timescale (i.e., several days) for the purpose of identifying

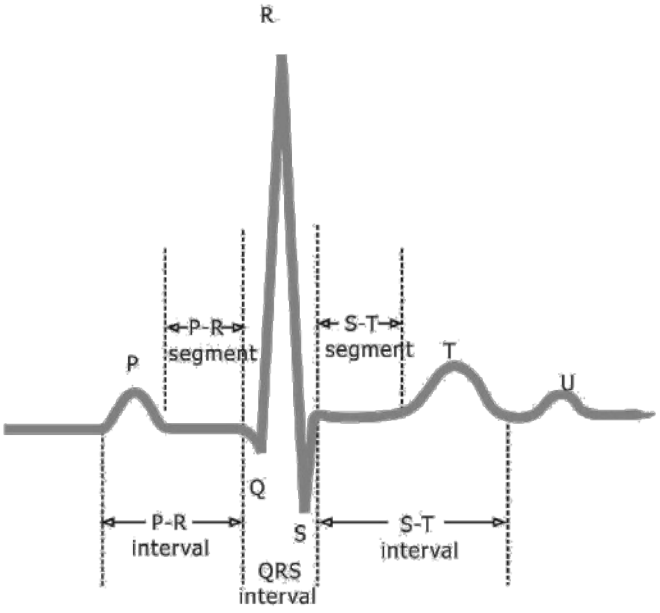

Fig. 1. Single Cycle Of Electrocardiogram Signal

intermittently occurring disturbances in the heart rhythm. As a result, the produced ECG recording amounts to huge data sizes that quickly fill up available storage space. Hence data compression is an essential operation and, consequently, represents yet another objective of ECG signal processing.

4. Removal of baseline wander is required in order to minimize changes in beat morphology that do not have cardiac origin. The main objective of the thesis is developing methods to analyse and detect small changes in ECG waves and complexes that indicate cardiac diseases and disorders.The contribution of this thesis are in the specific context of detecting different cardiovascular diseases like arrhythmia,sinus tachycarida,3rd degree atrioventricular block,right bundle brach block,left bundle branch block,sinus bradycardia ,dilated cardiomyopathy,Artial Fibrillation, Flutter and Supraventricular Tachycardia (SVT).Wavelet Transform is a very powerful technique for feature extraction and can be used along with neural network structures to build computationally efficient models for diagnosis of Biosignals (ECG in this case).This work utilizes the wavelet transform technique for ECG feature extraction and classification of the above mentioned diseases.

II. Relevance

The burden of cardiovascular disease (CVD) in the world is enormous and growing at a faster rate, and the majority of those affected are from developing countries. In 2002 it was estimated that 29 % of deaths worldwide (16.7 million deaths) were due to CVD and 43 percent of global morbidity and mortality, measured in disability-adjusted life years (DALYs), was caused by CVD [4].By 2020 it is estimated that CVD will become the leading cause of the global health burden, accounting for 73 percent of total global mortality and 56 percent of total morbidity[4]

Alarming statistics from India

Current projections suggest that India will have the largest cardiovascular disease burden in the world[1]

One fifth of the deaths in India are from coronary heart disease[3]. By the year 2020, it will account for one third of all deaths. Sadly, many of these Indians will be dying young.

Heart disease in India occurs 10 to 15 years earlier than in the west.[3]

There are an estimated 45 million patients of coronary artery disease in India. An increasing number of young Indians are falling prey to coronary artery disease. With millions hooked to a roller-coaster lifestyle, the future looks even more grim.[6]

There are at least 50.8 million diabetics in India, which is the highest ever reported number from anywhere in the world according to International Diabetes Federation. The prevalence of diabetes varies between 6-8

Indians tend to be diabetic at a relatively young age of 45 years which is about 10 years earlier than in West.[8] The prevalence of diabetes varies between 6-8 % in urban and 2-3 % in rural adults.[9]

There appears to be a steady increase in hypertension prevalence over the last 50 years, more in urban than in rural areas. Hypertension is 25-30% in urban and 10-15% in rural subjects.

According to the World Health Organization (WHO), 60 percent of the worlds cardiac patients will be Indian by 2010.[2]

From the different statistics given above,cardiovascular diseases are the leading cause of mortality in the world.Cardiovascular disease includes any damage to,or dis-ease of the heart,arteries,veins and smaller blood vessels.The ECG signal processing remains the simplest non-invasive diag-nosis method for determining various heart diseases.Physicians interpret the morphology of ECG waveform and decide whether the heartbeat belong to normal sinus rhythm or to the class of arrhythmia (abnormal), which can be used to identify the absent of early stage of cardiovascular disease such as atherosclerosis, myocardialinfarction and cerebrovascular accidents (stroke).Thus,ECG interpretation is one of the most important upcoming areas and widely used clinical tool and ECG monitoring system is one of the most significant moni-toring systems,in order to predict the heart disease especially for cardiovascular disease.Hence,the early diagnosis of various heart diseases by continuously monitoring the ECG signal data have become an major objective.

The rest of the paper is organized as follows.Section III provides the theoretical background on the principle of electrocardiogram and their interpretation,the electrical characteristics of ECG signal and their measurement.Section IV provides the literature survey on different algorithms used for

ECG feature extraction and classification,their advantages and disadvantages.Section V gives the analysis of the proposed approach.Section VI deals with the simulation results of biorthogonal wavelet transform algorithm for ECG feature extraction.Section VII details the different steps while analysing the biorthogonal wavelet transform in matlab.The last sections provides the conclusion and future scope of the work.

III. Theoretical Background

Electrocardiography (ECG) is a transthoracic interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the surface of the skin and recorded by a device external to the body.The information is presented in form of waves and time intervals between them. The waves in a normal record are named P, Q, R, S, and T waves as shown in Fig.1.

Waves, Segments, and Intervals[3][7]

There are certain elements in the ECG waveform :

The isoelectric line: a horizontalline when there is no electrical activity on ECG

Segments: the duration of the isoelectric line between waves

Intervals: the time between the same segments of adjacent waves.

The P-wave is the first deflection of the ECG. It results from depolarizationof the atria.Atrial repolarisation occurs during ventricular depolarization and is obscured.The QRS complex corresponds to the ventricular depolarization.The QRS complex is the most striking waveform within the electrocardiogram (ECG). It is necessary for the determination of the heart rate, and as reference for beat alignment. Since it reflects the electrical activity within the heart during the ventricular contraction, the time of its occurrence as well as its shape provide much information about the current state of the heart.Detection of QRS complex provides fundamental feature for further detection of other waveforms and subsequent automatic analysis.The T-wave represents ventricular repolar-isation, i.e., restoration of the resting membrane potential. In about one-quarterof population,a U-wave can be seen afterthe T-wave.This usually has the same polarity as the preceding T-wave.It has been suggested that the U-wave is caused by after-potentials that are probably generated rby mechanical-electric feedback.Inverted U-waves can appear in the presence of left ventricular hypertrophyor ischaemia.The PQ segment corresponds to electrical impulses transmitted through theS-A node, bundle of His and its branches, and the Purkinje bers and is usuallyisoelectric.The PQ interval expresses the time elapsed from atrial depolarization tothe onset of ventricular depolarization.The ST-T interval coincides with the slowand rapid repolarisation of ventricular muscle.The QT interval corresponds to the duration of the ventricular action potential and repolarisation.Then TP interval is the period for which the atria and ventricles are in diastole.The RR interval represents one cardiac cycle and is used to calculate the heart rate.

A. Interpretation of the ECG

After describing the predominant heart rhythm, the mean electrical axis, and the position of the heart in the chest, the next step of the ECG analysis is to evaluate the shape, amplitude, and duration of the waves,segments,and intervals.

The P-wave

The normal duration of the P-wave is no longer than 0.12s, and the voltage in the limb leads should not exceed 0.25and 0.15mV in the precordial leads.A P-wave that is notched, and exceeds the values given above (voltage, duration, and polar-ization in the appropriate leads) is considered abnormal.This can result from atria enlargement and hypertrophy or from atrial depolarization generated in locations other than the S-A node.

The PQ Interval

The normal range for the PQ interval is 0.12s -0.20s.Longer PQ intervals are seen in cases of rst- or second-degree atri-oventricular block.The PQ interval can be shortened in pre-excitation syndromes, in which depolarizations from the atria are transmitted to the ventricles via an anomalous accessory conduction pathway that bypasses the A-V node.

The QRS Complex

This is the largest group of waves on the ECG and represents ventricular depolar-ization.The rst downward deection is the Q-wave. The first upward deection is called the R-wave.The S-wave is the last downward deection of the QRS complex.The Q-wave is not a constant component of the QRS (ventricular) complex.The normal duration of the QRS complex does not exceed 0.12s.The voltage usually varies between 1.5mV and 2.0mV. Durations greater than 0.12s are most likely due to an asynchronous depolarization of both ventricles.The QRS complex is the most striking waveform within the electro-cardiogram (ECG).It is necessary for the determination of the heart rate, and as reference for beat alignment.Since it reflects the electrical activity within the heart during the ventricular contraction, the time of its occurrence as well as its shape provide much information about the current state of the heart.Detection of QRS complex provides fundamental feature for further detection of other waveforms and subsequent automatic analysis.

T wave:The T wave represents the repolarization (or recovery) of the ventricles.The interval from the beginning of the QRS complex to the apex of the T wave is referred to as the absolute refractory period.The last half of the T wave is referred to as the relative refractory period (or vulnerable period).The duration of T-wave is 160ms.

ST segment: Duration is usually about 100-120msec and is normally flat; is a non-event.

QT interval :The QT interval is measured from the beginning of the QRS complex to the end of the T wave.A prolonged QT interval is a risk factor for ventricular tachyarrhythmias and sudden death.It varies with heart rate and, for clinical relevance, requires a correction for this, giving the QTc.The normal range of a QT interval is upto 420ms in the heart rate of 60 bpm.

U wave:The U wave is hypothesized to be caused by the repolarization of the interventricular septum. It normally has a low amplitude, and even more often is completely absent. It always follows the T wave, and also follows the same direction in amplitude. If it is too prominent, suspect hypokalemia, hypercalcemia or hyperthyroidism.

J wave:The J wave, elevated J-point or Osborn wave appears as a late delta wave following the QRS or as a small secondary R wave. It is considered pathognomonic of hypothermia or hypercalcemia.

Different parameters of the ECG signals like P wave , beginning ,end and peak of QRS complex , T wave , PR interval , ST segment etc. tend to vary for different diseases.

IV. Existing Methods

ECG Feature Extraction plays a significant role in diagnosing most of the cardiac diseases.The shape and size of the ECG signal contain useful information about the nature of cardiac diseases.The corresponding details are difficult to analyse visually by the naked human eye,hence computer assisted analysis and classification of cardiac diseases can help physicians to monitor cardiac health easily and accurately.Thus,computer-aided automatic detection and classification of cardiac events is very useful in healthcare technology, as it will help the doctor to diagnose and act faster in case of emergency conditions.Recently numerous feature extraction techniques have been established to determine the current state of cardiac activity through analysis of rhythms and distortions found in electrocardiogram.Morphological or timing statistical-based features which are usually extracted from ECG signal include P and QRS widths, PQ/PR and QT intervals, P and T amplitudes, QRS height,and ST level.These features include both persistent and non-stationary characteristics of the ECG.A large number of techniques exist in the literature for the automatic detection and classification of different ECG signal morphologies.This section includes a comprehensive survey of different ECG feature extraction algorithms.

For an algorithm which provides a classification of the ECG features in real-time mode,the algorithm must satisfy the following circumstances:

the minimum cost of computing power; immunity to high noise;

an ability of the algorithm to classify the main ECG features

R-peaks are the mail indicators of QRS-complexes.

At present there are many methods of ECG analysis, which can be divided into the following groups:

time-frequency methods;

methods based on neural networks; syntactic methods;

methods of comparison with templates; combined methods.

Different approaches for ECG feature extraction and classification were surveyed.The interpretation of morphologi-cal features of ECG signal for different cardiovascular dis-eases were also surveyed.The important features exhibiting diagnostic properties are time intervals between consecutive R points,distance PQ, PR, QT,amplitudes of P, Q, R, S, T,duration of P, R, and T waves,heart rate, location of the center of the ST interval and slope of the ST interval.These are the primitive features that can be determined directly from the ECG signal.For diagnostic purposes , some other features called derivative features can also be extracted which are constructed based on the primitive ones.These are the shift of the QRS complex versus baseline known as offset,areas of waves of P, R, and T and position of the heart axis.Various techniques proposed earlier in literature for extracting the features from ECG is analyzed.Feature extraction method using wavelet transform and classification using support vector machines was first proposed in[12].A new approach to the feature extraction was presented for reliable heart recognition.To extract the coefficients of the transform as the features of each ECG segment wavelet transform is used[5].Concurrently, autoregressive modeling (AR) is also applied to get hold of the temporal structures of ECG waveforms.Then finally the support vector machine (SVM) with Gaussian kernel is used to classify different ECG heart rhythm.This method can be widely used to detect diseases like left and right bundle branch block.The main disadvantage of this method is that the accuracy of the method is very less due to the pres-ence of false peaks.Another technique using the Daubechies wavelet transform for feature extraction of ECG signal was proposed in[6].An electrocardiogram (ECG) feature extrac-tion system based on the multi-resolution wavelet transform had been developed and evaluated.But these methods have limited accuracy in analyzing ECG features in presence of high frequency noise as well as the ECG signal affected by severe base line drift.In[9],another algorithm called the Slope Vector Waveform for the detection of QRS complex and RR interval evaluation was discussed.In this proposed method variable stage differentiation is used to achieve the desired slope vectors for feature extraction, and the non-linear amplification is used to get better of the signal-to-noise ratio.The method allows for a fast and accurate search of the R location, QRS complex duration, and RR interval and yields excellent ECG feature extraction results.The main drawback is that only QRS complexes and RR intervals can only be obtained by this method.The other parameters like P wave ,T wave etc cannot be detected by this method.Thus by analyzing different methods from the literature,there arises a need for a new approach where different features from the ECG signal can be simultaneously obtained with more accuracy.Thus for accurate and efficient detection of multiple cardiovascular diseases, simultaneous monitoring of different parameters from the ECG signal by removing all the noise artefacts, a new approach has been proposed.The table I shows a comparitive study on different algorithms used for ECG feature extraction.

TABLE I
A COMPARITIVE STUDY ON DIFFERENT ALGORITHMS

ALGORITHMS	ADVANTAGES	DISADVANTAGES
Independent component analysis	Shows high performance for large sized data,Computationally efficient	Cant be applicable for under determined cases , Requires more computations for de-composition
Eigen vector	eigenvector methods can produce high resolution frequency spectra of the signal.So these methods are best suited for signals composed of noisy sinusoids	signal to noise ratio is poor
Principal compo-nent analysis	A powerful tool for analyzing and for reducing the dimensionality of data without important loss of information	Assumes data is lin-ear and continuous, For complicated man-ifold PCA fails to process data.
Wavelet transform	Capable to analyze signal with discontin-uities through vari-able window size , It can analyze signals both in time and fre-quency domains	Lacking of specific methodology to apply WT to the pervasive noise , Performance limited by Heisenberg Uncertainty.
Linear prediction	Reduces the compu-tation complexity and faster computation	cannot give detailed information regarding the ECG signal no matter how high is the order of the sys-tem.,Provides less ac-curate results compar-ing to other methods due to its linearity.
Auto regression	Requires only shorter duration of data records ,Reduces spectral loss problems and gives better frequency resolution	Difficulties exist in establishing the model properties of ECG signal , Not applicable to non-stationary signals.

V. ANALYSIS OF THE PROPOSED APPROACH

The main objective of the proposed approach is to analyse and detect small changes in ECG waves and complexes that indicate multiple cardiac diseases and disorders.The proposed approach includes a preprocessing stage followed by a feature extraction module which can be given as input to a classifi-cation scheme for accurate detection of ECG morphological features.The approach is developed to preprocess the ECG signal by multiresolution analysis using filter banks theory and automatically extract the features from ECG signal based on Biorthogonal Wavelet Transform.

Multi-Resolution Analysis using Filter Banks Theory[5] The parameters of the ECG signal can also be obtained by the wavelet decomposition dyadic tree.Filters are one of the most widely used signal processing functions.Wavelets can be realized by iteration of filters with rescaling.The resolution of the signal, which is a measure of the amount of detail information in the signal, is determined by the filtering operations and the scale is determined by upsampling and downsampling (subsampling) operations.The Discrete Wavelet Transform of a signal can be computed by passing it through the lowpass and highpass filters.This is called the Mallat algorithm or Mallat-tree decomposition.Figure 2 shows a three -level wavelet decomposition tree.At each level, the highpass filters produces detail information,while the lowpass filters associated with scaling function produces coarse approximations.The filtering the decimation process is continued until the desired level is reached.The maximum number of levels depends on the length of the signal.The DWT of the original signal is then obtained by concatenating all the coefficients and starting from the last level of decomposition.

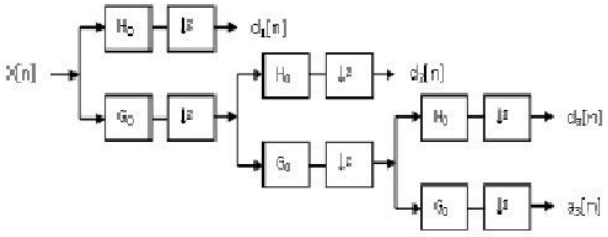

Fig. 2. Three -level wavelet decomposition tree[5]

Figure 3 shows a three -level wavelet reconstruction tree which represents the reconstruction of the original signal from wavelet coefficients.Basically,the reconstruction is the reverse process of decomposition.The approximation and detail coefficients at every level are upsampled by two,passed through the low pass and high pass synthesis filters and then added.This process is continued through the same number of levels as in the decomposition process to obtain the original signal.

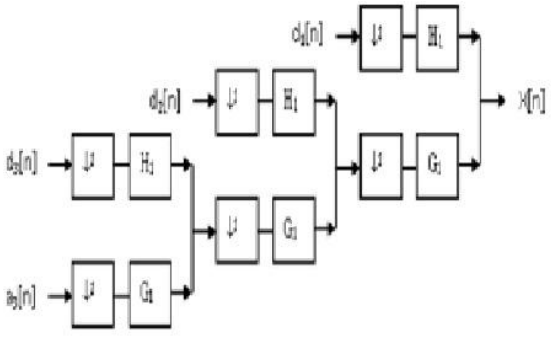

Fig. 3. Three -level wavelet reconstruction tree[5]

Choice of prototype wavelets[9][11]

For estimation of the ECG parameters, it is important that the proper choice of the basis functions be made.In this regard, one has to ascertain the desirable properties of such functions.For ECG parameters estimation,it is desirable that the basis functions (wavelets) be symmetric/antisymmetric.A symmetric basis will enable the detection of peak of wave as an extrema.In case of antisymmetric basis, the peak of the wave is detected as a zero crossing.Also, it is desirable that the basis have a minimum number of sign changes which will simplify the steps in the parameters estimation algorithm.Biorthogonal wavelets satisfy this property[11].A biorthogonal wavelet is a wavelet where the associated wavelet transform is invertible but not necessarily orthogonal.Designing biorthogonal wavelets allows more degrees of freedom than orthogonal wavelets.

The huge number of known wavelet families provides a good scope to search for a wavelet which would efficiently represent a signal of interest.The choice of the wavelet depends on its application.The Haar wavelet has the advantage that it can be computed easily and and is also easy to understand.The Daubechies algorithm involves complex concepts along with being a little difficult to compute.But,the Daubechies wavelet selects detail that the Haar wavelet may perhaps ignore.It is of primary significance that the selection of the wavelet family should closely match the signal of interest.Daubechies wavelets are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support.With each wavelet type of this class, there is a scaling function (also called father wavelet) which generates an orthogonal multi resolution analysis.Daubechies wavelets have structural similarity with QRS complex and their energy spectrums are concentrated around low frequencies.Thus it is expected that some detail coefficients from multiresolution decomposition will show better resemblance with QRS complex of the ECG wave in time scale domain.The main criteria that is required for the choice of wavelets used for feature extraction from a signal is that the shape of the wavelet should match with the given signal.The biorthogonal wavelet transform closely resembles the shape of the ECG signal.Thus for ECG feature extraction, biorthogonal wavelet transform proves to be efficient compared to other wavelets.

The developed approach initially performs preprocessing of the ECG signal by a filter inorder to remove Baseline Drift (De-trending) and to remove noise (De-noising) from the signal and then it uses the preprocessed signal for feature extraction from the ECG signal automatically.The preprocess-ing stage includes preprocessing of the signal by wavelet decomposition to improve the signal to noise ratio of the signal and extracting the features from the preprocessed signal by biorthogonal wavelet transform function.

VI. Simulation Results and Performance Evaluation

The results are validated on an Intel(R) Core i3 CPU running at 2.40GHz with 4.00GB of RAM.Software used for validation of the approach is MATLAB R2012a (Mathwoks Inc.) on MS Windows 7 64-bit operating envirinment.The MIT/BIH arrhythmia database is used in the study for per-formance evaluation.The database contains 48 records, each containing two-channel ECG signals for 30 min duration selected from 24-hr recordings of 47 individuals.

VII. Different Steps While Analysing the Algorithm in MATLAB

Biorthogonal wavelet transform was simulated in mat-lab R2012a to obtain different parameters from ECG sig-nal.Different parameters like QRS complex ,duration and am-plitude of QRS complexes , R peak detection,P wave detection and its amplitude ,T wave detection and its amplitude, RR interval,Heart rate,Heart rate variability etc were obtained

A. ECG Preprocessing

The developed algorithm initially decomposes the origi-nal ECG signal by using Discrete Wavelet Transform and Biorthogonal wavelet as mother wavelet. It removes the low frequency components in order to remove the Baseline Drift (De-trending) and removes the thresholded high frequency components in order to remove the noise (De-noising) from the original signal. Then it uses the preprocessed signal to extract features from the ECG signal automatically.

Four level wavelet decomposition is performed to obtain the baseline corrected and smoothed signal.The below figures shows the original signal, decomposed signal and the 4 -level reconstructed signal.The datasets used is MIT-BIH arrhythmia datasets.

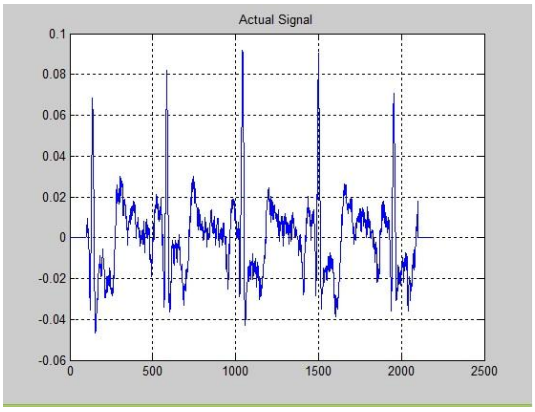

Fig. 4. Original signal

Baseline correction is done by removing the low frequency components from the decomposed signal.The below figure show the baseline corrected and smoothed signal.the figure 7 shows the baseline corrected and smoothed signal.

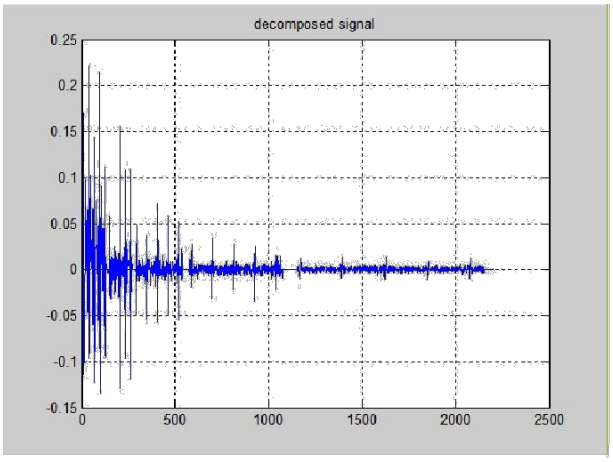

Fig. 5. Decomposed signall

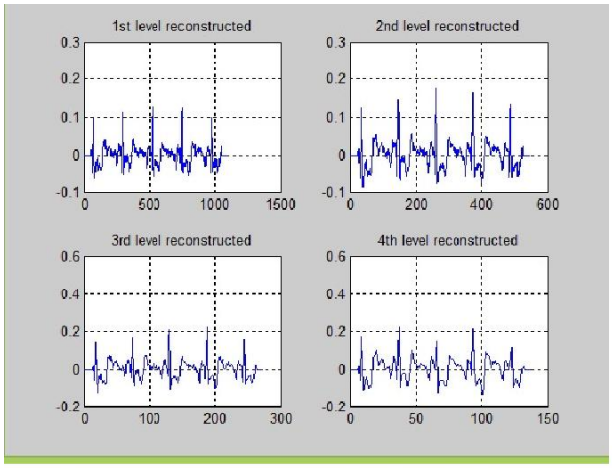

Fig. 6. Four level reconstructed signal

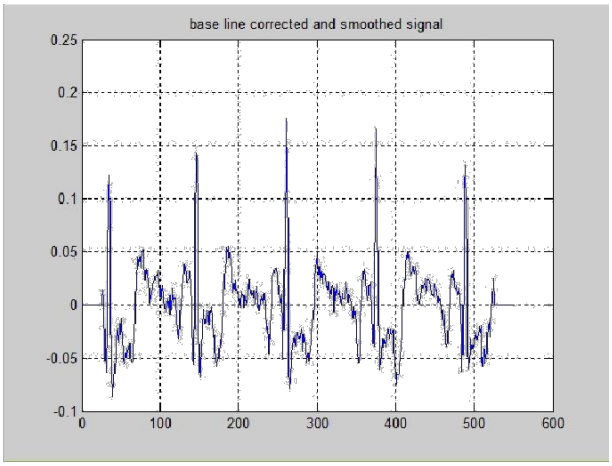

Fig. 7. Baseline corrected and smoothed signal

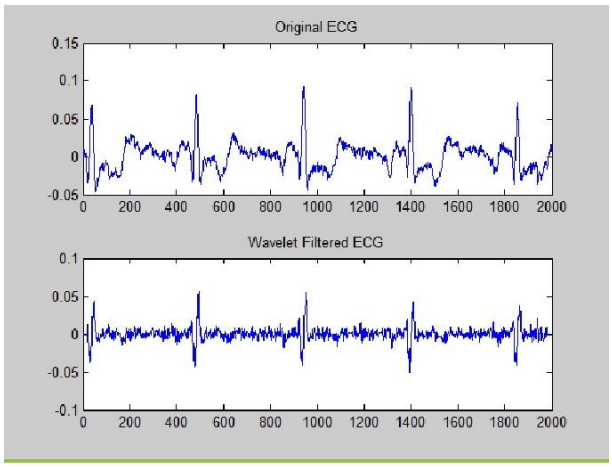

Fig. 8. Original ECG signal and wavelet filtered ECG signal

B. Detection of Different Parameters From ECG Signal

Biorthogonal function (bior 1.1 function) is used in this algorithm for obtaining the filtered ECG signal.The figure 8 shows the original signal and wavelet filtered ECG signal.

After obtaining the wavelet filtered ECG signal,thresholding is done to obtain the R peak.Since the peaks of R waves in the ECG signal have the largest amplitude values among the other waves, identifying the QRS complexes of an ECG signal by using the developed algorithm is an easy task. To detect the R waves, the developed algorithm removes the very low and very high frequency components from the ECG signal. In this study, the detail components of D3, D4 and D5 show the QRS complex more clearly comparing with other components.Figure 9 shows the R peak obtained.

The R-R interval of an ECG signal is the time interval between the R-waves. In order to determine the R-R interval of a signal, the developed algorithm determines the difference between the two consecutive R wave locations based on the identified.The first negative deflection to the left of the R-peak is denoted as Q-peak and the first negative deflection to the right of the R peak is denoted as S peak.Once the R-peaks are identified then it can be used by the developed algorithm to calculate the amplitude values of Q and S waves automatically.Figure 10 shows the R-R interval and QRS peak detection.

The amplitude of QRS wave or R peak is a very important parameter that helps in detecting different diseases like dilated cardiomyopathy.The normal value of QRS amplitude is 1mV.In dilated cardiomyopathy,the QRS amplitude may be less than the 1mv.The R-R interval is also required to obtain the heart rate which is used to detect different cardiovascular diseases like arrhythmia,sinus tachycardia,sinus bradycardia.The variation in the duration of QRS complexes will help in determining different diseases like right bundle

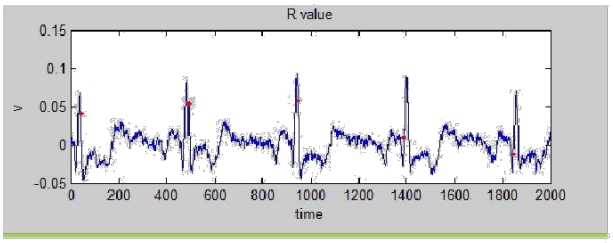

Fig. 9. R peak

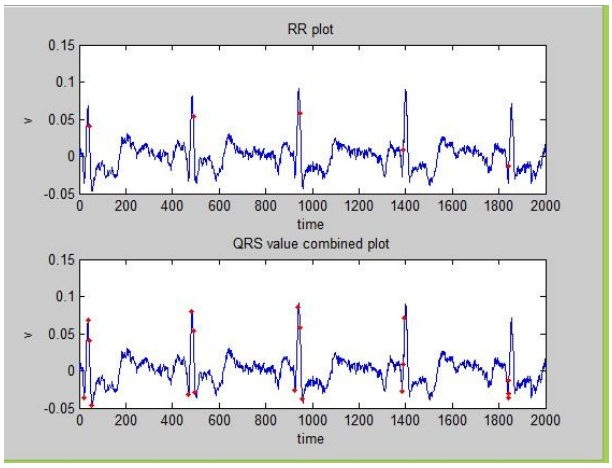

Fig. 10. R-R interval and QRS peak detection

branch block,left bundle branch block and 3rd degree atrioventricular block.The below figure show the R-peak detection,R-R interval and QRS complex detection.

The extreme of the signal before and after zero crossings about QRS complex denotes the P and T waves.The detected zero crossings of the signal about the P and T peaks are the onset and offset points of the waves respectively.The extreme of the signal before and after zero crossings about QRS complex denotes the P and T waves. The detected zero crossings of the signal about the P and T peaks are the onset and offset points of the waves respectively.Figure 11 and 12 shows the P wave and T wave respectively.

P-R Interval

Once the P and R waves are identified, it can be used by the developed algorithm to determine P-R intervals. In order to determine P-R interval, the developed algorithm determines the interval between the onset of P waves and onset of Q waves.

S-T Interval

Once the S and T waves are identified, it can be used by the developed algorithm to determine S-T intervals. In order to determine S-T interval, the developed algorithm determines the interval between the onset of S waves and offset of T waves.

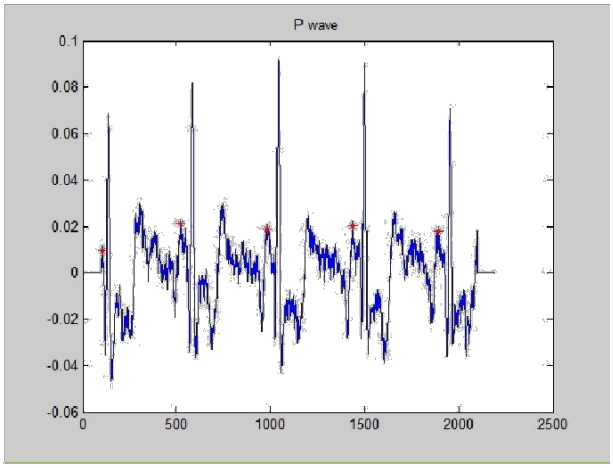

Fig. 11. P wave

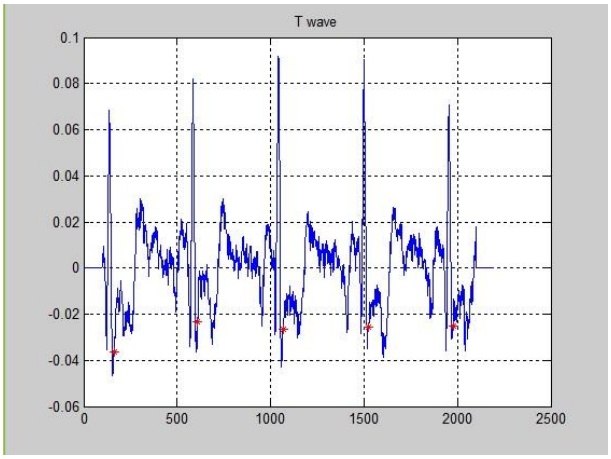

Fig. 12. T wave

Q-T Interval

Once the Q and T waves are identified, it can be used by the developed algorithm to determine Q-T intervals. In order to determine Q-T interval, the developed algorithm determines the interval between the onset of Q waves and offset of T waves.

The performance of the biorthogonal wavelet transform algorithm used for feature extraction of ECG signalcan be evaluated by the following parameters:

1.Accuracy

Accuracy is the ratio of the number of correctly detected patterns to the total number of patterns.

$$Acc = (TP + TN)=(TP + TN + FP + FN) \quad (1)$$

2. Sensitivity Sensitivity is defined as:

$$SE(\%) = TP=(TP + FN) \quad (2)$$

3.Positive Prediction
Positive prediction is given by:

$$+P\ (\%) = TP=(TP + FP\ ) \quad (3)$$

4.Detection Error Rate Detection
error rate is given by:

$$DER(\%) = (FP + FN)=totalR\ \ wavepeaks \quad (4)$$

where TP is the number of correctly detected true beat (actual R wave),TN represents the true negative,FN represents the number of missed true beat by the proposed algorithm,FP means the number of false beat detection. From the simulated results of the biorthogonal wavelet transform algorithm,the MIT-BIH arrhythmia database has true beat(TP) as 1865 and false beat(FP) as 5 beats and the number of missed beats are three.Thus ,the algorithm has an accuracy of 99.57%, detection error rate of 98.7% ,sensitivity of 99.8% and positive prediction of 99.73%.

VIII. Conclusion

ECG interpretation is one of the most important upcom-ing areas and widely used clinical tool.Interpretation of an Electrocardiogram (ECG) is one of the key skill developed by cardiologists to monitor the cardiac diseases.At present,the burden of cardiovascular disease (CVD) in the world is enor-mous and is increasing at an alarming rate.It is estimated that by 2020, CVD will become the leading cause of the global health burden, accounting for 73 percent of total global mortality and 56 percent of total morbidity.Therefore the prediction of cardiovascular disease diagnosis and prevention is an important significance.The present study is mainly aimed at using biorthogonal wavelets for the estimation of clinically significant parameters of ECG waveforms. It has been shown that these wavelets are ideally suited for the purpose since they excite the various morphologies (of the ECGs) at dif-ferent scales.Different features like duration and amplitude of QRS wave,R-R interval,R-peak ,P wave and its amplitude ,T-wave and its ampitude and Heart rate were detected and are used to classify different diseases like arrhythmia,sinus tachycardia,sinus bradycardia,dilated cardiomyopathy,left bun-dle branch block,right bundle branch block and 3rd degree atrioventricular block.Further these estimates are shown to be quite robust in the presence of noise as well as in baseline wander situations.Different cardiovascular diseases can also be classified by determining the variations in morphology of P wave or T wave or by looking at the absence or presence of these waves.The algorithm was imlemented in matlab and the wavelet technique provides less computational time and better accuracy for classification, analysis and characterization of normal and abnormal patterns of ECG.

IX. Future Work

The biggest challenge faced by the models for automatic heart beat classification is the variability of the ECG wave-forms from one patient to another even within the same person. However, different types of arrhythmias have certain characteristics which are common among all the patients. Thus the objective of a heart beat classifier is to identify those characteristics so that the diagnosis can be general and as reliable as possible. One of such methods which can be reliably used for ECG classification is the use of neural networks. Neural networks are one of the most efficient pattern recognition tools because of their high nonlinear structure and tendency to minimise error in test inputs by adapting itself to the input output pattern and thus establishing a nonlinear relationship between the input and output.However the performance of a neural network is highly dependent on the number of input elements in the computational layers. A large number of elements would lead to a large number of multiplication and additions and the network would become expensive on computing resources.Thus to reduce the number of inputs a pre-processing layer is used. This preprocessor uses wavelet transform to ”smooth” out the ECG waveforms and reduce the number of samples while preserving all the distinct signal features such as local maxima and minima.Thus the future work includes extension to this work to evaluate the improvement of the approach as a preprocessing step to ECG signal classification using artificial neural network.

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