DETERMINATION OF BRADYCARDIA & TACHYCARDIA FROM ECG SIGNAL USING WAVELET TRANSFORM

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Abstract: - The Automatic ECG signal analysis by wavelet transform (WT) along with MATLAB using signal processing and wavelet toolboxes to ease the
process to calculate the set on points, and set off points, and time intervals within QRS complexes, T waves and P waves. This process will allow the analyses on the characteristics of each QRS complexes, T waves and P waves. This can be done by using Wavelet filter Coefficients, for this procedure following steps are used for filtration:-

R-R interval detection

QRS Complex Detection

T wave and P wave detection

Keywords- ECG Signal, Analysis, approximate & detail coefficient, Processing, parameter extraction, QRS detection, thresholding, filteration

Introduction

Electrocardiograms (ECGs) are signals that originate from the action of the human heart. The ECG is the graphical representation of the potential difference between two points on the body surface, versus time. An electrocardiogram (ECG) represents movement of electrical current through the heart during a heartbeat. The first wave of the ECG, designated P- represents initiation of the heartbeat in the upper chambers of the heart (atria); the QRS complex represents movement of the electrical current through the lower chambers of the heart (ventricles); and the T- wave represents the recovery phase, in which the electrical current spreads back over the ventricles in the opposite direction. The heart, seen on the left, is beating in time with the ECG. Oxygen-depleted (blue) blood is pumped from the heart to the lungs, which supply oxygen; oxygen-enriched (red) blood returns from the lungs to the heart and is pumped throughout the body.
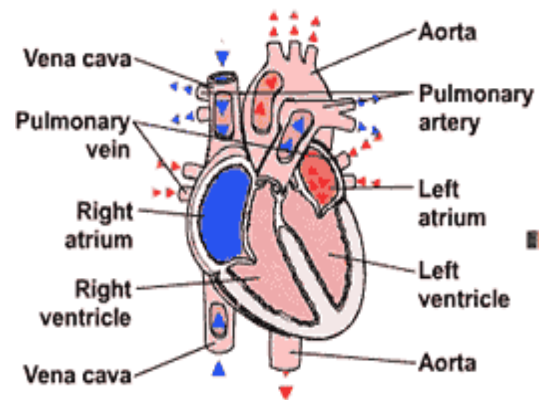

Fig. 1 Physiology of Heart

The biopotential generated by the muscles of the heart results in the electrocardiogram, the above fig. shows the cross section of the interior of the heart. The heart is divided into four chambers. The two upper chambers, the left and right atria, are synchronized to act together. Similarly, the two lower chambers, the ventricles, operate together.

- *THE ECG SIGNAL*

The cardiac cycle begins with the P wave, which corresponds to the period of atrial depolarization in the heart. This is followed by the QRS complex, which is usually the most relevant (recognizable) feature of an ECG waveform. The T wave follows the QRS complex and corresponds to the period of ventricular repolarization. The end point of the T wave represents the end of the cardiac cycle (presuming the absence of U wave).

The duration onset of particular parameters of the ECG (referred as a time interval) is of great importance since it provides a measure of the state of the heart and can show the presence of certain cardiological conditions.

In practice, interval measurements, wave interpretations are carried out manually by ECG specialists.
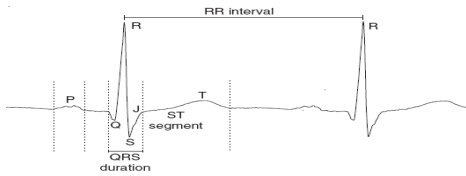

Fig. 2: The normal clinical features of the electrocardiogram

- *THE STANDARD 12 LEAD ECG:*

The standard 12-lead electrocardiogram is a representation of the heart's electrical activity recorded from electrodes on the body surface. The basic components of the ECG and the lead system used to record the ECG tracings. Its historical development has resulted in a tool for clinical diagnosis, the 12-lead electrocardiogram. Each heartbeat is a complex of distinct cardiological events, represented by distinct features in the ECG waveform. ECG recordings are examined by a Physician who visually checks features of the signal and estimates the most important parameters of the signal. Using this expertise the physician judges the status of a patient. Therefore the recognition and analysis of the ECG signals is a very important task. This could be difficult, because the size and form of these signals may change eventually and can be noised.

- Need of ECG recording and Analysis:

Many tools, methods and algorithms from signal processing theory have been proposed, described and implemented. All of them were developed under Matlab, using Signal processing and Wavelet toolboxes The object of automation of electrocardiogram (ECG) analysis is to reduce the time required for human interpretation and analysis of ECG recordings from the Holter monitoring Equipment. It is a subject of major theoretical and practical interest. It can also be used for online analysis. In Holter monitoring, the ECG signals from the patient under observation are digitized, compressed and stored in a hard storage device. This data are later uncompressed and analyzed by the cardiologists to detect abnormalities (normally, 24 h data are taken). The analysis of this data takes a substantial time and the automation of the analysis would be a promising one.

- *WHY WAVELET TRANSFORM?*

ECG signal is a sequence of cardiac cycles or 'beats'. ECG is not strictly a periodic signal. It differences in period and amplitude level of beats. Each region has different frequency components like QRS has high frequency oscillations; T region has lower frequencies, and P and U regions have very low frequencies. Signal contains noise components due to various sources that are suppressed during processing of ECG signal.

- Fourier Transform - provides only frequency information, time information is lost.
- Short Term Fourier Transform (STFT) - provides both time and frequency information, but resolves all frequencies equally.
- Wavelet transform - provides good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies.
- Useful approach when signal at hand has high frequency components for short duration and low frequency components for long duration as in ECG. Some of the existing techniques use a series of band-pass filters to extract the QRS complexes from the ECG signal, which under severe baseline drift and other high frequency noises, fails to detect the characteristic points to an acceptable accuracy. Some use neural network based adaptive identification algorithms, which can be used for only a particular type of pattern. The wavelet transform based technique can be used to identify the characteristic points of the ECG signal to a fairly good accuracy, even with the presence of severe high frequency and low frequency noises.

- *ECG SIGNAL PROCESSING*

Considerable attention has been paid to the design of filters for the purpose of removing baseline wander and power line interference; both types of disturbance imply the design of a narrowband filter. Removal of noise because of muscle activity represents another important filtering problem being much more difficult to handle because of the substantial spectral overlap between the ECG and muscle noise. Muscle noise present in the ECG can; however, be reduced whenever it is appropriate to employ techniques that benefit from the fact that the ECG is a recurrent signal. For example, ensemble averaging techniques can be successfully applied to time-aligned heartbeats for reduction of muscle noise. The filtering techniques are primarily used for preprocessing of the signal and have as such been implemented in a wide variety of systems for ECG analysis. It should be remembered that filtering of the ECG is contextual and should be performed only when the desired information remains undistorted.
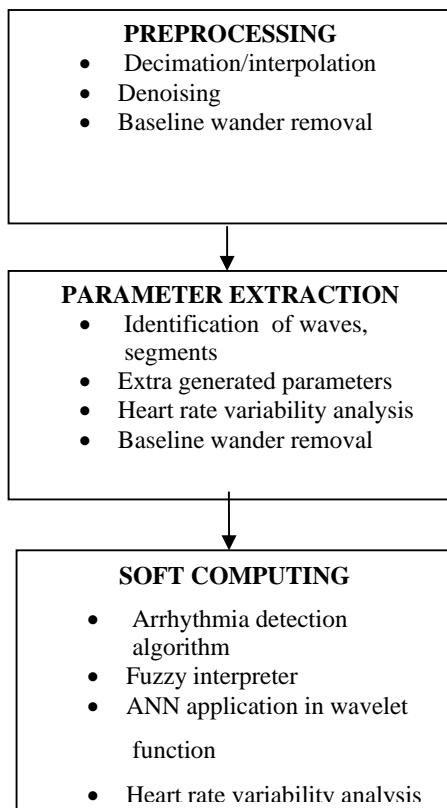
- This important insight may be exemplified by filtering for the removal of powerline interference. Such filtering is suitable in a system for the analysis of heart rate variability, whereas it is inappropriate in a system for the analysis of micro potentials; as such potentials spectrally overlap the power line interference.

ECG signal processing consists of following steps:

- *PREPROCESSING*

• Parameter EXTRACTION (recognition of waveforms, durations and segments computation) and application of SOFT COMPUTING methods on parameters. The whole processing procedure is focused on three topics presented below:

Fig. 3 ECG signal Processing steps

or the lowest frequency (large scale) components in the ECG signal. The typical baseline variation means 15 percent of peak-to-peak ECG amplitude variation of 0.15 to 0.3 Hz. The proposed algorithms were evaluated on test signals (known signal with added noise), performances were calculated following the obtained gain in signal to noise ratio. The results obtained in the preprocessing (mostly denoising) phase with these proposed wavelet transform based algorithms are very promising and slightly better than others.

The main advantage of these algorithms is that they can be applied again to the already filtered signal and correlated with the following procedures. In the parameter extraction stage, the main ECG signal features are identified, following the algorithm presented below. The steps are:

• The ECG signal data for analysis is selected (its length is 60 s (meaning 7680 at128 Hz sampling rate).

• A 4-th level wavelet decomposition is performed, using bi-orthogonal wavelet functions Determination of the R wave location (as local maxima) on first level approximation (first scale). An adaptive threshold is used (related to the maximum and mean values of the signal), to find the points over this value. After that, the R peaks are selected and stored in a parameter data vector.

• R-R intervals detection as R-R distances.

• Detection of Q, S points as local minimum points before and after R wave. The area of the QRS complex can be calculated from the Q-S duration and the value of the R peak.

• Elimination of the QRS complex from the signal to obtain the other parameters.

• Detection of the T wave location (as new local maxima) (scales3,4) (the same procedure as for R peak detection).The T peak value and the Q-T distances will be stored in a parameter data vector.

• *QRS DETECTION*
• *NEED OF QRS DETECTION :*
　　　　The presence of a heartbeat and its occurrence time is basic information required in all types of ECG signal processing. As the QRS complex is that waveform that is most easily discerned from the ECG, beat detection is synonymous to the detection of QRS complexes. The design of a QRS detector is of crucial importance because poor detection performance may propagate to subsequent processing steps and, consequently, limit the overall performance of the system. Beats that remain undetected constitute a more severe

All these steps were performed using wavelet analysis and its benefits. One of most important task was the choice of the wavelet function. A comprehensive comparative study was performed to achieve this goal. For processing were used signals from Physionet databases, such as MIT-BIH or Q-T databases. In the preprocessing phase were proposed new methods in denoising and baseline wander removal. The proposed denoising algorithm is performed as a choice of one from two already existing procedures, based on the estimated noise level. The baseline wandering removal was carried out by identifying the low

error than do false detections; the former type of error can be difficult to correct at a later stage in the chain of processing algorithms, whereas, hopefully, false detections can be eliminated by, for example, performing classification of QRS morphologies.

- *NOISE REDUCTION FROM QRS WAVE :* A QRS detector must be able to detect a large number of different QRS morphologies in order to be clinically useful and able to follow sudden or gradual changes of the prevailing QRS morphology. Furthermore, the detector must not lock onto certain types of rhythm, but treat the next possible event as if it could occur at almost any time after the most recently detected beat. Several detectorcritical types of noise and artifacts exist depending on the ECG application of interest. The noise may be highly transient in nature or be of a more persistent nature, as exemplified by the presence of power line interference.

In the case of an ECG recording with episodes containing excessive noise, it may be necessary to exclude such episodes from further analysis. Figure 4 illustrates two types of noise that are particularly problematic in QRS detection.
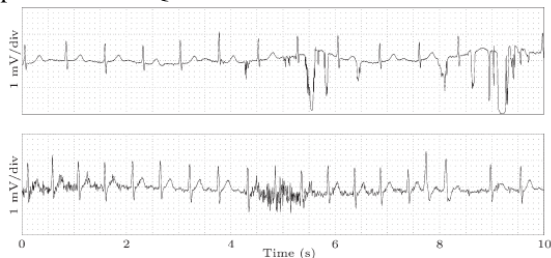

Fig. 4 : Examples of noise being problematic in QRS detection caused by electrode motion artifacts (top) and electromyographic noise (bottom).

The output of the preprocessor is then fed to a decision rule for detection. The purpose of each processing block is summarized below. The linear filter is designed to have bandpass characteristics such that the essential spectral content of the QRS complex is preserved, while unwanted ECG components such as the P and the T waves are suppressed as shown in Fig. 5. The center frequency of the filter varies from 10 to 25 Hz and the bandwidth from 5 to 10 Hz. In contrast to other types of ECG filtering, waveform distortion is not an ELECTROCARDIOGRAM (ECG) SIGNAL PROCESSING.
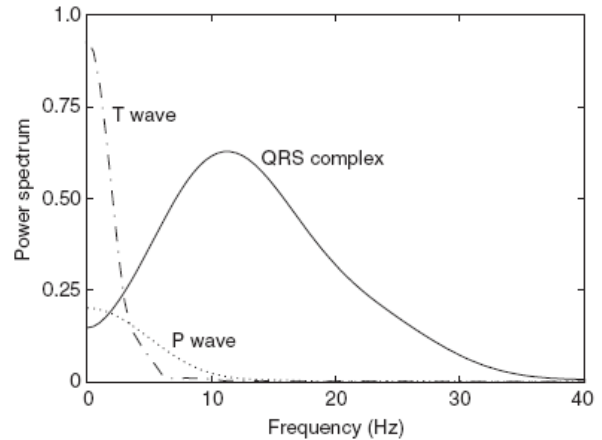

Fig. 5: Power spectrum of the P wave, QRS complex, and T wave. The diagram serves as a rough guide to where the spectral components are located; large variations exist between beats of different lead, origin, and subjects.

- *BASICS OF WAVELET FUNCTION:* A wavelet is simply a small wave which has energy concentrated in time to give a tool for the analysis of transient, nonstationary or time-varying phenomena such as a wave shown in figure 5.
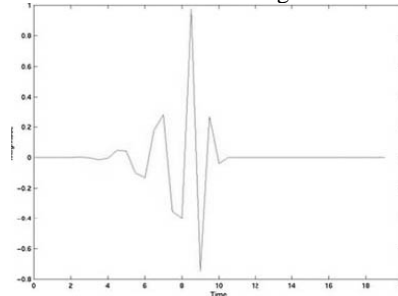

Fig. 6: Wavelet function.

A signal as the function of f(t) shown in Fig. 5 can often be better analyzed and expressed as a linear decomposition of the sums, products of the coefficient and function. In the Fourier series, one uses sine and cosine functions as orthogonal basis functions. But in the wavelet expansion, the two-parameter system is constructed such that one has a double sum and the coefficients with two indices. The set of coefficients are called the Discrete Wavelet Transform (DWT) of f(t).Namely called a wavelet series expansion which maps a function of a continuous variable into a sequence of coefficients much of the same way as Fourier series dose with the main useful four properties.

- *TYPES OF THRESHOLDING :* There are two main types of thresholding: Hard thresholding by which all the coefficients below a fixed threshold T that depends on noise variance are discarded.

$$H_{j,k} \blacksquare \dots\dots\dots(1)$$

Where.. T = Threshold

W j, k = Wavelet Coefficient

H j, k = Wavelet Based Filter

Soft thresholding by which all the coefficients below are discarded and all the coefficients above a fixed threshold T are shrunk, where j, k ,w , is the wavelet coefficient and j, k, H , is wavelet based filter. Enhancement filter is a wavelet based filter without discarding wavelet coefficient of (ECG) signal, which can carry clinical information: using combination of wavelet filters.

$$f = \sum_{m,n}(f, \psi_n \quad \text{...(2)}$$

The wavelet analysis of ECG signal is performed using MATLAB software. MATLAB is a high performance; interactive system which allows to solve many technical computing problems. The MATLAB software package is provided with wavelet tool box. It is a collection of functions built on the MATLAB technical computing environment. It provides tools for the analysis and synthesis of signals and images using wavelets and wavelet packets within the MATLAB domain.

TYPES OF ABNORMALITIES:

The normal ECG wave form and the waveforms with abnormalities consist of Sinus tachycardia and Sinus bradycardia which are as shown in Figures 7 and 8.
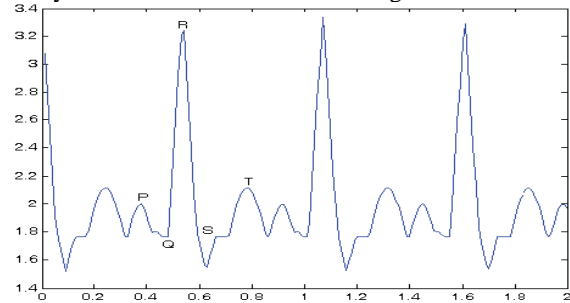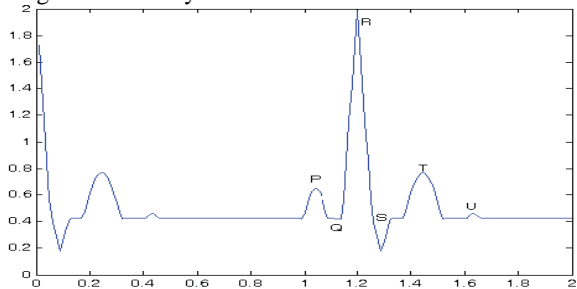

Fig. 7 Sinus tachycardia.

Fig. 8 Sinus Bradycardia.

- *FILTRATION OF ECG SIGNAL USING DWT*

Time-scale representation of signal obtained using digital filtering techniques. In DWT the resolution of the signal is changed by filtering operations. Scale is changed by up-sampling and down-sampling (sub-sampling) operations. Sub-sampling reduces sampling rate, or removing some of the samples of the signal. In up-sampling increasing sampling rate by adding new samples to the signal.

- *NEED OF DWT ANALYSIS:*

DWT of original signal is obtained by concatenating all coefficients starting from the last level of decomposition.DWT will have same number of coefficients as original signal.Frequencies most prominent (appear as high amplitudes) are retained and others are discarded without loss of information.

- *FILTERATION USING DWT:*

The basic steps for this method consist of First; we perform the DWT of the signal. Second we pass the transform through a threshold to remove the coefficients below a certain value. Third, we take the Inverse DWT (IDWT).

This able to remove noise and achieve high Signal-to-Noise ratios (SNR) because of the concentrating ability of the wavelet transform. The signal has coefficients relatively large compared to any other signal or noise that has its energy spread over a large number of coefficient. Thresholding or shrinking the wavelet transform will remove the low amplitude noise or undesired signals and any noise overlap as little as possible in the frequency domain and linear time-invariant filtering will approximately spare them. It is the localizing or concentrating properties of the wavelet transform that make it particularly effective when used with this nonlinear method.

- *CONCLUSION AND RESULTS*

Since the application of wavelet transformation in electro cardiology is relatively new field of research, many methodological aspects (Choice of the mother wavelet, values of the scale parameters) of the wavelet technique will require further investigations in order to improve the clinical usefulness of the signal processing technique. Simultaneously diagnostic and prognostic significance of wavelet techniques in various fields of electro cardiology needs to be established in large clinical studies.

Original ECG signal is filtered by low pass filter and the process was repeated many times, the residual of high pass filter is filtered out by low pass filter before the reconstruction of the original signal by IDWT. The number of repeating process of the original signal and the number of repeating process of the residual of high pass filter is determined where the result of filtration has the least signal distorting. For getting best quality of filtration, the filtration system is repeated many times.

The below results shows: Fig. 9-The decomposition of signals after applying wavelet transform on standard ECGsignal.
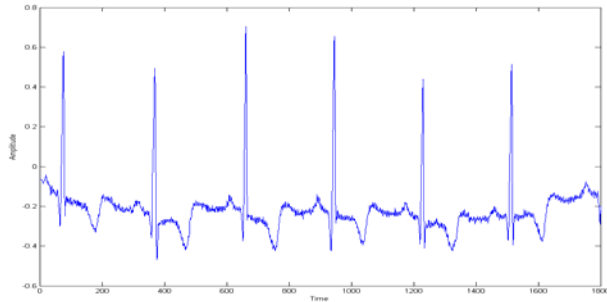
Fig. 9 Output at First Stage

Fig.10-After decomposition we get the Approximate & details coefficients (cA & cD). In approximations these signals are high-scale, low-frequency components of the signal. Where in Details we get the low-scale, high-frequency components. After the clearing the signals we remove the total noise signals from the original signal. Then by taking the threshold we double the original signal and detect the Bradicardia and Tachycardia of the signal. And also we calculate the number of beats in one minutes and distance between two pulses.
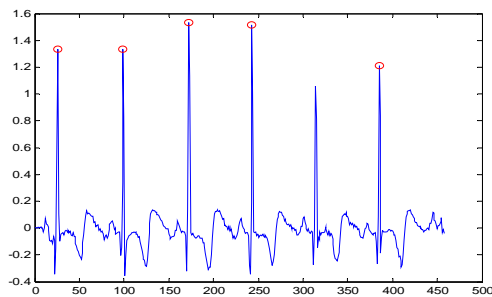

Fig. 10 Output at First Stage

- *FUTURE SCOPE*

After the detection of P wave, QRS complex and T waves of ECG, analyzing the extracted information by comparing with critical values. These values are used to diagnose the following problems :
1. Atrial Fibrillation
2. Ventricular fibrillation
3. Complete heart block.
4. Pre-ventricular contraction.
5. Left bundle branch block
6. Normal Sinus rhythm
7. Sick sinus rhythm

Also by implementing the Neural Network as a classifier we can diagnose the different ECG signals. By applying the wavelet Packet Transform for the detection of the QRS complex, ST Segment etc. Designing of wavelet packet filters and the calculation the optimal wavelet packet filter bandwidth which in line with the ECG.

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