QRS Detection of obstructive sleeps in long-term ECG recordings

Using Savitzky-Golay Filter

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ABSTRACT

Design better feature extraction methodology which can improve the classification result of cardiac arrhythmias in ECG signal. To analyse the classification accuracy using different classifier such that it can classify the beat arrhythmias in the approved manner. To modify the network structure according to cost function of multilayer neural network so that it can achieve better classification accuracy as compared to existing ECG beat classifier. Real time operation for recognizing the cardiac arrhythmias can also be done since the methodology uses the automatic detection of R-peaks and feature extraction techniques. From the results obtained using the developed algorithm, it can be observed that QRS detection is possible with higher amplitudes of the detected QRS peaks. This algorithm also eliminates the need of the high pass filter and the differentiator blocks as present in Pan Tompkins’ algorithm.

Keywords: Electrocardiogram (ECG), Savitzky-Golay Filter, QRS detection.

INTRODUCTION

Sleep apnea is found in 10% of middle aged adults. In long term it has effect on cardiovascular system. Sleep study (poly somnography) is a long term process where the patient is observed for the whole night and the respiratory signals are observed. In most of the cases this sleep study is not a comfortable process. Sleep apnea is the intermittent cessation of airflow at the nose and mouth during sleep. Apneas that last for at least 10 s duration are important but in most cases the apneas last 20-30 sand can last as long as 2-3 min. Sleep apnea is a cause of daytime sleepiness and also causes CVS (Cardio Vascular System) disorder. Existence normal range: 2% in middle-aged women and 4% in middle-aged men. By using ECG signal features here to overcome most of the negative factors in detection of sleep apnea. Electrocardiogram (ECG) is a diagnosis tool used to measure the electrical activity of heart recorded by skin electrode. The morphology and heart rate reflects the cardiac health of human heart beat. This is a non-invasive technique used to measure the signal on the surface of human body, which is used in the identification of the heart diseases. Any disorder of heart rate or rhythm, or change in the morphological pattern, is an indication of cardiac arrhythmia, which could be detected by analysis of the recorded ECG waveform. The amplitude and duration of the P-QRS-T wave contains useful information about the nature of the heart. The electrical wave is due to depolarization and repolarization of Na+ and K+ ions in the blood. ECG does not provide data on cardiac contraction or pumping function. Medical diagnosis is a complex procedure of determining if the patient’s body and its functions work in terms of normality. The diagnosis consists of collecting signs and symptoms from the results of various diagnostic procedures and making conclusion. Commonly numerous diagnostic procedures are performed: measuring blood pressure, checking the
pulse rate, listening to the heart with a stethoscope, urine tests, fecal tests, saliva tests, blood tests, medical imaging, electrocardiogram, hydrogen breath test and others, from these measurements is determine departure from homeostasis and the degree of departure. In some cases diagnosis can be time and resources demanding, especially in such cases which require making diagnosis at basis of multiple measurements examined for longer time, therefore appeared tendencies to move routine work from physician to automation and make the physician to make the final diagnosis. This is also the case of Polysomnography used in the diagnostic procedure for sleep studies which require observation of numerous signals during sleep time. Evaluating these signals in 30 seconds interval is time consuming even for experience physician. Because that these signals are recorded in digital form and the diagnosis is made directly from these records, so they are suitable for automatic processing. The aim of thework is to automatically classify sleep stage and sleep apnea using only the electrocardiogram (ECG) records and to find if conditions of sleep apnea (or other sleep disorder) are fulfilled for each analysed interval[9,10]. In this work, two problems are treated using non-invasive records such as Nasal Airway Flow (NAF), Electrocardiogram (ECG) and Pulse Transit Time (PTT) (Varon C et al., 2012). These problems are automatic sleep stage scoring which is based only on the ECG records and automatic sleep apnea syndrome detection based on NAF, ECG and PTT. The methods used for automatic sleep stage classification from ECG are described. All these methods are based on analysis of tachogram (record of RR intervals), but each introduces different approaches e.g. DE trended Fluctuation Analysis, Heart Rate Variability analysis[6,7,8].

PROPOSED WORK

The detection of QRS complex is the first step towards automated computer-based ECG signal analysis. QRS complex is detected more accurately identifying the exact R-peak were it is located in the recorded data. There are several techniques to improve the accuracy of QRS complex detection from ECG signal as the proper detection of QRS complex is tough, the ECG signal usually is added with different types of noise like electrode motion, baseline wander, muscles noise etc. The detection of QRS complex was achieved by filtering. In another method the QRS complex of ECG signal was found out using multirate signal processing and filter banks. The QRS complex is determined. Then finding the first differentiation of an ECG signal and taking the transformation of ECG signal by using Hilbert method is used to find the location of R-peak in the ECG signal.

WAVELET TRANSFORM

The wavelet transform is a convolution of the wavelet function ψ(t) with the signal x(t) and the scaling function is φ(t). The scaling function is convolved with the signal to produce approximation coefficients S. The discrete wavelet transform (DWT) is given by

\[ T_{m,n} = \int_{-\infty}^{\infty} x(t) \psi_{m,n}(t) dt \]  (1)

By choosing an orthonormal wavelet basis \( \psi_{m,n}(t) \) is used to reconstruct the original. The approximation coefficient of the signal at the scale m and location n is

\[ S_{m,n} = \int_{-\infty}^{\infty} x(t) \phi_{m,n}(t) dt \]  (2)

But the discrete input signal is of finite length N. Hence the range of scales can be investigated. Hence a discrete approximation of the signal is
\[ x_0 = x_M(t) + \sum_{m=1}^{M} d_m(t) \]  
(3)

Where the mean signal approximation at scale \( M \) is \( x_M(t) = S_{m,n} \phi_{m,n}(t) \) and detail signal approximation corresponding to scale \( m \), for finite length signal is given by

\[ d_m(t) = \sum_{n=1}^{M-m} T_{m,n} \psi_{m,n}(t) \]  
(4)

The signal approximation at a specific scale is a combination of the approximation and detail at the next lower scale.

\[ x_m(t) = x_{m-1}(t) - d_m(t) \]  
(5)

The Daubechies algorithm is conceptually more complex and has a slightly complicated computations, but algorithm picks up minute detail that is missed by other wavelet algorithms, like Haar wavelet algorithm. Even if a signal is not represented well by one member of the Daubechies family, it will be represented by another.

**FILTERING**

The signal to noise ratio ECG signal is increased by using QRS complex. A band pass FIR Butterworth filter of proper pass band frequencies is used to remove the power-line interference and high frequency noises from the original signal. The approximate popular pass band to maximize the QRS energy is verified in data base.

![QRS Detection Using Savitzky-Golay Filter](image)

Savitzky-Golay filter shown in Fig 1 has been used both for ECG noise reduction and compression. The filter is used as it has signal capability by least squares approach.
The band pass filter that has been used made by using a low pass filter and then a high pass filter in cascade. The low pass filter is to suppress the high frequency noise. Filter design uses digital filters having integer coefficients allows real time processing speeds. No floating point processing required so speed is high. QRS energy is maximised by the pass band for proper range. The filter is an integer filter which has poles located such so as to cancel out each other. Differentiation of the signal is done, after pass through the band pass filter. The signal is to be squared by a squarer. This is the non-linear processing of the signal. Done to get all positive values so that later these values can be processed to get the corresponding squared waves. This processing emphasizes the higher frequencies of the ECG signal which are due to the presence of the QRS complexes. The slope of the R wave is not the absolute way to detect QRS complexes in an ECG. There may be QRS waves in the ECG which is abnormal. Hence a moving window integrator is used so that these waves can be detected. The algorithm is represented in the block diagram as shown in Fig 2. This algorithm uses a combination of several processing methods, drawing heavily on digital filtering techniques and peak selection rules.

**EXPERIMENTAL RESULTS:**

![ECG Signal Processing Diagram](image)

**Fig. 3 Simulation for Heartbeat Rate 72/Sec**

The Fig 3 shows the waveform simulated for 72 beats per second heart rate, which is the normal ECG wave of any person and PQRS peaks are obtained.
Fig 4: Simulation for Heartbeat Rate 60/Sec

The Fig 4 details the waveform simulated for a slightly lower heart rate of 60 beats per second and shows abnormality in PQRS peaks when compared with previous normal ECG. Person may have low blood pressure, sleep apnea, anaemia and other cardiac disorders.

Fig 5: Simulation for Heartbeat Rate 80/Sec

The Fig 5 represents the waveform of slightly higher peaks from normal heart rate of about 80 beats per second and hence changes in the PQRS peaks are shown.

Fig 6: Output for QRS Detection
In the above Figure 6 the raw ECG signal generated using QRS detection algorithm is filtered and smoothed for elimination of noise and then the processed signal is obtained.

![Fig 7 ECG Signal Filtering for Normal and Abnormal](image)

The filtering of both normal and abnormal ECG signal is done by taking the FFT of the filtered ECG signal and the signal is filtered using two pass filters then R peaks are detected and shown in Figure 7.

![Fig 8 ECG Signal using R peak Detection Plot](image)

The Figures 8 shows the plot for two different samples of ECG signals and differences of the two R-peaks can be obtained by comparison of both the plots.

CONCLUSION

The work provides an algorithm for accurate detection of QRS complex and automatic classification of cardiac arrhythmias recommended by Association for the Advancement of Medical Instrumentation (AAMI). Feature extraction methodology proves an essential process for reducing the inputs to the classifier drastically. The automatic classification of arrhythmias helps in recognizing the diseases more accurately with less time. Automatic cardiac abnormality classification is necessary for real time application. The classification accuracy can improve by extracting the better features of ECG signal.

REFERENCES


