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Detection of Variation in Ventricular Depolarisation in ECG Signal: A Review

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***Abstract*—Different methods for detection the QRS complex on the electrocardiographic signal is done. This proposed paper discusses various techniques and transformations proposed earlier in literature for extracting feature from an ECG signal. In addition this paper also provides a comparative study of various methods proposed by researchers in extracting the feature from ECG signal. The paper highlights the real time extraction of QRS complex techniques with less computation.**

***Index Terms*— Zero frequency filtering, Differential threshold, Continuous wavelet transform, Multi-resolution Decomposition, Empirical mode decomposition, Variational mode Decomposition.**

I. INTRODUCTION

The ECG is the electrical activity of the heart. The beat detection is necessary to determine the heart rate, and several related arrhythmias such as Tachycardia, Bradycardia and Heart Rate Variation. Each heartbeat in the Electrocardiogram (ECG) signal is characterized by the succession of five waves (the P, Q, R, S, and T waves), shown in Fig-1.

The QRS complex is a vital wave in any ECG beat. The increased QRS width and distortions in the QRS shape indicate asynchronous activation of ventricles. The difficultiesarise mainly because of the huge diversity of the QRS complex waveforms, abnormalities, low signal to noise ratio (SNR) and the artefacts accompanying the ECG signals. The detection of QRS complex is done in at least two stages: pre-processing stage and decision stage. The detection of QRS complexes in an ECG signal provides information about the heart rate, the conduction velocity, the condition of tissues within the heart as well as various abnormalities.

The P wave occurs when the SA node (sinus node or sinatrial node) creates an action potential that depolarizes the atria. As long as the atrial depolarization is able to spread through the AV node to the ventricles, each P wave should be followed by a QRS complex . The time from the beginning of the P wave (atrial depolarization) to the beginning of the QRS complex (ventricular depolarization) is called the PR interval.

The PR segment is the portion of the ECG signal from the end of the P wave to the beginning of the QRS complex. The PR segment differs from the PR interval that is measured in units of time (ms). The segments

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are different than intervals. The important factor to analyze the segments on the ECG is their change from the isoelectric line (elevation or depression) while the important thing to analyze for intervals is their duration.

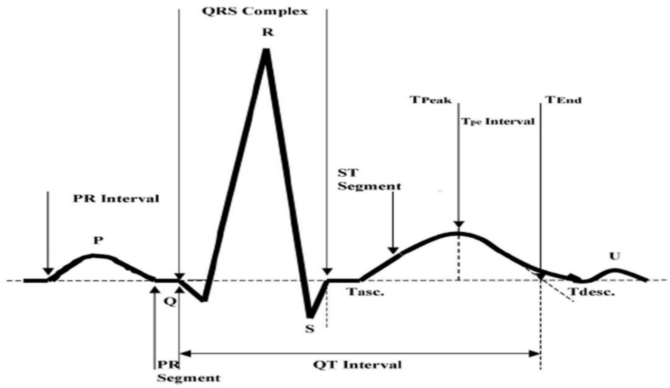

Fig-1 Electrocardiogram of a heartbeat

The Q wave is the first downward deflection after the P wave and is a first element in the QRS complex. When the first deflection of the QRS complex is upright, then there is no Q wave is present. The normal individual will have a small Q wave in many, but not in all ECG leads. The “QRS complex” is the combination of the Q wave, R wave and S wave and represents ventricular depolarization. The normal duration (interval) of the QRS complex is 0.08 and 0.10 seconds (80 and 100 ms). When the duration is between 0.10 and 0.12 seconds it is intermediate or slightly prolonged. A QRS complex duration of greater than 0.12 seconds is considered abnormal.

The T wave occurs after QRS complex and is the result of the ventricular repolarization. T waves should be asymmetric in nature. Second portion of the T wave should have a steeper decline when compared to the incline of the first part of the T wave. If the T wave appears symmetric ,cardiac pathology may be present such as ischemia.

This paper provides an over view on various techniques and transformations used for extracting the QRS complex from ECG signal. The different methods are discussed with respect to sensitivity and selectivity of QRS complex .The ECG signal is pre-processed to remove noise present in signal[1]. Digital filters were used to remove noise[2].The real time signal need to be computated much faster with good accuracy[3].The different methods on feature extraction verified with MIT-BIH database are discussed[4].

II. LITERATURE REVIEW

ECG feature extraction has been studied from early time and lots of advanced techniques as well as transformations have been proposed for accurate and fast QRS complex feature extraction.

A. Zero frequency filtering

Zero frequency filtering method is suitable for real time application, as it requires less computation time and threshold or decision logic is not required. ECG is pre-processed to remove noise. Noise was removed by using moving average subtraction method to remove the base line drift and Hilbert envelope is computed. The base line drift is corrected using local mean subtraction approach.ECG signal is passed through a zero frequency resonator to get magnitude spectrum. The mean subtraction method is used to remove noise. Auto-regression method used to find R-R interval. Hilbert envelope is used for peak correction. A zero crossing based method was implemented, where the number of zero crossings showed as a valuable feature for the QRS detection.

A QRS detection algorithm, which uses nonlinear transformation and simple peak-finding techniques based on energy thresholding, Shannon energy computation and smoothing process was proposed. In ECG, impulses due to QRS are quasi-periodic in nature because, the pumping activity of heart is quasi-periodic. Such quasi-periodic, impulse-like nature of ECG at QRS has a strong correlation with the quasi-periodic discontinuities present in the speech signal at pitch epochs. ZFF method was proposed for the epoch extraction from speech signal by exploiting the presence of impulse information at zero frequency. Similar to speech, ZFF is expected to give QRS locations present in the ECGThe negative zero crossing corresponds to

QRS complex.The proposed method is based on the presence of strong impulses at QRS peaks. The threshold value need not be used hence the method is simple and suitable for real time application[5,6].

B. Differential threshold technique

For real time ECG signal analysis pre-processing should be done faster. First derivative method was used to find R-peak.ECG signal is filtered using differentiator and square operation is done on the signal. Adaptive threshold technique is used to detect the R-peak. Adaptive threshold is nothing but taking the averaged of difference minimum threshold and maximum threshold. Adjacent Differential signals are used to detect the R-peak. The minimum differential signal Q & S found between R-R interval .This method helps to find QRS complex with less computation and performance is good. The proposed straightforward algorithm shows an obvious advantage comparing with the previous algorithms. The low computation requirement and a better performance makes it be implemented easily for portable monitoring applications . The performance of detection would be effectively improved if manual adjustment of the thresholds parameters is permitted during the detection process, especially for the ECG records with frequent premature ventricular contractions [7,8].Moving average filters (MAF) used in real time ECG analysis. Moving average filters used to remove high frequency noise .MAF removes baseline wander effect[9,10].

C. Wavelet

The derivative and its related information of ECG were mainly used for QRS detection, to access the deep slope of the R waves[1].Wavelet functions deals in both time and frequency domain. This transform is suitable for non stationary signal. ECG signal has high frequency component like QRS complex. Selection of wavelet and number of decomposition level is important for the analysis. The Wavelet Transform can be easily implemented in practical cases as a cascade consisting of sequential short length unit impulse response (FIR) filters. The choice of the duration of the sliding window results in a trade-off between false and missed detections. The absence of very low (< 2 Hz) and very high (>40 Hz) frequency concentration of the ECG signal helped us to de-noise the signal from movement artefacts and external interfering noises easily[11]. The envelope signal property of the Hilbert Transform has been applied on the QRS onset and offset detection. The envelope is defined as the modulus of the complex signal formed by the filtered ECG signal (the real part) and the Hilbert Transform of the filtered ECG Signal. For the QRS detection, the Wavelet and Hilbert Transforms are combined with first-derivative filter and adaptive threshold techniques[12].

The Continuous wavelet transform(CWT) with mother wavelet is used in Zero crossing method for QRS detection. The main disadvantages of the CWT are computational complexity and redundancy[13].The discrete wavelet transform performs an adaptive time-frequency decomposition of a presented pattern[14].DWT has flexibility in analyzing the time-varying morphology of ECG data. Soft Thresholding is applied to make signal less than 1 count as zero and signal more than 1 count as 1[15].The coefficients of featured ECG segment are obtained by applying wavelet transform technique. DB10 Wavelet is applied over original signal. On applying Db10 wavelet and decompose it till fourth stage will give us de-noised, and important feature extraction[16]. Daubechies wavelet of order 4 correlate well with the frequencies of required signal classification[17]. Autoregressive modelling (AR) technique is a stochastic process. AR modelling applied on ECG to reduce error. AR coefficients are also be used to extract the feature of ECG data. Because of the reduced dimensions of feature vectors, the classification can be done quickly. Then the support vector machine pattern recognition technique with Gaussian kernel was used to classify the ECG signal. The AR model along SVM detection gave improved accuracy[18,19]. The QRS complex detection could also be realized by Multi-resolution Decomposition Scheme based on MM (MMMD). And QRS complex detection methods based on MM, distinguished steep R peaks more easily than gentle ones[20].

D. Empirical mode decomposition

Empirical mode decomposition(EMD) is an Adaptive nonlinear technique which avoids diffusion and leakage of signals.EMD is based on sequential extraction of energy associated with various intrinsic time scales of signal. The Empirical Wavelet Transform (EWT) to explicitly build an adaptive wavelet basis to decompose a given signal into adaptive subbands. The masking signal method also allows EMD to be used to separate components that are similar in frequency that would be inseparable with standard EMD techniques. ECG signal is Pre-processed to remove noise. ECG signal is decomposed to get Intrinsic mode functions(IMF).Initially EMD was used to denoise ECG signal.

Later the method used in detection of QRS complex. R–peak is captured by the lower order IMF. The frequency of the functions decreases towards the higher order on IMFs[21]. The Lower third order IMFs are needed to completely identify the QRS complex. To find the IMF, Initially the extrema of signal is calculated and then interpolation with corresponding maxima and minima of the signal[22]. Compute the mean of the signal. The extraction of signal was done using sifting process. The name, sifting, indicates the process of removing the lowest frequency information until only the highest frequency remains. The process ends when the mean between the upper and lower envelopes becomes close to zero. The fast oscillatory QRS complex is highly detectable in the lower order IMFs irrespective of other characteristic wave amplitude. [23,24]. The set of IMF representing the QRS are selected . The EMD algorithm exhibits better performance than the threshold based technique. The peak correction factors are added and non-linear transformation is done to increase accuracy [25-29].

E. Variational mode Decomposition

Variational mode Decomposition (VMD) is a frequency domain non-recursive technique. The input signal is decomposed into different modes around the center frequency. In VMD each mode has a limited bandwidth. Demodulation time will be less & processing is fast.ECG signal is decomposed into spectral domain. The decomposed mode signals are dense around their central frequency. Third mode has the high frequency QRS region and further processed to find the exact duration of QRS signal. The decomposed signal is normalized for maximum amplitude and then squared to move all the points in positive quadrant. These steps convert different amplitude signals into a standard frame. The edge of small values diminishes with respect to R-peak. The main advantage of this technique is that it decomposes the signal into less number of modes hence the processing speed is high. Another advantage is that the whole signal is processed at a time and fixed threshold value is used. The drawback is the selection of terminal threshold value.VMD method helps in efficient detection of QRS component in ECG signal [30,31].

Difference Operation Method (DOM) for detecting the QRS complex is proposed. The proposed DOM includes two stages. The first stage is to find the point R by applying the differenceequation operation to the ECG signal. The second stage looks for the points Q and S according to the point R to find the QRS complex. DOM is a simple, fast and reliable ECG detection method. The method is easy to perform and does not need complex mathematical calculations. DOM is a suitable and reliable detection method for on-line real-time detection QRS complexes of the ECG signal. [32].

III. Comparison of different methods

It is seen that most of the reported works are validated with MIT-BIH Arrhythmia database. The results are comparable to some of the earlier reported works as indicated in Table I. The performance of QRS complex detection methods were evaluated in terms of selectivity, specificity and accuracy.

TABLE I. COMPARISON OF DIFFERENT METHODS

Method	Parameters		
	Sensitivity	Specificity	Accuracy
Zero frequency filtering	97.52%	99.5%	99.5%
Differential threshold	99.69%	99.63%	99.65%
Wavelets	99.66%	99.68%	99.68%
Empirical mode decomposition	99.82%	99.89%	99.85%
Variational mode Decomposition	99.53%	99.84%	99.67%

IV. Conclusion

This proposed paper provides an over view of various ECG feature extraction techniques and algorithms proposed in literature. Each technique presented in the previous project of ECG analysis has their advantages and disadvantages. The real time ECG signal must be analysed properly to diagnose disease with high speed and accuracy. The future work mainly concentrates on developing an algorithm for accurate and fast QRS feature extraction of the real time ECG signal. A good performance of an automatic real time ECG analysing system depends heavily upon the accurate and reliable detection of the QRS complex.

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