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Methods of R Peak Detection

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Abstract

Electrocardiogram (ECG) is a noninvasive, easy to perform, low cost test and important bioelectrical signal used to assess the cardiac state of a person. This paper presents a comparative study of various techniques of R peak detection like Digital Signal Processing, Hilbert transform, Wavelet transform along with other ANN techniques of Perceptron Model without Feedback and α-Least Mean Square Learning, wavelet transform. The comparision was carried out by testing them against a standard CSE database. Fast convergence and more precision in feature recognition were the key features found in the used approaches. Final results suggest that EBP gives a better recognition rate and hence, higher performance. In addition, the analysis results have been found acceptable by the clinical practitioners.

Keywords: ANN, EBP, Wavelet Transform, ECG, QRS

INTRODUCTION

This scheme is made to develop a system that will assist heart patient in remote areas, where the availability of doctor is relatively poor. With the increase in stress, the rate of heart diseases is also increasing. Therefore a need is felt to develop an automated ECG analysis system. The in-time diagnosis of heart diseases can save many lives. For the purpose of standardized measurements in quantitative electrocardiography, ECG [1] databases are available that can be used for computer ECG measurement programs. Some of these international standard databases are the CSE ECG database and MIT/BIH database. For this work, CSE ECG database has been used. The sampling frequency is 500Hz for this database [2].There are various methods for ECG signal analysis:

(1) Spatial Velocity Method: This is mainly used for QRS detection. First of all P wave is detected followed by QRS and T waves.

(2) Artificial Neural Network: Artificial neural network is an efficient tool EBPA method [1, 3] has been used here, as it provides supervised learning where by the network is trained for the desired output and the weights are adjusted according to deviation from the desired output. The other methods like least mean square learning and Perceptron model can also be used

1.1 Electrocardiogram

The electrocardiogram is composed of a series of electrical phenomenon resulting from atrial and ventricular depolarization and repolarization and thus manifests in a sequence as P wave, QRS complex, T wave in every cardiac cycle [4] as shown in figure 1.

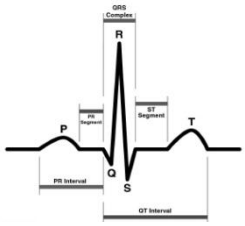

Figure 1. ECG Waveform

The normal ranges of parameters of various components of ECG [14] are as shown in Table 1.

Table 1. Normal limits of ECG Parameters

Parameters	Normal Value
Heart Rate	60-100 bpm
QRS Duration	0.08-0.12 sec.
P Wave Amplitude	< 0.25 mV
T Wave Amplitude	< 0.11 mV
P Wave Duration	< 0.10 sec.
PR Interval	0.12 – 0.20 sec.
Corrected QT Interval	< 0.42 sec.

1.2 System Layout

For extracting the parameters of interest from the ECG signal for further classification is achieved through the following processing stages [5]:

1. Preprocessing of ECG
2. Identification of waves and characteristic points
3. Parameter extraction

In the first step, noise in the signal is minimized using preprocessing of the signal so as to improve signal to noise ratio. For this, a third order low pass Butterworth filter of higher cut-off frequency 40 Hz is

used, which also removes the harmonics present in the signal. For removing the baseline wander a third order high pass Butterworth filter of lower cut-off frequency 0.05 Hz is used. The digitized data is then processed for wave recognition and delineation in second step. After the wave has been identified, base line estimation for establishing time and amplitude references are marked. This forms the basis for parameter measurement. Recognition of ECG wave starts with the R peak identification, which is the most significant in the ECG signal. Here onward processing is application dependent. In step three, depending on the application for which the processing is to be done; a few relevant parameters are extracted from the measured parameters [2].

2 Methodology and results

2 .1 various methods for qrs detection

ANN Based Detection

The algorithm for detecting the R wave comprises the following steps:

1) Training of Artificial Neural Network,

2) Detecting the R wave from the ECG using the trained ANN [1].

3) QRS complex analysis for the identification and amplitude measurement of the characteristic peaks [6].

For this work the ANN architecture of 25:5:1 is used [7, 8, and 9]. This means 25 nodes in input layer, 5 nodes in hidden layer and finally one in output layer. The reason for this is that R wave can be completely characterized by 25 samples and results in faster convergence.

Moving average based DSP technique

The new QRS detection algorithm is composed of three main stages:

- A pre-processing stage,
- A processing stage, and
- A determination stage.

In the pre-processing stage, band pass filtering is applied to the ECG signal. Next, the QRS complex in the filtered ECG signal is enhanced during the processing stage. The QRS complex is finally detected and its location determined in the last stage.

Wavelet Transform

Wavelet transform [10] appears to be a promising method describing time and frequency characteristics of ECG waves. A dyadic wavelet transform is used for extracting ECG characteristic points. The local maxima of the WT modulus at different scales can be used to locate the sharp variation points of ECG signals[12]. The position of the maximum values of the coefficients of the transform at different values of the scale gives us the location of the R/S peak present in the waveform. The Cubic B Spline Wavelet is used as the mother wavelet for the transformational purposes [13].

Hilbert Transform

Hilbert transform allows R waves to be differentiated from large, peaked T and P waves with a high degree of accuracy and minimizes the problems associated with baseline drift motion artifacts and muscular noise.

However, this is often difficult to achieve, since various sources of noise contamination [11] are frequently encountered, such as baseline drifts, motion artifacts and muscular activity. Furthermore, morphological differences in the ECG waveform increase the complexity of QRS detection, due to the high degree of heterogeneity in the QRS waveform and the difficulty in differentiating the QRS complex from tall peaked P or T waves [2].

This algorithm uses the first differential of the ECG signal and its Hilbert transformed data to locate the R peaks in the ECG waveform. This has a number of advantages, the unwanted effects of large peaked T and P waves are minimized and the new algorithm performs excellently in the presence of significant noise contamination.

Simulations

The ECG signals used were from Common Standard for Electrocardiography (CSE) database available in the website. The software used is MATLAB and its toolboxes. The values of CSE database of 12 different leads is applied to the different programs developed using Matlab. The entire record was used for the analysis. In this, the program is tested on the samples of 12 leads i.e. lead V1, lead V2, lead V3, lead V4, lead V5, lead V6, lead I, lead II, lead III, lead aVL, lead aVF and aVR and the value of two 'R' peaks is detected. By the use of the 'R peaks' heart rate of any patient can be calculated.

Results analysis

The validation of the method was assessed by applying the values of CSE database of 12 different leads, each of 2000 samples to the different algorithms to a 5-minute portion of the database ECG signals. The heart rate was calculated using MATLAB code and the percentage accuracies by different methods were detected. For doing the result analysis the R peaks calculated using MATLAB were compared with the actual R peaks. By calculating the R peaks the heart rate is calculated. Here we have calculated for one lead, the same process can be repeated for other 11 leads and percentage accuracy can be calculated.
The system is a step towards development of an expert system for the Cardiac Disease Classification. The system processes the filtered ECG to produce a large output indicating the presence of the R wave and then other component of ECGs were determined using window and slope detection method. All the approaches assume that the R wave is significantly different from the remainder of the ECG. Following the standard definitions, in the present work, the ECG analysis is carried out over lead II of a standard multi lead ECG and its successful validation establishes the potential application of the ANN based methods. In addition, the analysis results have been found acceptable to the clinical practitioners
The following results were obtained after performing the analysis and implementing the different algorithm.

Table 2. Comparative study

Method	Percentage accuracy
Error back propagation	98.50
Least mean square learning	96.25
Perceptron model	72.5
Moving average based DSP technique	96.25
Hilbert transform	80.5
Wavelet transform	85.71

CONCLUSION

In this study, we compared four methods for the detection of the R-wave peaks like Digital Signal Processing, Hilbert transform, Wavelet transform alongwith other ANN techniques of Perceptron Model without Feedback and α-Least Mean Square Learning was carried out by testing them against a standard CSE database. The computational load and the detection performance have been the major parameters of comparison among the techniques. Fast convergence and more accuracy in feature recognition were the key features found in the

used approach. Final results suggest that EBP gives a better detection rate and hence, higher performance.

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