Processing Of ECG Signal Using Image Processing

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ABSTRACT

An Electrocardiogram (ECG) is a graphic tracing of electrical patterns produced by the heart. This test is frequently used for patients who have heart problems and is an important diagnostic procedure. Standard ECG are recorded on paper has a grid on it. The grid work on ECG records is made up of many tiny blocks that are 1 mm square. Each of these tiny boxes is generally 40 ms duration. Heavier lines are used to make larger squares of five boxes tall and five boxes wide. Each larger square has a duration of 200 ms. Five of these larger squares (200 × 5) equals 1000 ms or 1 sec. By counting out the grids, we can get a fast approximation of the duration of a particular cardiac cycle or timing cycle. However this becomes increasingly complicated when we would like to analysis the ECG data for higher precision. The normal ECG record comprises a P wave, QRS complex, ST segment, and T wave. Analysis of each segment duration is very important for critical decisions by clinician. In view of this we have developed MATLAB based algorithm to read the ECG images, which has options to calibration in both X and Y axis, followed by algorithm to remove the background grids and extract the numerical coordinates of individual points of ECG curve. The numerical data extracted from ECG are highly useful for high precision diagnosis and the details are discussed in the manuscript.

INTRODUCTION

Analysis of electrocardiogram (ECG) as a tool for clinical diagnosis has been an active research area in the past decades. The validity of using ECG tracing for heart disease detection supported by the fact that the physiological differences of the heart in different individuals display certain uniqueness in their ECG signals [1]. Human individuals present different patterns in their ECG regarding wave shape, amplitude, PT interval, due to the difference in the physical conditions of the heart [2]. Further, ECG signal is a life indicator, and can be used as a tool for liveness detection. An ECG graph paper can find wide applications in physical access control, medical records management and forensic applications. ECG tracing is printed on graph papers for accurate interpretation. On ECG graph the Y-axis represents voltage in mV. The bar indicated below represents 1 millivolt (mV). This denotes the electrical strength of the signal. Therefore, each big square represent 0.5 mV and each small square represent 0.1mV. The X-axis represents time in seconds. Each big square represent 0.2 seconds. Therefore, each small square represents 0.04 seconds. There any application of ECG tracing on graph paper but in many application ECG tracing without grids are needed, so in such cases extraction of plane ECG signal without grids from the scanned graph paper is important. This process is known as feature extraction or image background removal.Background subtraction is a process of extracting foreground objects in a particular image. The foreground object boundaries extraction reduces the amount of data to be processed and also provide important information about the object. The various methods are presented to remove background, among them (SHARP) is the widely used background field removal technique .

OBJECTIVE OF THIS PROJECT

Some of the image processing techniques are developed for an electrocardiogram (ECG) feature extraction and signal regeneration as a digital time series signal. In general the ECG is recorded on a thermal paper which cannot be stored for a long time, because thermal trace over time becomes erased gradually. Some hospitals are saving the ECG thermal papers as scanning images in the electronic equipments (like computers) to maintain medical records, but this method needs to high memory capacity, and use less scanning resolution that gives signal accuracy is less at preview. The main aim of this paper is to extract the 12-lead ECG signals from the thermal paper and converting it to a digital time series signals. Feature extraction and the digital time series signal were tested on 30 of 12-lead ECG paper records from the MIT-BIH arrhythmia database, and the accuracy was between 96.31% and 98.25%. Evaluation of the proposed method for ECG feature extraction was done by comparing the obtained values with manual data and this method offered an accuracy of 98.06%. In addition can be using features extraction to perform an automatic heart disease classification using one of the artificial intelligence methods.

Scanning the 12-lead ECG paper, convert it into gray-scale levels and select the desired signal.

REVIEW OF LITERATURE

This survey begins by reviewing some of the previous studies in ECG signal feature extraction and analysis techniques. The survey is divided into feature extraction and classification techniques.

A. ECG Feature Extractions

The first step in the analysis of ECG signal is the denoising of ECG signal. Denoising or pre-processing of ECG signal is important because noise severely limits the utility of the recorded ECG. After pre-processing, the second stage towards classification is to detect certain features of ECG signals mostly QRS complex, P and T waves. The features, which represent the classification information contained in the signals, are used as inputs to the classifier used in the classification stage. The goal of the feature extraction stage is to find the smallest set of features that enables acceptable classification rates to be achieved. In general, the developer cannot estimate the performance of a set of features without training and testing the classification system. Therefore, a feature selection is an iterative process that involves training different feature sets until acceptable classification performance is achieved.

A. Coast Doughlas et al. in [2] described an approach to cardiac arrhythmia analysis using Hidden Markov Models.This technique classified by detecting and analyzing QRS complex and determining the R-R intervals to determine the ventricular arrhythmias. The Hidden Markov modeling approach combines structural and statistical knowledge of the ECG signal in a single parametric model. The Hidden Markov modeling addresses the problem of detecting low amplitude P waves in typical ambulatory ECG recordings.

C. Li et al. in [3] used the Wavelet Transform (WT) method including N.V. Thakor et al. [4], David Cuesta-Frau et al. [5], Louis C Pretorius and Cobus Nel [6] and S.Z. Mahmoodabadi et al. [7] because the results indicated that the Discrete Wavelet Transform (DWT)-based feature extraction technique yields superior performance. C. Li et al. in [3] have done the ECG analysis using WT.

B. ECG Training and Classification Algorithms

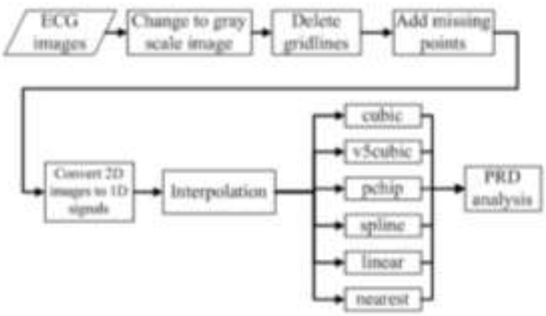
In ECG training and classification analysis stages, some researchers have tried to maximize the detection level of accuracy in many different ways. The performance of the developed detection systems is very promising but they need further evaluation. The automatic detection of ECG waves is important to cardiac disease diagnosis. A good performance of an automatic ECG analyzing system depends heavily upon the accurate reliable detection of the disease.

Neural Network

The classification of the ECG using NNs has become a widely used method in recent years. The network architectures for modelling process modelling in NNs include the feed forward network, the radial basis function (RBF) network, recurrent network, and other advanced network architecture as explained by the Centre for Process Analytics and Control Technology (1999) and Sjoberg in [15]. The efficiency of these classifiers depends upon a number of factors including network training. It has the inputs models in the training parameters and the output indicated the point at which training should stop. Simple feed forward neuron model was shown by Dayong Gao et al. in [16]. Researcher from Harvard University, M. Sordo in [17 indicated that the training and testing of the models was based on the results from the signal database of the normal patient and heart disease patient.

Rosaria Silipo and Carlo Marchesi in [18] also developed an automatic ECG analysis based on ANN. This project presented the result by carrying out the classification tasks for the most common features of ECG analysis which are arrhythmia, mycordial ischemia and chronic alterations and achieved high classification accuracy.

BLOCK DIAGRAM



WORKING PRINCIPLE

This research proposed two ECG signal retrieval techniques based on spatial and frequency oriented methods. The spatial-oriented method mainly applied histogram segmentation, missing pixel replenishment, and interpolation. The frequency-oriented method majorly applied 2D Fourier transform, 2D lowpass filter, 2D median filter, missing pixel replenishment, and interpolation. In order to evaluate two systems fairly, a standardized database for both methods is essential.

In spatial-oriented process (figure 1), a color image may directly eliminate the red component to remove gridlines or convert to a gray or binary tone image after selecting a suitable threshold with the help of histogram analysis. A suitable threshold selection after histogram analysis can mostly remove the background and gridlines of ECG charts. Then, the computer program searches background-removed images for missing points on the columns without any ECG pixel points. The missing point has been replenished by the darkness point of the same column on pervious gray scale image. If the same column has more than one pixel, the thinning algorithm is applied. Next, the co-ordinate of each black pixel was extracted and then the values were calibrated according to the co-ordinate system of the chart. Because of the image resolution is 990 x 124, the interpolation is applied to fill the number of points in x-axis up to 5000 points (10 sec.* 500 sps). Finally, five interpolation functions and their PRDs are calculated. The equation (1) defined PRD function which describes the difference between the reconstructed and original signal as follows,

$$PRD = \sqrt{\left\{\frac{\sum_{i=1}^{n}[x_{org}(i) - x_{rec}(i)]^2}{\sum_{i=1}^{n}[x_{org}(i)]^2}\right\}} \quad ...(1)$$

where n is the number of samples and xorg and xrec are samples of the 1D original and reconstructed data sequences. Figure 2 shows a processing example from an original color image (figure 2a) to a 1D recovered ECG signal (figure 2d).

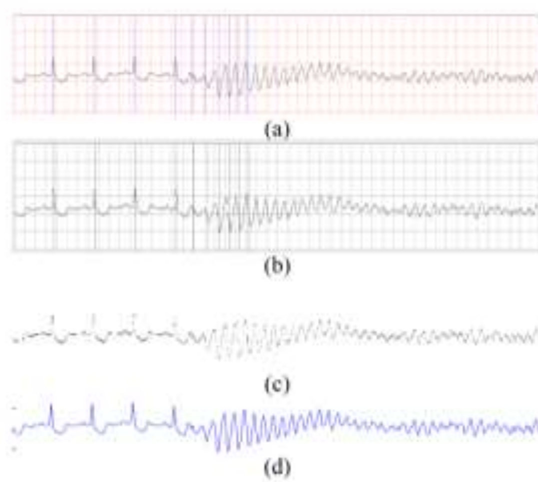


Figure 2. The procedures of spatial-oriented method: (a) an original color image; (b) a gray tone image after selecting a suitable threshold on histogram; (c) missing pixel replenishment and interpolation; (d) a

recovered and calibrated ECG signal.

RESULT AND DISCUSSION

Our proposed methods processed on color or graylevel electrocardiogram charts. To summary, first, threshold segmentation or 2D Fourier transform were applied to remove the chart grids and marker lines. Second, column searching on missing pixels or dots was utilized, which were refilled by image matching and pixel interpolation. Then, the 2D image was converted to 1D signal by using five interpolation methods (cubic, v5cubic, pchip, spline, linear, and nearest) that rebuild sampling frequency to 500 sps. The example results are plotted in figure 7 & 8.

Figure 7. Spatial-oriented method – the recovery signal (red) versus the original signal (blue)

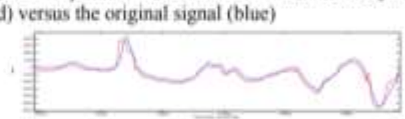


Figure 8. Frequency-oriented method – the recovery signal (red) versus the original signal (blue)

Finally, the performance was evaluated by percentage of root mean square for calculating waveform similarity. Twenty-three ten-second charts (about 990 by 124 pixels) were processed and compared with original ECG data for performance evaluation. The spatial and frequency methods provided each best result on average 45.46% and 54.33% PRD by using linear interpolation.

CONCLUSION

Overall, our image processing methods successfully converted 2D ECG images into one-lead ECG signals to make further CAD analysis and modelling simulation possible. The results show that the spatial method offered better performance than the frequency method, especially if the RGB colours in chart are kept. Unlike spatial method, 2D Fourier transform method contains more saltand-pepper noise on chart images, as well as scattering noise. Our recovered signals also include amplitude displacement and inconsistent waveform phase shifting. The above factors cause the higher average PRD. However, for improving the system performance, high resolution images is a necessary condition to reduce dispensable interpolation. In addition, according to this investigation, the linear interpolation is the best interpolation method with less overall PRD.

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