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ECG Trace Digitization Using Image Processing Techniques

Hussain K. Khleaf[1,3], Kamarul H. Bin Gazali[1] ,Ahmed N Abdalla[2] , Mithaq Na'ma Raheema[3]

Abstract— 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.

Keywords— Feature extraction; electrocardiogram (ECG); ECG image processing

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1 Introduction

Recently the thermal paper Electrocardiogram (ECG), has been a common practice in heart disease diagnosis, and became a very helpful tool to assure of the patients help, and the ECG thermal paper is important pointers to provide helpful information about the waveform shape for the heart, and can be reviewed periodically. For these reasons the hospital managements store the ECG paper based records for the patient history repository. But there are significant challenges to keep these papers for large periods of time in the patient history repository (traditional repository or electronic repository). In the densely populated countries a huge storage space is required to save the ECG papers, also this method needs long retrieval time, finally the ECG is recorded on a thermal paper which cannot be stored for a long time, because thermal trace over time becomes erased gradually. These are in the traditional repository, and in the hospitals that use electronic repository (electronic equipments) to save the ECG thermal papers as scanning images are needed for high memory capacity, and use less scanning resolution that gives signal accuracy is less at regeneration.

2 Methodology

The proposed method steps are shown below, and have been carried out in order to feature extraction and regeneration as a digital time series signal.

A. Scanning the 12-lead ECG paper, convert it into gray-scale levels and select the desired signal.
B. Separation of the desired signal from its background (lines of squares grid).
C. The signal and the background lines must be of finite thickness (one pixel must represent width lines).
D. Compute the size of the small and large square from the background (scaling).
E. Signal period identification and find feature extraction.

2.1 Scanning, Selecting and Converting.

Typically, the 12-lead ECG signals are printed by thermal trace on the paper at 25mm/sec speed [1]. The optical scanning technology was used to scan ECG paper at 200 dpi (pixel or dots per inch) and stored as a color image in many types of format files such as (jpg, gif, …, and gif) [2]. Figure (1) shows the image of the 12-lead ECG paper. The first step was done by using the mouse to select and crop one of the 12-lead ECG signals as shown in the figure (2-a) for cropping III lead, and then converting the cropped color image into grayscale levels as shown in the figure (2-b).

Fig. 1. The color image of 12-lead ECG paper.

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1. *Faculty of Electrical and Electronic Engineering, University Malaysia Pahang, Pekan 26600, Malaysia.*
2. *Faculty of Engineering technology, University Malaysia Pahang, Gambang 26300, Malaysia.*
3. *Department of Electrical and Electronic Engineering, University of Technology, Baghdad, Iraq.*

E-mail: eng_h_k_msc@yahoo.com

a) Color image.

b) Grayscale levels

Fig. 2. Cropping the III lead.

2.2 Signal Extraction and Digitization.

This step is to isolate the target object (signal) from its background in the selected (cropped) image and then digitizing it. First, finding the gray threshold. There are many algorithms do a fairly good job of finding the gray threshold such as Mean or Median value, Iterative Method, K-means and Otsu algorithm. In computer vision and image processing, the Otsu's method is used to automatically perform histogram shape-based image thresholding, [3] or, the reduction of a gray level image to a binary image. The algorithm assumes that the image to be thresholded contains two classes of pixels or bi-modal histogram (e.g. foreground and background) then calculate the optimum threshold separating those two classes so that their combined spread (intra-class variance) is minimal [4].

The graythresh function uses Otsu's method, which chooses the threshold to minimize the intraclass variance of the black and white pixels. Multidimensional arrays are converted automatically to 2-D arrays using reshape. The graythresh function ignores any nonzero imaginary part [5, 6].
In the Otsu's method we exhaustively search for the threshold that minimizes the intra-class variance (the variance within the class), defined as a weighted sum of variances of the two classes:

$$\sigma_\omega^2(t) = \omega_1(t)\sigma_1^2(t) + \omega_2(t)\sigma_2^2(t) \tag{1}$$

Weights ω_i are the probabilities of the two classes separated by a threshold t and σ_i^2 variances of these classes.
Otsu shows that minimizing the intra-class variance is the same as maximizing inter-class variance [4, 5].

$$\sigma_b^2(t) = \sigma^2 - \sigma_\omega^2(t) = w_1(t)\omega_2(t)[\mu_1(t) - \mu_2(t)]^2 \tag{2}$$

Which is expressed in terms of class probabilities ω_i and class means μ_1. The class probability $w_1(t)$ is computed from the histogram as t :

$$\omega_1(t) = \sum_{0}^{t} p(i) \tag{3}$$

while the class mean $\mu_1(t)$ is:

$$\mu_1(t) = \left| \sum_{0}^{t} p(i) * x(i) \right| / w_1 \tag{4}$$

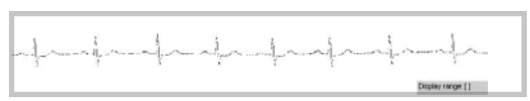
Where $x(i)$ is the value at the center of the i_{th} histogram bin. Similarly, you can compute $w_2(t)$ and μ_t on the right-hand side of the histogram for bins greater than t.
The class probabilities and class means can be computed iteratively. This idea yields an effective algorithm.

Algorithm

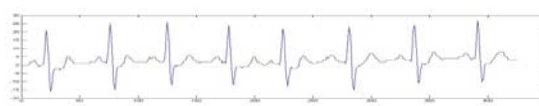
1- Compute histogram and probabilities of each intensity level.
2- Set up initial $w_i(0)$ and $\mu_i(0)$.
3- Step through all possible thresholds $t=1$ … maximum intensity.
   a) Update w_i and μ_i.
   b) Compute $\sigma_b^2(t)$.
4- Desired threshold corresponds to the maximum $\sigma_b^2(t)$.
5- You can compute two maxima (and two corresponding thresholds). $\sigma_{b1}^2(t)$ is the greater max and $\sigma_{b2}^2(t)$ is the greater or equal maximum

$$\text{Desired threshold} = (\text{threshold}^1 + \text{threshold}^2)/2 \tag{5}$$

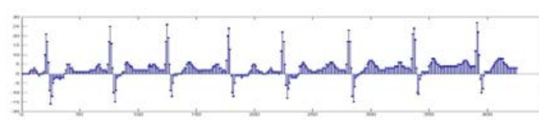
The final desired threshold is self-calculated from the image by using above algorithm, then using this threshold to separate between two regions (desired represented by signals and undesired represented by background grid lines and vice versa). then convert it into black and white image as shown in the fig. 3-a. and from this black and white image will be obtained on the digital time series for signal as shown in the fig. 3-b. and redraw as discrete time signal (sampling signal) as shown in the fig. 3-c.



a



b



c

Fig. 2. Signal extraction. (a) Black and white image. (b) Digital time series for signal. (c) Discrete time signal.

2.3 Slandering the Signal Line

In any image scanning, the signal lines are several pixels wide, and these pixels cause many values in the amplitude and time that can be read. In this step the method that can be used to achieve the slandering signal line is time slice. The time slice is a vector of pixel positions containing values transmitted by the scanner as it scans the signal line. The time lit pixel refers to a pixel whose value is the signal line [7].

2.4 Scaling and Calibration of Extracted Signals.

After extracting signals now must measure the amplitudes and the periods with standard scale. The standard scale is calculated by extracting the background grid lines from ECG image, then computing how many pixels in the large and small squares (pixel scaling) [8].

The digital color image consists of a Red, Green and Blue (RGB) colors. Each pixel has a particular color, that color is described by the amount of RGB in it. If each of these components has a range (0 – 255), this gives a total of 256^3 different possible colors. Such an image is a stack of three matrices representing the red, green and blue values for each pixel. This means that for every pixel there correspond 3 values [9].

In most ECG papers, the signals tracing are drawn in black color and the background grid lines are drawn in red color [10]. By separating the RGB matrices and using some image processing techniques such as gray threshold as mention previously and special calculations (special calculation means using some traditional mathematical methods like multiplication and division ..etc). We got the background grid lines and draw it as shown in the fig (3), and scaling each large square in 20 pixels and small square in 4 pixels. Now we have scaled to represent the amplitude axis (y-axis) for each 0.5mV by 20 pixels (vertically in large square) or for each 0.1mV by 4 pixels (vertically in small square), and in the time axis (x-axis) each 0.2Sec by 20 pixels (horizontally in large square) or for each 0.04Sec by 4 pixels (horizontally in small square).

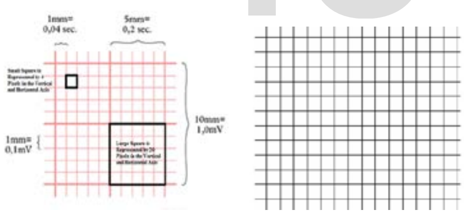


Fig. 3. Section of ECG background grid lines.

3.5 Period Identification and Feature Extraction.

The period for each signal of 12-lead ECG is implemented by finding specific points, such as peaks and bottoms in the extracted signals. Then record the values between these two points (peaks or bottoms) as a vector, and redraw these vector values (pixels) on the zero axis as shown in fig. (4) and compute their number. The final vector (sampling signal) is representing period for one of the 12-lead ECG. Finally, feature extraction will be calculated from the final result (sampling signal) as shown in the table (1).

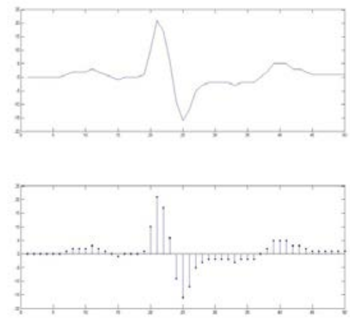


Fig. 4. Period for one of 12-lead ECG and it's sampling rate.

3 Result and Discussion

The proposed method is convert's the ECG signals that are stored as an image in the computer into a digital time series, and store them in the electronic files such as Microsoft Excel file and be easy to using it by the various computer programs. and so we were able to achieve the first goal it to minimize the storage file size and increase the storage capacity. The second goal is to redraw the signals as a digital signals series in the computers and then by using sampling signal directly to automatically read and calculate the features. Table 1 shows a comparison between the proposed method and the manual method for one of the 12-lead ECG signals. This method offered an accuracy of 98.06%. This accuracy is represent the extent of matching between these two methods for taken the ECG features.

TABLE I.
COMPARISON OF THE PROPOSED METHOD AND MANUAL METHOD FOR ONE OF THE 12-LEAD ECG SIGNALS.

Morphology	*Manual Method*	*Proposed Method*
Heart rate	66 bpm	65.45 bpm
P Duration	0.12 sec	0.1222 sec
QRS Duration	0.11 sec	0.115 sec
T Duration	0.24 sec	0.24 sec
PR Interval	0.16 sec	0.16 sec
QT Interval	0.42 sec	0.42 sec
ST Interval	0.3 sec	0.3 sec
P Amplitude	0.1 v	0.11 v
R Amplitude	0.86 v	0.85 v
T Amplitude	0.3 v	0.3 v

4 Conclusion

In this work, image segmentation is used for partitioning of an ECG as a digital image into multiple segments (sets of pixels). The goal of segmentation is to simplify and/or change the representation of an ECG image into something that is more meaningful and easier to analyze. Image segmentation is used to locate objects and boundaries (signals, lines, curves, etc.) in ECG images.

The advantage of this process is to self-extract information from an ECG image and convert them into real information that can be used by other processes via computer, such as diagnosis of heart disease using artificial intelligence.

Also can be stored this information in the memory of the computer devices, in the form of an electronic files that have small size such as Microsoft Excel, or save as type (.xls, .txt, ..., elc.). This gives us the liberation of large storage capacity, also can redraw the signals and self-analysis, and this gives us reducing the time and effort in the process of reading and interpreting an ECG signal manually.

a.

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