Implementation of a Robust Algorithm for Digitization of ECG Paper

Ananya Gupta

PG Scholar
Department of Electronics and Communication Engineering,
Rameshwaram Institute of Technology and Management, Lucknow, India.

Vikash Kumar Sachan
Asst. Professor,
Rameshwaram Institute of Technology and Management

Abstract: In present date, ECG is an essential diagnostic medium for monitoring the activity of heartbeats. Due to the rise in the capacity of the recorded ECG paper, a lot of man-power is involved in storing and retrieval of those biomedical maps. This paper presents a software approach for digitization of ECG paper through MATLAB, which converts analog ECG paper into digital time signal series, without needing any committed hardware. Digitization of ECG paper provides ease in storing records of patients and can be helpful in storing bulk of ECG waveform without any loss of detail for a long time. Also, making the retrieval of information more swift and easy.

IndexTerms – **Analog to digital, Digitization, ECG, Non-Local Mean Filter, Segmentation, Vector Conversion.**

I. INTRODUCTION

ECG (Electrocardiogram) is a major tool to detect any disease or any kind of abnormality present in the heart of a patient. It is basically a graph of voltage versus time, formed by the electrical activity of the heart, detected through the electrodes which are carefully placed on the skin of a patient. It is obtained in a waveform printed on a thermal paper strip, showing several dips and spikes which represent the electrical activity of heart [1]. By accessing through these ECG strips, doctors diagnose the cardiovascular disease. Due to the extensive use of ECG in medical field, there is a need of storing and maintaining these waveforms. Image processing is highly useful in implementing a tool that provides a way to convert ECG graph in digital time signal series. Digital records can be stored and maintained for a long period of time. Digitalization provides flexibility for saving clinical information without requiring any dedicated equipment.

A single 12-lead electrocardiogram is a graphical record of electrocardiography, which is the trace of electrical activity taking place within a heart. ECG basically consists of P, Q, R, S, T waves. There are also few major segments and intervals present between waves. These waves and segments represent heart rhythm which can be regular or irregular. Studying and observing these waves helps in understanding of heart activities and its functions. Figure 1 illustrates the basic ECG waveform and its various components.
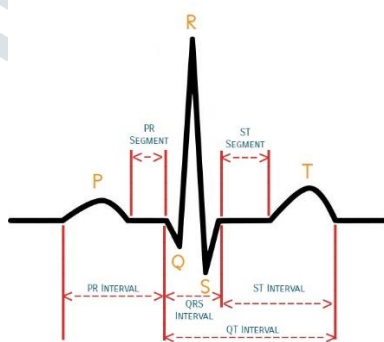

Figure 1: ECG Waveform

Chebil *et. al.* [2] carried out the binarization of ECG's scanned image by using selective threshold values. Although, the threshold values were chosen randomly and were not chosen according to the type of image. Therefore, it resulted into the loss of details and information in the obtained digital signal, which was extracted from the base image. Gomes *et. al.* [3] proposed removal of axis from the base image before carrying out median filtering on the obtained image. It was observed that by removing axes from the scanned image resulted in loss of important details from image, leading to distortion of extracted digital signal and many of its properties. Kao *et. al.* [4] chose the morphological method to eliminate the background grid from ECG. After obtaining the binary image of ECG, an XOR operation is implemented on the image's first periodic distance vertical direction, denoted as PDVD along with its shifted version. This process only works when a precise estimation of PDVD is done, which also depends on the correct binarization of the selected ECG image. Badilini *et.al.* [5] proposed three methods for the identification of background grid in ECG namely, precise mode, range mode and manual mode. The main aim of these three modes is to precisely detect and identify the

location of ECG grid lines. However, the presence of noise and uneven broken line served as a barrier in detecting grid line position. Mitra *et. al.* [6] presented an algorithm to remove position of grid lines by tuning a threshold distance between two significant points.

II. PROPOSED METHODOLOGY

In this paper a robust algorithm has been proposed to convert the ECG waveform to digital format by using MATLAB, without misplacing any of its major details and removing any unnecessary noise interference if been found. Figure 2 shows the algorithm of proposed methodology, which involves the following steps:
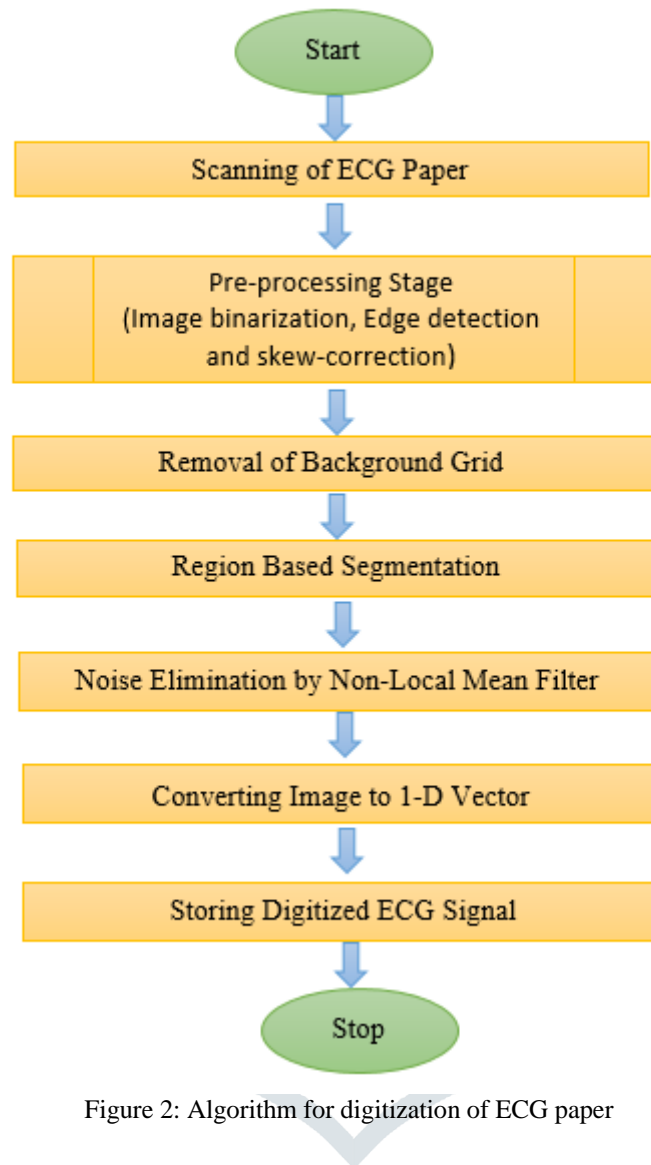

Figure 2: Algorithm for digitization of ECG paper

2.1 Scanning of ECG Paper

In the first step, scanning of ECG paper is done by using high speed A4 scanner. Resolution for scanning can be 600/300/200 dpi (dots per inch). The scanned image is saved in JPEG format. The ECG image can also be acquired using a digital camera.

2.2 Pre-processing Stage

Pre-processing stage, consists of three main image processing techniques namely image binarization, edge detection and skew correction. This step is important as well as base of the whole algorithm as it provides ease for the further processing of image. Image binarization is a task done for the extraction of important detail from an image [7]. It converts a grayscale image to binary image (black and white), thereby reducing the information and providing ease for extraction of an object from image. It is also known as image thresholding. Edge detection is a vital image processing technique that helps in tracing the outer boundary of an object within an image. For achieving image segmentation, edge detection is must. It works by identifying the redundancy in the brightness of the image. Commonly used edge detection algorithms includes Soble, Canny and Roberts's method. During scanning of ECG paper, there's a high chance for the image to be slightly tilted. The obtained image can be titled up to few angle, which is called skew angle. Therefore, to adjust the image in its right position skew correction is done to get a correct image. Here, de-skewing is done through Hough transform [8].

2.3 Removal of Background Grid

The purpose of this step is to eliminate the matrix grid lines from the background of the ECG image. Usually those lines are in lighter shade compared to the main ECG waveform, therefore one can simply eliminate those grid lines by selecting a particular

threshold value. In previous step, the ECG image has already been converted in binary image, which provide an ease for selecting the target pixel. Following this manner, a particular area is scanned to select a target pixel and a threshold value is adjusted based on its pixel intensity [9]. After eliminating the background grid lines, ECG waveform is obtained.

2.4 Region Based Segmentation

Beside the grid lines, ECG paper also consists of few characters and abbreviation. Thus to discard such elements the region based segmentation is performed, which divides the main ECG image in sub-images, and then each sub-image is processed separately. Following steps involved in region based segmentation:

Step 1: Trim the outer border of the input image.
Step 2: Scan the ECG image column wise.
Step 3: Repeat the same for each column.
a.   Extract the pixels that represents the signal (black pixels).
b.   In case, if there is presence of isolated pixels (which do not represent the signal), eliminate them.
c.   In case, if more than one black pixel is found:
-    Algorithm then checks for the former and later column, if they also contains black pixel.
-    If it is found that the former and later columns also contains black pixel, then in that case, the middle pixel is selected which is the current column.
Step 4: Store the index of the selected pixel. The procedure of choosing middle value in step 2 is explained in the following steps:
a.   Store the centres of alternate regions.
b.   Calculate the centroid of each region.
Step 5: Select next pixel which is placed at the shortest distance to the previous pixel index.

2.5 Noise Elimination by Non-local Mean Filter

The original ECG image can contain numerous noises such as muscle noise, electromyogram noise and power line interference. Thus, to discard such interference non-local mean filter is been applied. Non-local mean filter is based on an algorithm for carrying out the process of denoising of an image. This algorithm follows the concept of self-similarity. The algorithm first choses a target pixel in one particular grid, then searches for similar pixel around the area. The pixel are selected on the basis of the similarity with the target pixel. Pixel with the similar geometrical configuration and pixel intensity are selected, thereafter the mean average is calculated of those surrounding pixel. There is also a high probability of noise to be induced in ECG image during scanning process. Therefore, to eliminate unwanted noise and for retaining fine details of image, non-local mean filter is applied on the image. This step also ensures the enhancement of the image and its properties.

2.6 Converting Image to 1-D Vector

For obtaining a better resolution image, pixel to vector conversion is carried out. In low resolution image, few peaks are identified as successive vertical black lines whereas in vectors the number of columns where pixels are analyzed is doubled. A component of vector is represented by complex number. The components calculated in the same column have similar real part that is column index of pixel matrix [10]. Whereas the imaginary part of the same component implies the lower and upper limit of vertical black line.

For the conversion of 2D-vector in one dimension, the algorithm calculates the modal distance among the imaginary part of two successive components that is the amount of vertical black line pixels forming the signal at a certain column. If the resultant difference calculated between two imaginary components is found to be within a range limit of modal distance, then the imaginary portion of the second co-ordinate is saved in 1D form of the vector. This value is further taken as reference for the next analysis of column. In other case, if the resultant difference exceeds the range of modal distance, then the algorithm calculates mode of the difference between the reference value of and both of the two components. Whichever element gives the greater value, that value is stores as 1D-value.

Many times, the waveform obtained by plotter are somewhat incomplete or found to be distorted. In such case, to facilitate 1D vector at empty place, the components are calculated by means of linear interpolation.

2.7 Storing Digitized ECG Signal

In the last step, the resultant waveform obtained after the digitization of ECG waveform, is saved in .dat file format in MATLAB.

III. RESULTS AND DISCUSSION

The following figures shows the performance of proposed algorithm. Beginning from figure 3 which shows the original ECG image scanned by high speed A4 scanner with resolution of 600 dpi (dots per pixel). Followed by figure 4 which displays the result after pre-processing phase i.e. edge detection, image binarization and skew correction. Figure 5 is obtained after the clearance of faded background grid lines.
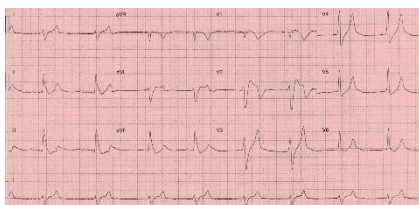

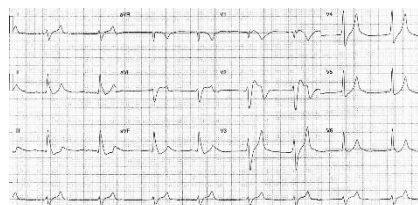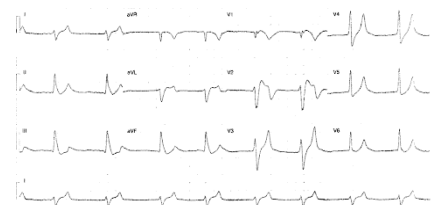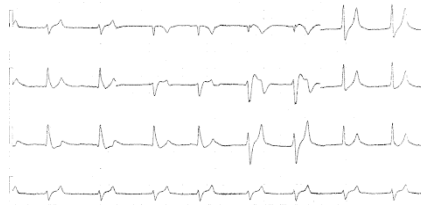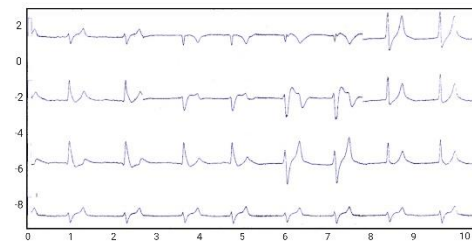Figure 3   Figure 4   Figure 5

Figure 6

Figure 7

Figure 6 shows the result after applying region based segmentation which was necessary for eliminating unwanted symbols and abbreviation from the image and applying non-local mean filter for retaining its important details. And at the end, figure 7 the resultant image which shows the digitized version of the original waveform obtained at the last step of the algorithm and is saved as .dat file format. From the following result, we can conclude that the proposed algorithm was able to retain the original ECG waveform without any loss of important details and properties.

IV. CONCLUSION

The proficient strategy for extraction and digitization of ECG signal from digital sources has been carried out in this paper. After analyzing the final obtained image, we can conclude that the proposed algorithm was able to extract the original waveform of ECG and provided a very favorable result, without misplacing any of its main feature. Also, the algorithm was able to enhance the original image by removing the characters and discarding the noise presence. The digitization of the ECG waveform ensures the less usage of storage, therefore making the retrieval and assessment of patient's records easier and swift. For the future aspect of this software approach of digitizing of ECG waveform, it tends to be widely used in medical field and can provide an efficient medium for storage of biomedical maps.

REFERENCES

[1] Qince, Li., Wang, K., He, R. and Zhang, H. 2019. A Novel Method for ECG Paper Records Digitization. Computing in Cardiology (CinC), 46: 1-4.

[2] Chebil, J., Al-Nabulsi, J. and Al-Maitah, M. 2008. A Novel Method for Digitizing Standard ECG Papers. Proceeding of International Conference on Computer and Communication Engineering, 1308-1312.

[3] Gomes e Silva, A.R., Magalhães de Oliveira, H. and Lins, D.R. 2007. Converting EEG, ECG and other Paper Legated Biomedical Maps into Digital Signals. Conference: XXV Simpósio Brasileiro de Telecomunicações, 5046: 21-27.

[4] Kao, T., Hwang, L.J., Lin, Y.H., Lin, T.H. and Hsiao, C.H. 2001. Computer Analysis of Electrocardiograms from ECG Paper Recording. Proceeding of 23rd annual International Conference of IEEE, 4: 3232-3234.Gomes e Silva, A.R., Magalhaes de Oliveira, H. and Lins, D.R. 2007. Converting EEG, ECG and other Paper Legated Biomedical Maps into Digital Signals. Conference: XXV Simposio Brasilerio de Telecomunicacoes, 5046: 21-27.

[5] Fabio, B., Tanju, E., Wojtek, Z. and Arthur, M. 2005. ECGScan: A Method for Conversion of Paper Electrographic Printous to Digital Electrocardiographic Files. Journal of Electrocardiology, 28(4): 310-318.

[6] Mitra, S., Mitra, M. and Chaudhari, B.B. 2004. Generation of Digital Time Database from Paper ECG Records and Fourier Transform Based Analysis for Disease Identification. Computers in biology and medicine, 34(7): 551-60.Fabio, B., Tanju, E., Wojtek, Z. and Arthur, M. 2005. ECGScan: A Method for Conversion of Paper Electrographic Printous to Digital Electrocardiographic Files, 28(4): 310-318.

[7] Swamy, P., Jayaram, S. and Chandra, M.G. 2010. An Improved Method for Digital Time Series Signal Generation from Scanned ECG Records. International Conference on Bioinformatics and Biomedical Technology of IEEE, 400-403.

[8] Shen, T.W. and Laio, T.F. 2009. Image Processing on ECG Chart for ECG Signal Recovery. Computers in Cardiology, 36: 725-728.

[9] Zhang, Z.M., Prineas, R.J., Case, D., Soliman, E.Z. and Rautaharju, P.M. 2007. Comparison of the Prognostic Significance of Electrocardiographic QRS/T Angles in Predicting Incident Coronary Heart Disease and Total Morality. Amer. J. Cardiol, 100(5): 844-849.

[10] Wang, J.T. and Mital, D.P. 1996. A Micrcomputer-Based Prototype for ECG Paper Record Conversion. J. Network Computer Application, 19(3): 295-308.