

Digitalization of ECG Records

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ABSTRACT

Electrocardiogram (ECG) is the most important and widely used method to study the heart related diseases. The detailed study of ECG graph by the medical practitioner helps them to understand and identify the condition of the heart. Measurements of parameters from electrocardiograms (ECGs) are largely performed from paper ECG records. In some cases, doctors seek help from senior doctors in the interpretation of ECG records. As the absence of the integrated system leads to many problems. The person having a medical history of heart ailments will have to maintain a record of all the ECG papers for timely analysis and diagnosis of the diseases. This process requires large storage space and extensive manual effort. The conventional technique of visual analysis to inspect the ECG signals by doctors or physicians are not effective and time consuming. We present a tool to convert electrocardiography (ECG) information from paper charts into digital ECG signals. Thus in this digitized world, it is required to have a tool that converts existing paper ECG records into digital format.

Keywords: ECG, Digitalization, Image Processing

Date of Submission: 07-06-2020

Date of Acceptance: 23-06-2020

I. INTRODUCTION

ECG is an easy non-invasive method of recording the electrical activity of the heart by placing an electrode to the skin of the chest. ECG is essential for the diagnosis, and therefore the management, of abnormal cardiac rhythms [1]. It helps with the diagnosis of the cause of chest pain, dizziness, syncope and breathlessness. The contraction of any muscle is associated with electrical changes called 'depolarization' and these changes can be detected by electrodes attached to the surface of the body. ECG machines record changes in electrical activity by drawing a trace on a moving paper strip. ECG machines run at a standard rate of 25 mm/s and use paper with standard-sized squares. Each large square (5 mm) represents 0.2 second (s), i.e. 200 milliseconds (ms) [2].

Normally, ECG has to be printed on a thermal paper for further physical inspection by medical practitioner [3]. This leads to large volume of ECG reports that results in a tedious and error prone process of examining and retrieval of the same [4]. A cardiac patient with history of heart ailments will always have to carry and maintain a bulk of such ECG reports while visiting a physician for consultation. Further these bulk ECG records are

very hard to be shared among doctors. Even in hospitals due to lack of space and difficulty in maintaining records a huge amount of data is discarded time to time. Doctor in some cases seeks help from senior doctors for the interpretation of ECG records. Thus, the doctors use media like the mobile-phone camera to capture the picture of the graph and then send through social media like WhatsApp for sharing of the records from the remote place to the senior doctors, due to which there is a decrease in accuracy, decrease in quality and lack of security.

At the same time, the new needs justify the requirement to have a tool which converts existing paper ECG records into digital format. The paper-based ECG information doesn't support the sharing ability in a seamless manner from one place to another place which makes it limited access to the information. There is no proper means for the exchange of information and storing it securely.

Our goal is to design and evaluate a system that transforms a paper ECG into digital. Efficient noise removal and image enhancing algorithms are also required so as to increase overall digitization process accuracy. Digitizing the ECG paper signal will help to solve storage problem. It is also cost

effective when comes to sharing and diagnosis. Our approach is to present a tool for the conversion of electrocardiogram (ECG) information from paper charts into digital ECG signals. We propose a GUI application tool where the users get access to locate the image of ECG paper records and select them, then from this selected image the user can crop the desired region and readings present in the ECG records is been extracted. Based on the parameters further analysis is done regarding the information present in the image. And this file can be easily stored in the system.

II. METHODOLOGY

We propose a GUI application tool where the users get access to locate the image of ECG paper records and select them, then from this selected image the user can crop the desired region, and required ECG records is been extracted.

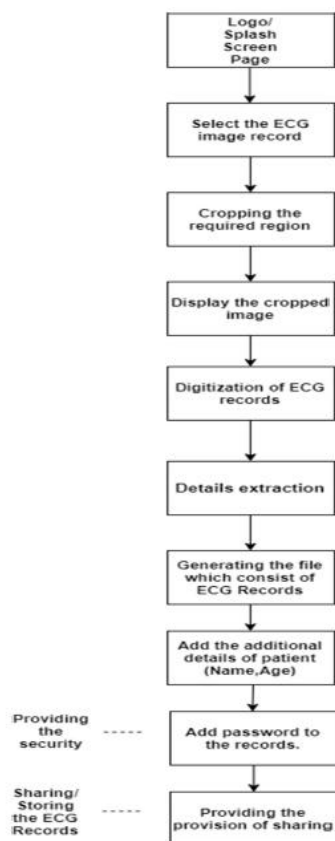


Fig.2.1 Flowchart

We can see the flow diagram of the GUI application tool for the conversion of paper-based ECG Records to digital records. In which the 1st is starting of the GUI application where we can see the logo or introduction page on the screen. Then in the GUI application, the user can select the ECG image records from the system. Then from the selected

image, the user can crop the desired area of interest from the displayed image. Followed by which the digitization process will take place and now this file can be shared further or can be stored in the system.

The proposed method steps are shown below and have been carried out for feature extraction of ECG signals.

- Selecting the ECG image records, convert it into grayscale levels, and select the desired signal.
- Separation of the desired ECG signal from the background.

2.1 Selecting and Converting

The ECG image records are stored as a colour image in many types of image file format files such as (jpg, JPEG, ... and png) [5]. The first step is selecting the required ECG image file from the system as shown in figure 2.2.

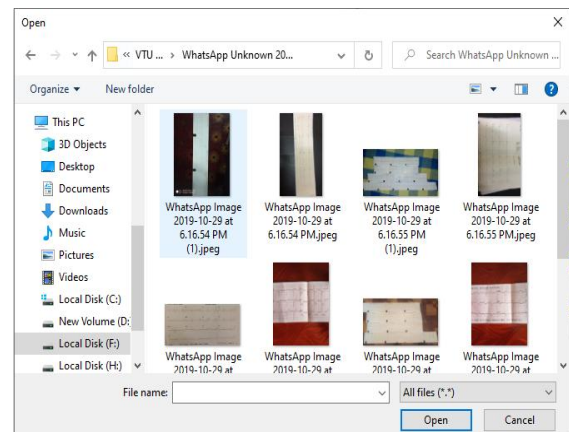


Fig. 2.2: Selecting the ECG image records

Then followed by cropping the desired area of interest from the image which is done by using the mouse to select and crop one of the ECG signals as shown in figure 2.3 for cropping, followed to this we get the cropped image as shown in figure 2.4, and then converting the cropped colour image into the grayscale level by using OpenCV command in the Python as shown in the figure 2.5.

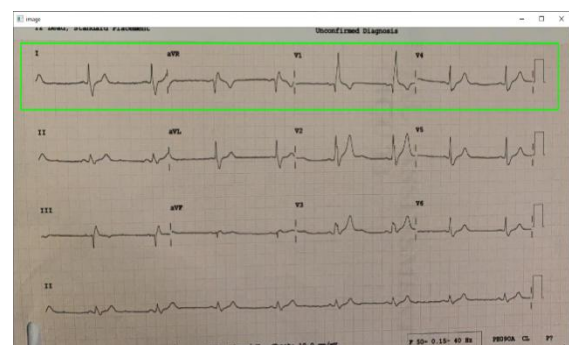


Fig. 2.3: Cropping the desired area of interest

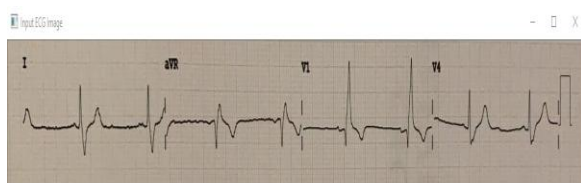


Fig. 2.4: Colour Cropped image



Fig. 2.5: Grayscale levels

2.2 Signal Extraction

This step is to isolate the target signals from its background within the cropped image and so digitizing the signals. In the image processing, the Otsu's methodology is used to automatically perform histogram shape-based image thresholding. According to the algorithm, it is assumed that the image to be threshold contains two classes of pixels which are foreground and background then it computes the optimum threshold which separates the two classes so that their intra-class variance is minimum.

Here the method used is simple, where if the pixel value is greater than a threshold value then it is assigned on a set of value e.g. such as white, else it is assigned another set of values e.g. May be black. The function used can be `cv2.threshold`. The syntax for the `cv2.threshold` is:

Syntax: `cv2.threshold` (source, threshold Value, maxVal, Thresholding Technique)

Parameters are:

- source: Input image which must be in the grayscale level.
- Threshold Value: value of threshold (t) for which below and above pixels values will change accordingly.
- maximum value(maxValue): It is the maximum value that can be assigned to a pixel.
- Thresholding Technique: The type of thresholding technique which can be applied, here we make use of the Otsu Thresholding.

The first argument is the source image path, which should be the grayscale level image. And the second argument is the threshold value which is used to classify the pixel values eg. foreground and background. A value that is given if the pixels value is more than the threshold value is the 3rd argument and it is the maximum value. Finally, the fourth parameter is the technique which is been used, we make use of the Otsu thresholding technique.

2.2.1 Otsu's Thresholding Technique

In computer vision and image processing, In the Otsu thresholding technique, the value of the threshold is not chosen but it is been determined automatically [6]. A bimodal image, in simple words, is an image whose histogram has two peaks. For that image the Otsu's technique, it automatically calculates a threshold value from the image histogram form a bimodal image. Otsu's method is used to automatically perform histogram shape-based image thresholding, or, the reduction of a grey level image to a binary image. The algorithm assumes that the image to be threshold contains two classes of pixels or a 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 [7].

The `graythresh` function uses Otsu's method, which chooses the threshold to minimize the intra-class 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 [8-9].

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 [10]:

$$\sigma_w^2(t) = \omega_1(t)\sigma_1^2(t) + \omega_2(t)\sigma_2^2(t) \quad (1)$$

Weights ω_i are the probabilities of the two classes separated by a threshold t and variances of these classes.

Otsu shows that minimizing the intra-class variance is the same as maximizing inter-class variance.

$$\sigma_b^2(t) = \sigma^2 - \sigma_w^2(t) = w_1(t)w_2(t)[\mu_1(t) - \mu_2(t)]^2 \quad (2)$$

Which is expressed in terms of class probabilities ω_i and class mean μ_1 . The class $W_1(t)$ probability is computed from the histogram as t :

$$\omega_1(t) = \sum_0^l p(i) \quad (3)$$

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

$$\mu_1(t) = \left| \sum_0^l p(i) * x(i) \right| / w_1(t)$$

Where $x(i)$ is the value at the center of the histogram i th. Similarly, you can compute $w_2(t)$ and μ_2 on the right-hand side of the histogram for bins greater than t .

$$\mu_1(t) = \left| \sum_0^l p(i) * x(i) \right| / w_1 \quad (5)$$

$$\omega_{1(t)} = \sum_0^l p(i) \quad (6)$$

The class probabilities and class means can be computed iteratively. This idea yields an effective algorithm [11].

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 $t=1 \dots$ maximum intensity.
 - a) Update w_i and μ_i .
 - b) Compute equation 2.
4. Desired threshold corresponds to the maximum.

In figure 2.6 you can see the Otsu thresholding been performed for the above grayscale levels image of figure 2.5.



Fig.2.6 Otsu threshold image

2.3 Hardware Module

The signals from the body are taken by the electrodes (Ag-AgCl electrodes), the signals are very weak hence it is given to the amplifier. The front-end for the signal acquisition system is an instrumentation amplifier. It has a very high common-mode rejection ratio (CMRR) and high input impedance which is required for capturing ECG signals. Along with the signal noise also gets amplified, this noise is removed by the bandpass filter. Since the acquired signals are weak it is given to the buffer amplifier. The signals are digitized using Analog to Digital Converter(ADC).

To measure the human body activity of heart we need to measure the ECG of the human body and monitor the heart activity which gets useful feedback like the possibility of heart attack or serious arrhythmia.

To build the ECG monitoring device we may use the controller module which can be Raspberry Pi. To detect the ECG signals the fundamental component is an Instrumental amplifier, which is responsible for the measure of the voltage difference between the electrodes by amplifying the signals.

We make use of the Analog Device chip that covers all the necessary aspects, called AD8232, it is a Single-Lead ECG Frontend.

2.4 Block Diagram

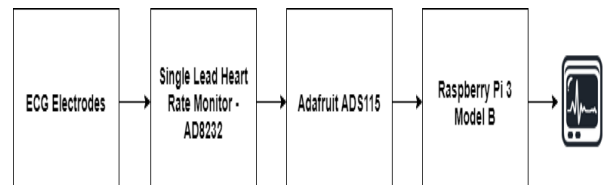


Fig. 2.7: Block Diagram of the ECG monitoring system

The above figure shows the block diagram of the ECG monitoring system where we make use of ECG Electrodes, AD8232, and ADS115 Analog to Digital converter and Raspberry Pi 3 Model B and the display unit.

Signal Input

The Electrocardiogram is a valuable aid in the diagnosis of a wide range of cardiac conditions. The electrocardiogram (ECG) is the recording of the potentials at the selected location of the body surface and is related to the electrical activity of the heart. The heart performs its function of pumping blood through the circulatory system which in turn is related to this ECG. The electrode is used for sensing bioelectric potential caused by muscle cells as a result of mechanical events inside the heart muscle are a certain sequence of electrical activity or ECG signal.

The ECG electrodes are to be attached to the skin, which can detect the small electrical currents to provide information about the heart. The ECG electrodes are typically wet sensors which are required the use of a conductive gel to increase conductivity between skin and electrodes. We can place these electrodes in several parts of the body, here we can make use of the following 3-lead electrodes system on the body.

These ECG electrodes are then attached to the AD8232 single-lead ECG front end which is an Instrumental amplifier that is responsible for the measure of the voltage difference between the electrodes by amplifying the signals.

As the Raspberry Pi doesn't have an Analog to Digital converter of its own so we make use of the external Analog to Digital converter, which can be ADS1115, it is a 16 Bit 4 Channel Analog to Digital converter that provides more accuracy and this counts with a programmable gain. As the output from the AD8232 is not directly given to the Raspberry Pi it given through the ADS1115 Analog to Digital converter only.

Then the Raspberry can be used as the controller unit for controlling the overall operation and then displaying the recorded ECG signals which are been acquired by the electrodes.

III. CONCLUSION AND FUTURE WORK

In this paper we have discussed the efficient method of conversion of paper-based ECG graph into a digitalized format, which can then be stored securely and shared between the users. The GUI tool is simple in use and hence it gives added advantages. By which many users can make use of the tool in a wide manner as its low cost and ease of access. We have made use of image processing with the help of python language. Open CV has also played an important role in our project. In the hardware module, we are making a simple-low-cost ECG monitoring system with the help of AD8232, ADS115, and Raspberry Pi. AD8232 is a tiny chip to sense the electrical activity of the heart. ADS115 is used as an analog to digital convertor. The overall operation is controlled by the Raspberry Pi. Future work is to enhance the overall efficiency of the method and generating automatic diagnosis reports as well. This tool can be made more user-accessible by developing the App based software with the same functionality.

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