

Digitization of ECG through Anisotropic Diffusion Technique

R. R. Karhe, S. N. Kale

Abstract—An Electrocardiogram (ECG) is widely used diagnostics tools for heart diseases now a days. Transformation of ECG papers into digital form is very important for both clinical and research purposes. Mainly the ECG is recorded on a paper which cannot be stored for a longer duration because thermal trace overtime becomes erased gradually. The main aim of this paper is to take out the ECG signal from the paper and transforming it to a digital time series signal. Few of the image processing techniques are developed for an ECG signal regeneration as a digital time series signal.

Keywords—Digitization, ECG, Image processing.

I. INTRODUCTION

AN Electrocardiogram (ECG) is a bioelectric signal that represents the performance and the properties of human heart. The Pattern of ECG signal composed with QRS complex, P waves, and T waves. The P waves, which represents the ventricles depolarizing, and T wave which occurs with the repolarization of ventricles.[1][2][3]

In this study a method is proposed for converting a ECG paper into digital form. It will utilize the main algorithm to take out the digitized signal from ECG paper strip. Hough transform is utilized for de-skewing the scanned/captured images with the anisotropic diffusion techniques. This algorithm introduces an iterative process for the desired work. In this research work, our main aim is to implement a MATLAB based tool for digitization of paper ECG data.



Fig. 1 Original Image

It will make use of various image processing techniques involves scanning of the paper ECG to an image, thresholding for graphic grid removal and detecting the ECG signal outline followed by digitization.[14][15][16]

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II. OBJECTIVE

A.

To design a new algorithm which reduces the unwanted high frequency components and enhances the required low frequency components so that the grid lines can be blurred while the ECG trace remains unaffected or less affected.

B.

To solve the problem in de-skewing an automatic de-skew deformation correction algorithm is designed, it depends on the size of an image & amount of rotation.

III. PROBLEM DEFINITION AND PROPOSED WORK

Processing for blurring of grid lines with minimum effect on signal trace is main task. Need is to identify the high and low frequency components of grid lines and ECG trace, need is to separate the component of both and reduce or blur the grid components only so that the image we got will be easily processed for retrieval of trace only. The manual image capturing of an image has a major problem in the field of image processing. Even with expert photographer the image captured may have various errors. Most common error during manual capturing an image is orientation of image. Orientation detection and correction and de-skew algorithm are already proposed by many authors but while correcting the image is distorted and it may affect on the digitization of an image. Similarly there is a problem of ECG paper skewing.[4]

Novel digitization algorithm is proposed for getting digitized ECG signal from papered ECG image. Anisotropic filtering is used for solving a problem of reduction of high frequency components in image. It enhances low frequency components with blurring the grid lines of papered ECG image. As the grid lines are blurred, no need to detect & remove it. Thresholding is suitable for identifying the raised pixels of ECG trace.

The algorithm is specifically designed for working on skewed images (rotated images). Most of the system already implemented used de-skewing method but after de-skewing, manual cropping was done for the use of digitization purpose. Automatic cropping is performed by developing automatic De-skew deformation correction algorithm. (ADDC Algorithm).

IV. METHODOLOGY

The process for extraction of the thermal ECG trace from the image to convert it to a time series signal and its morphological feature extraction is shown in fig 2.

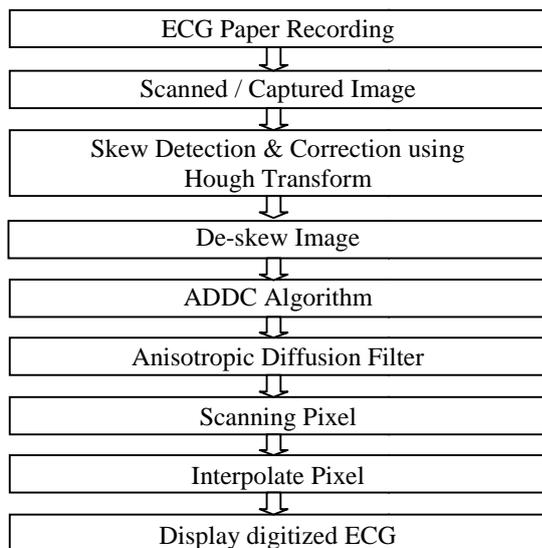


Fig. 2 Process of Digitization

A. Scanning:

As an effort of human error, The scanning of ECG paper record results in skew. This could be overcome by skew detection and correction. Hough transform is implemented for de-skewing image. Various researches have been used for de-skewing algorithm.[6]

B. De-Skewing:

Skewing rotates the image to an angle resulting in a rotated image. Hough transform implemented to de-skew image. Skew angle can be determined using the background gridlines of scanned ECG image. Various researchers have been used de-skewing algorithm but requires manual interference. ADDC algorithm is also designed for de-skewing purpose but it removes the manual interferences. It uses automatic rotation correction with removal of deformation produced due to the rotation effect.[7][8]

C. Hough's Transform Algorithm:

1. Parameter space (a,b) is quantized such that it is divided into two cells
2. This quantized space is usually called as the accumulator cells.
3. Count the number of times a line intersects a given cell.[8]
4. For each point (x,y) which has value 1 in the binary image we need to calculate the value of (a,b) in the range [(a min, a max)], [(b min, b max)] referring the line representing this point
5. Enhance the value of the accumulator for these (a', b') point.
6. Then move to the next point in the image.
7. Cell obtaining a minimum number of "Votes" are assumed to corresponding to lines in (x,y) space.

8. Line can be found as peak in this accumulator space.

D. ADDC Algorithm

De-skew algorithm used is based on a Hough transform which finds the straight line in image and according to the orientation of maximum straight lines it estimates the orientation of an image.[7] According to the estimated orientation, image can be rotated but it provides deformation of image in terms of size and distortion along the corners of images. Exact cropping of the required region of interest from the image basically requires manual assistance. For the purpose of ECG retrieval, ADDC algorithm is designed. It requires passing the various parameters like rotational angle, size of image according to which a deformation is calculated & dimensions of original non-deformed estimated. The deformed portion is then cropped out to get horizontally oriented non-deformed image having no black & white strips / distortion.[9]

Estimation of vertical dimension is given as

$$y1 = \left(\frac{r}{2}\right) \times \left(\frac{z(1)}{f}\right) \quad (1)$$

$$y2 = z(1) - y(1) \quad (2)$$

Where $z(1)$ and $z(2)$ are the x and y dimensions of input image respectively, r is a factor based on the size of

$$\text{Input image} = \frac{z(2)}{z(1)}$$

f is a linear parameter based on rotation of image in the range of 0-12 for 2n-0 angle of rotation because the fact that distortion as angle of rotation increases deformation also increases.

Estimation of horizontal dimensions is given as,

$$x1 = \frac{z(2)}{r \times f} \quad (3)$$

$$x2 = [(r \times f) - 1] \times \frac{z(2)}{r \times f} \quad (4)$$

The cropping dimensional is estimated as,

$$\text{rec} = [x1; y1; (x2 - x1); (y2 - y1)] \quad (5)$$

Where, rec is the matrix used for cropping rectangular region of interest in MATLAB.

E. Anisotropic Diffusion

Diffusion algorithm eliminates noise from an image. It modifies the image via a partial differential equation (PDE). Consider applying the isotropic diffusion equation given by $I(x,y,t)/dt = \text{div}(\nabla I)$ using the original (degraded / noisy) image.

$I(x, y, 0)$ as the initial condition, where $I(x,y,0) : \mathbb{R}^2 \Rightarrow \mathbb{R}^+$ is an image in the continuous domain (x,y) specifies spatial position, t is an artificial time parameter and where I is the image gradient.

Modifying the image with this isotropic diffusion equation is equivalent to using Gaussian filter on the image.

Perona & Malik replaced the classical isotropic diffusion equation with.

$$\frac{\partial I(x, y, t)}{\partial t} = \text{div} [g(\|\nabla I\|)\nabla I]$$

Where $\|\nabla\|$ is the gradient magnitude & $g(\|\nabla I\|)$ is an edge stopping function. This function is selected to satisfy $g(x) \rightarrow 0$ when $x \rightarrow \infty$ so that the diffusion is stopped across edges.[22]

Anisotropic word originated from the words: "an" for not, "iso" for same, and "tropic" from tropism, relating to direction; Direction based filtering is possible using anisotropic filtering. It is a technique to improve the image quality of textures at slant viewing angles. This is done with respect to the camera where the projection of the texture appears to be non-orthogonal.

Anisotropic filtering can be applied for different degrees or ratios during rendering. Current rendering techniques set an upper limit on this ratio. This degree gives the maximum ratio of anisotropy, which is supported by filtering. For example, 4:1 anisotropic filtering will continue to sharpen more slant textures beyond the range, as sharpened by 2:1 anisotropic filtering.[11]

This means that, in highly slant-texturing situations, a 4:1 filter will be double as sharp as a 2:1 filter. In some cases, only the more oblique and usually more distant pixels will require the sharper filtering.

When the degree of anisotropic filtering continues to be twice, the returned visible quality decreases with less and less rendered pixels affected, and the results become less oblique to the viewer. In this case, anisotropic filtering is also used.[12]

As we have to blur the vertical and horizontal texture in ECG paper and need to preserve and enhance the remaining angled component, anisotropic filtering is suitable for extraction of ECG trace.

It includes the processes like edge detection, edge refining using 2d diffusion convolution for enhancement of low frequency components and Solving Partial Differential Equation (for anisotropic filtering).[13]

F. Scanning, Interpolation And Displaying Process:

Scanning of raised pixels is required to find out its locations over the image. Once the locations of raised pixels are found out, then connectivity of the locations has to be found out.[17][18] For this, all the locations of all raised pixels are organized in ascending order and then the missing and extra pixels should be identified. Extra pixels locations

are removed by finding the connectivity between the adjacent locations and missing pixels are need to be added by 1st interpolation. 2nd interpolation is used to enhance the resolution of graph to be displayed. Display of graph is possible in different scales as linear-linear scale, semi-log scale, log-log scale.[19][20]

V. RESULTS AND DISCUSSION

The proposed method is to convert the ECG signals as an image into digital time series. Figure 3 shows the image of the 12 Lead ECG paper as rotated is input to the designed algorithm. Then converting the cropped color image into grayscale image of original image using `rgb2gray()` command [9]. As shown in figure 4.

The image is cropped at middle position, edges are found using Canny edge detection algorithm, and edges as shown in figure 5.

Hough's transform is used to find the rotation of maximum lines extracted in the above image. Rotation of maximum lines is called the orientation of image. According to the orientation estimated, the original image is rotated to make the orientation horizontally as shown in fig. 6. ADDC algorithm is used to crop the above image according to the size and rotation of image. The cropped image is shown in fig. 7. Anisotropic diffusion filtering is applied using convolution process to get blurred horizontal and vertical lines. (i.e. horizontal & vertical components of the image) by retaining the other component unaffected. Filtered image is shown in fig. 8. The standard process of image scanning, interpolation and displaying is used to display the raised pixels of above image. The final image shows the graph of extracted ECG on linear scale.

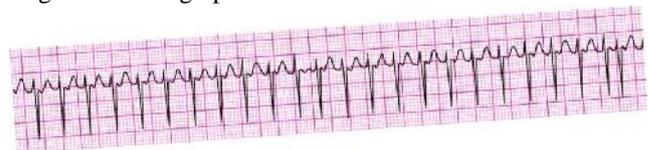


Fig. 3 Initial ECG Image

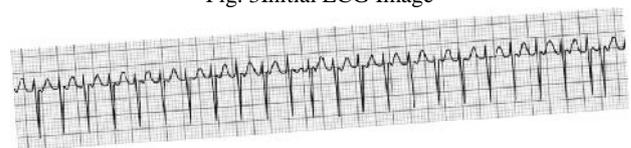


Fig. 4 Initial ECG Image in Gray Scale



Fig. 5 Output of Canny Edge Detection

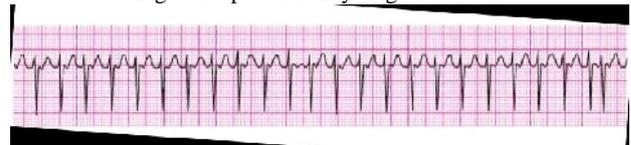


Fig. 6 Output of Hough Transformation



Fig. 7 Output after Image Cropping



Fig. 8 Output after Anisotropic Diffusion Filtering

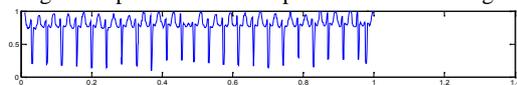


Fig. 9 Final Digitized ECG

VI. CONCLUSION

In this paper, we presented technique for de-skewing and removal of deformation portion from image. The algorithm for it have been implemented in MATLAB and are tested on a sample of scanned ECG images. The performance of each of de-skewing and Blur of grid lines extraction algorithm were evaluated by visual inspection of the results. The technique for enhancing low frequency using anisotropic diffusion approach reduced complexity significantly.

Hence, the availability of an automatic procedure is now a day a necessary requirement.

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