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ARRHYTHMIA DETECTION BASED ON COMBINATION OF FREEMAN CHAIN CODE AND FIRST ORDER TEXTURE FEATURES

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ABSTRACT

This paper presents a novel method of detection and classification an Arrhythmia based on ECG chart using image processing techniques and neural network as classifier tool .The method consist of three major stage firstly preprocessing to prepare the ECG chart image, secondly features extraction stage represent by freeman chain code and first order features which are arranged in vector consist of 14 input each one hold one feature value, finally stage this vector of features entered to BPNN classifier to classify an Arrhythmia type. The system applied on dataset consists of 90 ECG chart images. Two different ratios of training/testing groups which are (30% to 70%,50% to 50%) are applied to the classifiers. The higher system's accuracy in first ratios was100% for training group and 90.5% for testing group while higher system's accuracy in second ratio was 100% for training group and 97.8% for testing group with time 31.6 second. The system achieved using Matlab.

Keywords: *ECG chart, Arrhythmia, Freeman chain code, First order features, Artificial neural network.*

1. INTRODUCTION

Nowadays one of the most important reasons which cause death are heart diseases and heart failure. In 2006 Heart Disease took 631636 lives in US which are 26 percent of whole death in US in this year. The number one cause of death worldwide according to the World Health Organization, are heart disease or cardiovascular diseases (CVD).With rate 82% of these deaths, happen in low- and middle-income countries[1].

One of the most considered and clinically used dynamic signs is Electrocardiogram ECG. ECG can be defined as the electrical action of the heart note down by resources of electrodes on the body outward. By electrical phenomena in dissimilar parts of the heart we can originate the classic waves (P-Q-R-S-T complexes, as its clear in figure(1) of a normal ECG are created which synchronized by the electrical action in the sinus node cells inside the right atrium[2].

An ECG wave as it is shown in figure1symboled by capital letter P, Q, R, S, T waves. The Atrial Contraction represented by the P wave, the ventricular relaxation represented by the T wave. The ventricular contraction contained in the QRS complex wave. The QRS complex, ST segment, PR interval, RR interval, PR segment, QT interval is the most significant sections in an ECG signal used in the diagnosis of many cardiac diseases. [3].

A major kind of abnormal heart action is Cardiac arrhythmia. An arrhythmia can be defined as a problem with the heartbeat rate or rhythm of the heartbeat. For the period of an arrhythmia, the heart may beat too fast or too slow, or with an irregular rhythm. Tachycardia state is said to be Fast heartbeat while slow heartbeat is named Bradycardia. Most arrhythmias are not dangerous, but some can be and some can be even fatal [4].

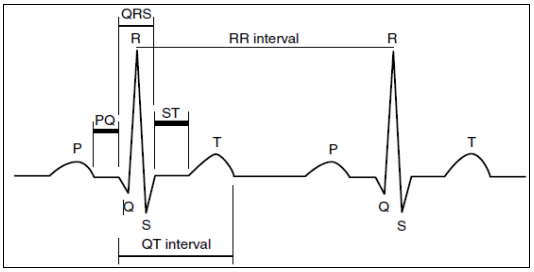

Figure1: Normal ECG of a healthy human heart.

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The purpose of this paper is prepare automatic recognition and classification system to some type of heart daises based on ECG chart which is give curve detect the electrical action of the heart. The benefit of this system summarize in following items:

1) Simulate the ability of the physician in diagnoses the state of heart.
2) Reducing the burden on the physician by reducing the time spent in the diagnosis.
3) The ability to save digital information about the pathology detected in an electronic file that can be returned when needed at a later time.

2. RELATED WORK

There are many previous researches worked in the direction of ECG, Some of these research highlights how to transform the image of electrocardiogram into a digital format for the purpose of storing and archiving it using image processing methods and patterns recognition as in researches [5,6], while others work toward diagnosis of heart disease using digital signal processing techniques as in researches [7,8]. In[5], Prashanth et. al. proposed method for mining and digitization of ECG signal from two sources thermal ECG printouts, scanned ECG and captured ECG images. The Radon transform is used for de-skewing while morphological techniques are applied to extract the time series from ECG image. In [6] Deepak et. al. proposed method to generate time series digitized signal from ECG chart image using set of techniques that are deal with digital image processing. The method also involves compute of Heart rate, QRS Width and Stability (variation in R-R peaks) from the resulted signal .In [7] Mohammad et.al. develop a procedure to excerpt information from Electrocardiogram (ECG) data & conclude kinds of Arrhythmias. The decisions were done by determining diverse intervals such as PR Interval, RR Interval, Heart Rate (HR) etc. and those intervals were matched with the model intervals. . In[8] N. N. S. V. Rama Raju Butterworth Filter is used to remove noise from the signal as preprocessing step. The number of parameters are extract using wavelet transform these parameter distinguish different arrhythmic daises. The Classification step is perform by Neural Network classifier.

In this paper we propose recognition method for detect and classify arrhythmias based on ECG chart which enter to our system as image. Number of image processing techniques and statistical measures are applied to extract the vital features to be enough to judge if the ECG are normal or have cardiac daises (Bradycardia, Tachycardia).

The remainder of the paper is organized as follows: section 3, describes freeman chain code algorithm, Section 4 briefly definition to first order texture features computation; in section 5 steps of our proposed recognition and classification method. Experimental results and discussions are presented in Section 6; Section 7 concludes the paper.

3. CHAIN CODE

The techniques which is used to denote frequent number data of the stroke An 8-direction called Freeman Chain Code (FCC). The Freeman code brings connectivity and formal information about the objects in image [9].

The code of the boundary of character image can be founded using chain code representation, this codes is demonstrating the direction of where is the location of the next pixel and match to the neighborhood in the image. For binary image there are two types of boundary depiction algorithm that are frequently applied: chain code based and run-length based algorithms. The run- length algorithm usually used in image compression, this algorithm works by register the successive 'runs' of similar objects and background pixels. While chain code based algorithm of a character image begin through a binary image as input. The representation of binary image is done with only two possible gray values for each pixel, such as "0" and "1"[10].

Commonly, binary images present in two types of groups are the foreground is represented by 1 and the background is represented by 0. The descriptions of object boundaries in image processing field achieved using 8- direction FCC because of simplicity and data representation in compact form and its fitness for fast processing. Figure2 display 8-neighbourhood and the directions which processed by FCC which is used in this paper as feature extraction tool from ECG curve [11].

An adjoining boundary pixel must be found at one of the eight locations surrounding the current boundary pixel. Also at least one that is a boundary pixel will be found when looking at each of the eight adjoining pixels. Based on which one it is, a numeric code of between 0 and 7 as already shown in Figure 2 will be assigned.

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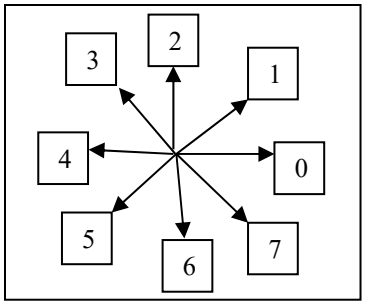

Figre2: 8-connected neighbors

For example, a code "0" is assigned if the pixel found is located at the right of the current location or pixel. a code "1" is assigned If the pixel found is directly to the upper right. Until we return to the first location or boundary pixel the process of assigning a code for location of the next boundary pixel is repeated. A list of chain codes is the result of this process in this list the direction that taken in moving from each boundary pixel to the next is showing. The process of assigning a code of the located boundary pixel that is found is shown in figure3 [12].

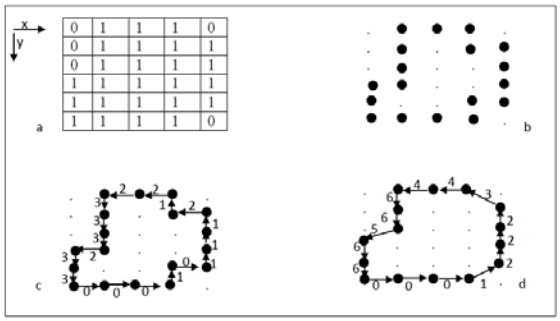

Figure3 (a,b) 4-connected objects ,(c,d) chain code to these objects with c to 4-connected boundary with d for 8-connected boundary

4. FIRST-ORDER HISTOGRAM BASED FEATURES

One of a means of extracting information from imagery is texture analysis which is consider mathematical procedures used to determine the spatial variation within image. Texture can be defined as an a real construct that describes local spatial organization of spatially varying spectral values that is repeated in a region of larger spatial scale. Thus, the perception of texture is a function of spatial and radiometric scales [13].

Some measures such as first-order texture measures can be calculated from the original image values. These measures do not take in consideration the relationships with neighborhood pixel. Texture analysis using histogram-based approach is established on the intensity value concentrations on all or part of an image represented as a histogram. From this approach many features derived include moments such as mean, standard deviation, average energy, entropy, skewness and kurtosis [14]. The gray-level histogram calculates by a simple summary of the statistical information of the image and individual pixels. Therefore, the histogram comprises the first-order statistical information about the image (or sub image). These statistics are defined by the following equations [15].

$$mean(\mu_i) = \frac{\sum_{x=1}^{M}\sum_{y=1}^{N} I_i(x,y)}{M \times N} \cdots (1)$$

$$s\tan dard\ \ deviation \quad (\sigma_i) = \sqrt{\frac{\sum_{x=1}^{M}\sum_{y=1}^{N} (I_i(x,y) - \mu_i)^2}{M \times N}} \cdots (2)$$

$$Energy \quad (e_i) = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N} I_i^2(x,y) \cdots (3)$$

$$Entropy_i = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N} I_i(x,y)(-\ln I_i(x,y)) \cdots (4)$$

$$Skewness = \frac{\sum_{x=1}^{M}\sum_{y=1}^{N} (I_i(x,y) - \mu)^3}{M \times N \times \sigma^2} \cdots (5)$$

$$Kurtosis(k) = \frac{\sum_{x=1}^{M}\sum_{y=1}^{N} (I_i(x,y) - \mu)^4}{M \times N \times \sigma^4} - 3 \cdots (6)$$

The most frequently used central moments are variance , Skewness and Kurtosis given by M2, M3 and M4 respectively. The variance defined as a measure of the histogram width that measures the deviation of gray levels from the mean. Skewness is a measure of the degree of histogram asymmetry around the Mean and Kurtosis is a measure of the histogram sharpness [16].

5. PROPOSED METHOD OF ARRHYTHMIA DETECTION

The purpose of this paper is build a recognition and classification method of an Arrhythmia from ECG chart which entered to our system as digital image acquired by scanner. ECG chart throw in many steps start with preprocessing of ECG image which consist from branch steps in order to illumination enhancement and noise removing the output of this stage is binary image contain the curve of ECG and black background, secondly stage implies feature extraction using first order feature and freeman chain code feature which result

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in vector contain 14 feature ,third stage perform classification to this vector and determine if the ECG normal or tachycardia or bradcardia. Figure(4) shows our proposed method.

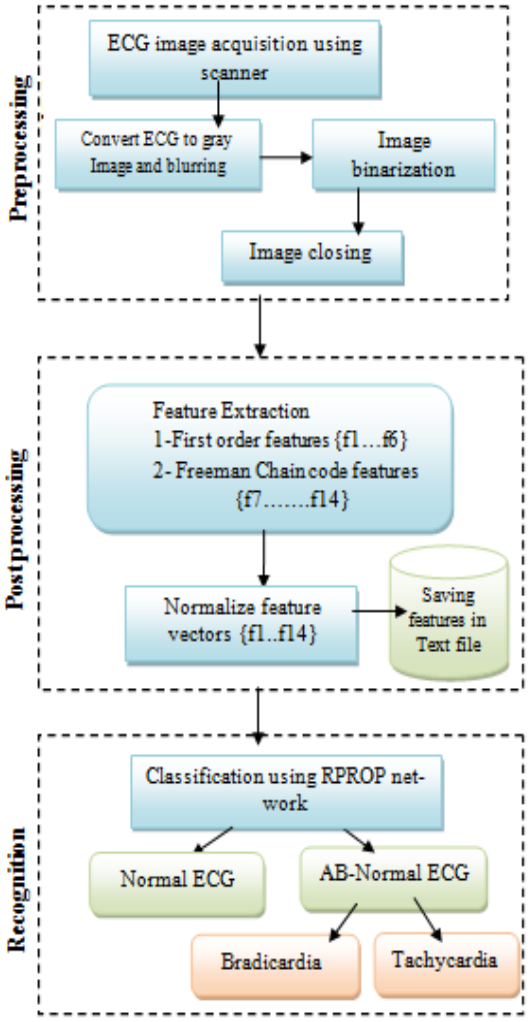

Figure4. diagram of ECG daises detection method

5.1 Preprocessing stage

First stage in our proposed method is the preprocessing which implies four sub- steps which is ECG image acquisition , convert ECG image to gray scale and blurring, image binarization and image closing. The aim of this stage is to prepare the image and remove the noise from it to be ready for the subsequent processing stage (the post processing).These sub-steps are explained in more details in item a to d.

a. ECG image acquisition

The ECG image acquisition by using HP Scan Deskjet F2400 scanner with horizontal and vertical resolution 300 dpi, bit depth 24, and the image store in JPEG format as shown in Figure(5) .

b. Convert ECG image to gray scale and blurring

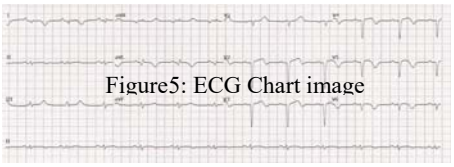

Figure5: ECG Chart image

In this step ECG image is converted from 3-dimension image to 2-dimension image (gray scale image) by computing the average of each pixels in three layer in original image and place this average value in same position in new image. as it declare in the following equation .

$$Newpixle = (I_R(i.j) + I_G(i,j) + I_B(i,j))/3 \ldots\ldots (7)$$

Where: IR=value of pixel (I,j) in Red layer.
IG=value of pixel (I,j) in Green layer.
IB=value of pixel (I,j) in Blue layer.

After that, the gray image will be blurred using motion filter in order to decrease the effect of grid found in ECG chart image . By applying this filter with length 5 and degree 90 the ECG curve region will be more obvious and the grid will be foggy this will help us in next step (image binarization).

c. Image binarization

Because we need to deal with interest region of ECG chart which is represent by curve of ECG image we need to convert the blurred gray image to binary image. Global threshold method is applied to this image this process result in image with binary value 0 to curve pixels and binary value 1 in background pixels the complement process is performed on the resulted binary image to give the high value (binary value 1) to curve pixels because this curve consider the interest region in image.

d. Image Closing

The resulted binary image have curve with small broken (holes) in some region so we apply morphological closing on binary image to close this broken and get on ECG curve clear along image. The shape of structural element used in closing operation is line shape with length 7 this helps us in fills holes smaller than the structural element.

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5.2 Post processing stage

This is the second stage in our method which consist of two stage (feature extraction stage, Normalization stage).These two-stage explained with more details below.

5.2.1 Feature extraction stage

We extract from binary closing image vector of feature consist of 14 features first eight was extracted from applying chain code algorithm on image which compute the movement change of ECG curve in eight neighbors (0,1,2,3,4,5,6,7). After that we calculate summation of movements in eight direction and save it in spreadable variables. The remaining six feature is extracted using first order measurement (mean , variance, skewness, kurtosis, energy, entropy) on binary closing image. This vector of features initiate to enter the recognition stage so to determine the state of heart action if it is normal or there is an Arrhythmia based on these features , if it is founded the classification system ANN must classify the type Arrhythmia either it is bradicardia or tachycardia. Table(1) bellow detect the features vector for one ECG chart image consist of combination of freeman chain code and first order features.

Table 1: vector of chain code and first

Name of feature	The value
Ch0	4737
Ch1	4745
Ch2	5685
Ch3	3250
Ch4	4656
Ch5	4894
Ch6	5468
Ch7	3318
mean	0.018
variance	1187.7
skewness	0.00018
kurtosis	3.88
energy	0.964
entropy	0.131

The numerical features which are extracted using chain code and first ordered measurement saved in text file this process help in digitization the ECG image in small size text file resulting in suitable storage and retrieval of ECG information for each patients in speed and easy way.

5.2.2 Recognition Stage

Artificial neural networks (ANNs) will be used for recognition and classification of the ECG chart image. ANNs are a kind of artificial intelligence which tries to simulate the actions of nervous system in the human brain. It is consist of a number of computational units or neurons. In ANNs neurons are arrange in different layers. These layer are(input, hidden, output). Network weights that are used to connect each neuron to other neuron in the next layers are adjustable through a learning process. In order to obtain the output of ANNs the hidden and output layers multiply each input by its network weights and then do summation on these multiplying which then passed through a transfer function to get the result[18].

ANN that are used in this paper is trained using Resilient back-propagation (Rprop) algorithm. Resilient back-propagation (Rprop) algorithm is a learning algorithm which is the finest algorithm in terms of combining correctness, speed as well as strength with respect to the training parameters. The Rprop is a local adaptive learning algorithm, the simple notion is to minimize the harmful influence that present due to the size of the partial derivative on the weight step [19].

ANN architecture which is used in our method shaped as one hidden layer where we put 14 neurons in input layer one for each input features in database vector and 10 neurons in hidden layer and three neuron in output layer one for each case of ECG. The network is trained with target matrix has Rows equivalent to number of information vectors of ECG features vector and columns equivalent to class number equivalent to that input vector. Each rows in this matrix contains on zeros value with a 1 value in element with position i, where i is the class number that we need to treat it. The highest correct classification rate in this method was 100% in training group and 97.8% in testing group. Figure (6) shows the construction of ANN which is used in classification stage.

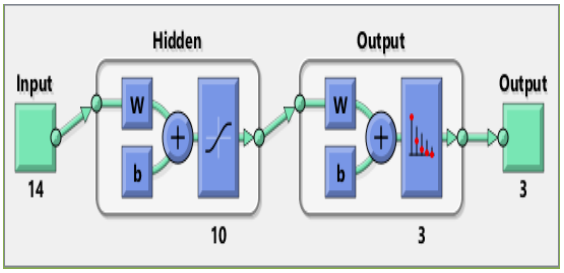

Figure 6. Architecture of ANN used to ECG recognition

6. EXPERIMENTAL RESULTS AND DISCUSSION

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To verify this proposed method we create dataset consist of 90 ECG chart image using scanner device where the scanning operation of the ECG chart with resolution 300dpi vertically and horizontally these images store in JPEG format. We got on ECG Chart from Nasiriya heart center in Dhi-Qar Governorate. The collected dataset implies normal and arrhythmia groups of dissimilar age sets both male and female patients .The ninety image in our dataset include 39 image has normal action of ECG, 27 image with bradycardia daises and the remaining 24 image have tachycardia daises.

This dataset divided into two groups training and testing the first group include 30% of image for training,70 of image for testing. The second group include 50% of image for training and 50% of image for testing the selection of image is done randomly. The classification results obtained from our method are 100% for training in both two group while testing we get on 90.5% on first group and 97.8% in second group. Table (2) shows the classification results in two group where the number marked in bold font detect the correct classification for ECG state. Our method is programmed using MATLAB R2017a with computer has processor Intel(R) Core(Tm)i7 CPU @ 2.10 GH with RAM capacity is 8GB.

Table2: testing ratios of the proposed method

Train to test ratio		30/70			50/50		
Class Name		Target class			Target class		
		normal	bradycardia	tachycardia	normal	bradycardia	tachycardia
Output class	normal	28	0	6	20	0	1
	bradycardia	0	16	0	0	14	0
	tachycardia	0	0	13	0	0	10
Accuracy		90.5%			97.8%		

The difference between our method with previous work is in[5] the purpose of system is generate series signal in digit form using image processing techniques database used involves of ECG records of 10 persons, the resolution of scanner is 600 dpi black and white mode then the resulted image stored as JPEG image. The accuracy of this system is 95%.

In[6] also used image processing techniques to prepare digitization record of ECG chart dataset containing paper records of 20 patients. The accuracy rate was 96.4% in converting an ECG paper record to a digital signal. As Comparing with [5] and [6] our method generate new form of digitization to ECG record where we save the fourteen features extracted form post processing stage saved in text file also our method apply on 90 ECG chart image. In[7] digital signal processing with if ..then ..else rule are used to arrhythmia detection higher accuracy noticed from this system was 90%.

In [8] the goal of system was Identification of cardiac arrhythmias based on features extracted form signal where signal processing techniques was used to achieve this goal with principal component analysis and neural network as classifier the accuracy of this system was 97.1% with PCA-NN. In Our method neural network with resilient back propagation algorithm is used as classifier tool which gave us 97.8% accuracy in classification which is more than accuracy obtained in the two searches mentioned in [7, 8].

Table(3) shows a comparison between our method which is proposed to detect the daises of heart based on image processing techniques with past researches in field of ECG that interest in digitization ECG or detection daises of heart using ECG.

Table3: comparison accuracy the method with previous works

Searchers	System task	Technique	Accuracy
Prashanth et. al 2010 [5]	Digital Time Series Signal Generation	Image processing	95%
Deepak et. al. 2012[6]	Paper Records Digitization	Image processing	96.4%
M. R. Islam et.al 2015 [7]	Arrhythmia Detection	Digital signal processing With if ..then ..else rule	90%
N. N. S. V. Rama Raju et.al. 2017[8]	Identification of cardiac arrhythmias.	Digital signal processing With PCA-NN	95.% with NN 97.1% with PCA-NN
Our method	Digitization and Arrhythmia detection	Image processing with BPNN	97.8%

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7. CONCLUSION

A condition in which the heart beats with an irregular or abnormal rhythm is known as Arrhythmia .In medical field apply an automated systems, need to be handled very carefully because this system deal with human life. From the study that has been carried out in this paper and based on the obtained results the ECG state action can be determine using this method and decide if there is a need to treatment or not based on classification result of this method. High success result came from the robust features which are extracted carefully using freeman chain code in 8-neigbros in addition to statistical features represented by first order measurement. The selection of classifier also play major role in success this method since, the accuracy in a pattern recognition system not only be subject to features extraction method but also depend on the good selection of classifier. Two types of training/testing groups which are (50% to 50%, 30% to 70) are used for the classifiers. Highest classification result was on 50 training-50 testing group where we get 97.8% as correct classification which consider promise result in pattern recognition system. Also From the result it observed that the training data size has less affect on the result of neural network where even when the training data are few it gave best results.

This paper is established on a limited number of image which capture to ECG using flatbed scanner, for that reason experimental results cannot be comprehensive. In the future research on more samples of ECG chart image is needed, using the same method proposed in this study and comparing the new results with current results.

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