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ECG image classification in real time based on the haar-like features and artificial neural networks

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Abstract

The paper presents a ECGs classification system that uses powerful algorithms image processing and artificial intelligence. The descriptor haar-like is based on the concept of the integral image to accelerate the calculation of haar features and the classifier multilayer perceptron type. The training and testing of the proposed system were performed on two basic types: a learning base containing labeled data (normal ECG and ECG sick) and another base unlabeled data. The experimental results have shown that the system combines between the respective advantages of haar-like descriptor and artificial neuron networks in terms of robustness and speed.

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Keywords: ECG classification, haar like features, the integral image, artificial neuron networks.

1. Introduction

Cardiac pathologies are increasing day by day; they represent a number of health problems related to the heart[1]. To determine these heart diseases and abnormalities, doctors use the ECG electrocardiogram signals. The ECG is commonly used biomedical test for the diagnosis of various heart abnormalities for over a century[2,3].

An electrocardiogram (ECG) is an electrical recording of the heart representing the cardiac cycle[4], on a graph representing the electrical activity of the heart obtained by connecting electrodes adapted to the body surface[5].

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The ECG signal fig.1 is formed by a set of waves: a P wave, a QRS complex and a T wave. These waves are characterized by their shapes and durations. Each change that affects a characteristic of these waves is a heart defect[6].

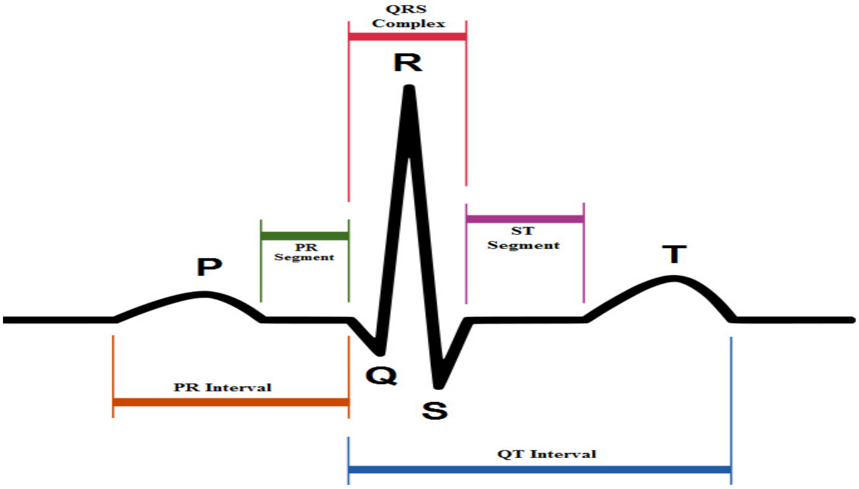

Fig.1.The ECG signal.

Detection and treatment of anomalies have become the main research topics in the field of cardiac care and the information processing domain (signal and image)[7]. This paper is concerned with methods of image processing that have showed several advantages in various fields such as pattern recognition, the driver assistance systems, medical assistance systems, etc.

In doing so, the study of medical assistance systems is an area that requires technical and highly advanced image processing algorithms. This paper discusses in detail the combination of two algorithms; an algorithm for extracting the characteristics of the image which is the descriptor nickname Haar[8], and other classification or detection algorithm capable of detecting cardiac abnormalities such as tachycardia, bradycardia, etc. ..., which is the artificial neural network[9].

This paper discusses a set of contributions. First, the use of the descriptor nickname haar which is based on the notion of haarwavelet or windows, and the concept of the integral image in order to facilitate the calculation of this descriptor in terms of method and speed. Then the use of artificial neural network type multilayer perceptron to classify cardiac signals according to their characteristics from the descriptor haar. And finally, the selected performance criteria yielded more than satisfactory results in terms of robustness (detection rate and false alarm) and speed.

The paper is divided as follows. The following section presents previous research on the classification of ECG. Section 3 describes in detail the descriptor and the classifier we studied and its combination. Various experimental results are presented and analyzed in Section 4. The last section is devoted to the conclusion.

2. Related work

Several approaches to implementation of image processing algorithms and learning have been presented in the literature for making decisions on electrocardiogram signals or the detection of cardiac abnormalities.

[10], in his article, presented a software developed for capturing ECG image signals. He was able to use image processing methods (filtering, enhancement and binarization) to give an interpretation of the patient's heart condition. The results of this application showed high accuracy.

[7], in his paper presented image processing methods (conversion to grayscale, removal of bottom screens) to convert the samples of an electrocardiogram signal from the database MIT-BIH at intervals desired so that the database can be used in various applications, both for detection and for decision making.

[4]Presented in his article a diagnosis of cardiovascular disease based on the shape of the waves from ECG and scanned using the segmentation method. The results of this application showed accuracy for different group of diseases.

[5] Presented in his article a study based on MATLAB, using image processing methods (segmentation based on color filtering) from ECG papers to retrieve useful information for interpretation.

[1] Presented in his work an intelligent method of classifying ECG signal types based on fuzzy neuro adaptive system resulting from the approach of fuzzy logic. The system showed a high accuracy when detecting ECG: normal and abnormal.

[11] Proposed in his article some improvements to the scanning process by using image processing tools such as median filtering based on the MATLAB software. Also[22] proposed a signal processing method to distinguish between heart defects from an image of the ECG, via an image conversion to a signal.

[12] Showed interesting results in terms of accuracy and execution time, combining between the performance of algorithms for analyzing quartermaster and wavelets and artificial neural networks by acting on the number of multilayer perceptron node. The classification of ECG with this system achieved an accuracy of 96%.

[13] Showed in his article more robustness when ECG processing from different sources, using image processing methods such as binarization and morphological operations.

However, all the previously quoted works have opted for two methods of processing ECG signals; a method based on image processing tools to extract the characteristics of ECG images, without the use of tools for decision-making and another clever method that uses the combination of the extractor as signal processing tools feature and tools of artificial intelligence as a classifier.

The proposed system aims to combine pseudo haar descriptor of performance in terms of speed of calculation and accuracy and performance of the classifier based on artificial neuron networks in terms of accuracy of decision.

3. Our classification system

This section describes the classification system of heart defects, which consists of two main parts:

- Feature extraction for learning.
- The feature extraction for classification (decision making).

Before extracting the haar like features from the paper scanned images of normal fig.2.a and abnormal fig.2.b ECG. A binarization step of these images is necessary to remove unnecessary information (grids) using the method of the overall threshold. Then the descriptor nickname haar[8] extracts the information contained in each integral image, calculated as a feature vector. The artificial neural network is the database comprising these vectors to train to adjust its synaptic weights.

a

b

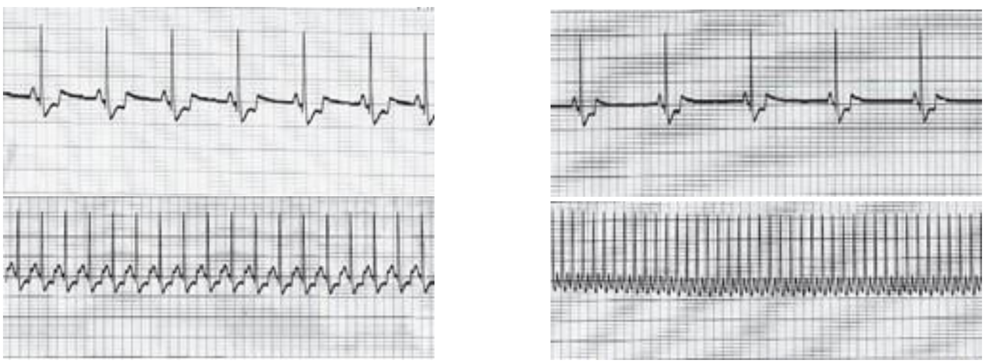

Fig.2.(a) The normal ECG; (b) The abnormal ECG.

In the classification phase, the artificial neural network receives at its input a feature vector extracted descriptor haar representing the image of the ECG to process, to decide if the ECG is normal or abnormal. The following diagram illustrates the overall system of classification of ECG fig.3.

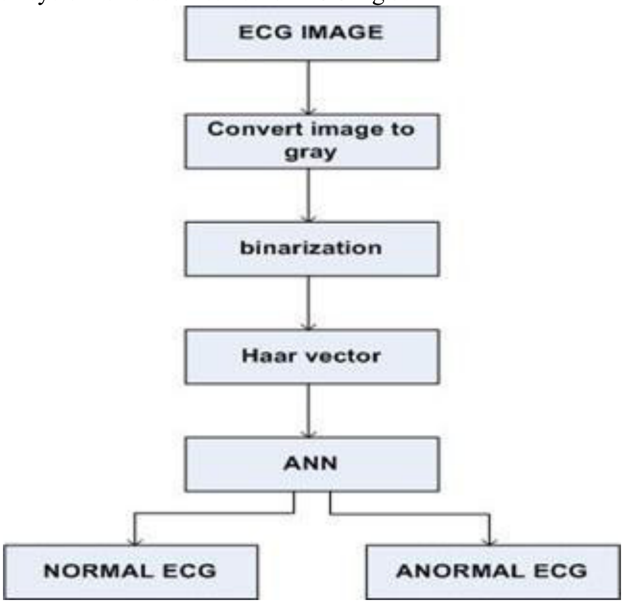

Fig.3.The overall system of classification of ECG.

3.1. The binarization

Binarization is often the first step in treatment systems and image analysis[14]. Binarization chosen in our work is the global binarization by thresholding of comparing the gray levels of an image with a selected threshold manually to decide which of the two classes up this point.

Fig.4.Binarized images.

Its goal is to reduce the amount of information present in the image, and keep only the relevant information. The threshold is given by the following expression[15]:

$$b_i = \begin{cases} 255 & \text{Si } x_i \geq T \\ 0 & \text{Si } x_i < T \end{cases} \quad (1)$$

With:

T Is the overall threshold.

x_i Is the gray level of each pixel of the image.

b_iIs the new value of the pixel.

3.2. The haar vectors

The haar like features orhaarwindowsare proposed forthe first time by[16,17] for object recognition. They are a quick and easy way to calculate the derivatives regions at different scales.

The first concept used for the haar features is the consideration of the integral image introduced by Viola and Jones that presents an interesting performance in terms of speed of calculation. The integral image is calculated using the following equation[18]:

$$ii(x,y) = \sum_{x \leq x', y \leq y'} i(x',y') \quad (2)$$

With:

$ii(x,y)$ Is the integral image.

$i(x,y)$ Is the original image.

Then the use of the two equations allows calculation of haar windows at various scales in an image:

$$s(x,y) = s(x,y-1) + i(x,y)$$
$$ii(x,y) = ii(x-1,y) + s(x,y) \quad (3)$$

With $s(x,y)$ denotes the cumulative sum of the line and $s(x,-1) = ii(-1,y) = 0$.

The use of the integral image facilitates the calculation of rectangular sums; four references for a rectangular sum, six references can be calculated for the features of two rectangles and eight in the case of three rectangles[8].

Our approach is to use only 2 rectangular filters (vertical and horizontal) of a fixed scale, ie, in our case 24x24. Rectangles roam throughout 40x100 sized images and at each position they calculate the Haar features for constructing a vector for each image that is in the learning process or the classification. In an image size 40x100 feature vector (the set ofhaarlike features) using the two filters is 2432.

These vectors, whose size is 2432, will be the input vectors of the learning process and classification for artificial neural network.

3.3. The artificial neural network

Artificial neural networks have become highly sought solutions in several areas that require artificial intelligence in tasks such as pattern recognition and classification.

An artificial neural network is a mathematical model that simulates two essential properties of the human brain in the information processing: the first property is to learn from a sample base and the second is to generalize the knowledge to the unseen examples during the learning phase[19].

The basic unit of artificial neuron networks is the formal neuron, developed by McCulloch and Pitts. This model, which receives at its input a vector of synapse weight and a parameter vector dedicated to the desired application so that it performs a weighted summation between the two vectors eq.4. The result of this operation is transferred to the output through a transfer function (activation function). The activation function used in our work is the sigmoid which has advantages of differentiability and continuity.

$$V = \sum_{i=0}^{n} Wi.Xi \quad (4)$$

These processing units interconnect them to form a network capable of solving difficult problems requiring artificial intelligence.

The most used in the literature is the multilayer perceptron architecture MLP fig.5, which will be used in this application. It uses, besides the input and output layer, hidden layers[20].

The most interesting task for the operation of the MLP artificial neural networks, for any application, is learning. It is a process of adjusting the synaptic weights interconnecting neurons between them.

For the multilayer perceptron learning algorithm used is the retro propagation (Back pro) is an adequate algorithm that simulates the learning error phenomenon. The algorithm aims to minimize the overall error using the gradient descent method[21].

$$E(n) = \frac{1}{2} \sum_{j \in C} (dj(n) - yj(n))^2 \quad (5)$$

The network learns the types of cardiac ECG from the training set of data and applies it to classify the new ECG to detect heart defects.

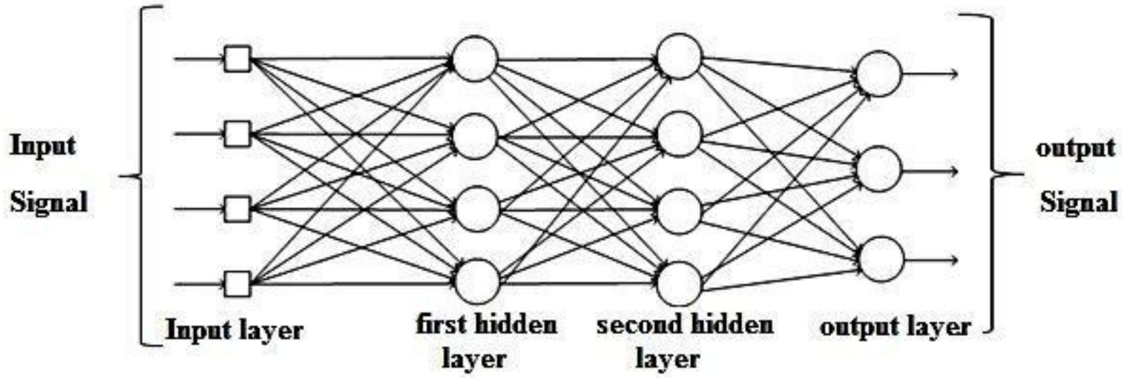

Fig.5.The architecture of the MLP.

4. Experimental result

The preparation of the database of learning or test the proposed system consists initially to digitize ECG papers of different people (normal and diseased), then each scanned image is dissected into a set of thumbnails on a fixed time interval of 5s fig.6. Then these thumbnails are binarizedfig.4 by thresholding method and recorded with a standard size of 40x100, allowing the Haar descriptor extracting feature vectors whose size is set to 2432 characteristics.

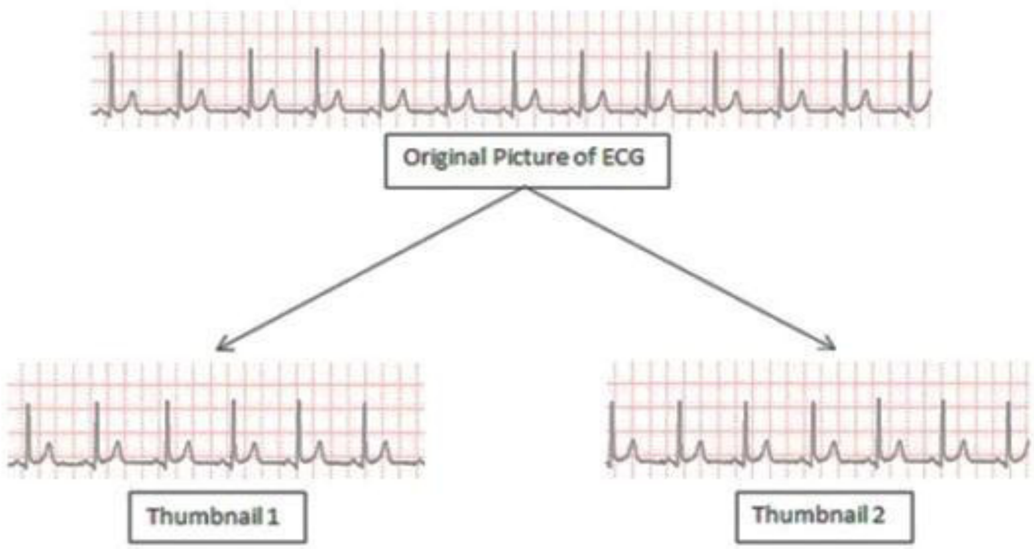

Fig.6.The thumbnails diecut from the original image.

Before testing the proposed system, it must go through a learning phase. During this phase, the system receives in its input16 thumbnails ECG normal patients and 29 thumbnails ECG sick patients who suffer a heart defect. From these 45 thumbnails, descriptor haar extracted feature vectors, the size of each is 2432, to build a training base of the artificial multilayer perceptron type neural network. The iterative processof theneural networkendsby minimizingthe overall errororby reachingthe maximum number ofiteration

After adjusting the connection weights between neurons (synaptic weights), artificial neural network is ready to be tested. During this phase, the system receives 20 randomly chosen thumbnails to test the performance of this system. These thumbnails, whose size is 40x100, pass through the extraction phase of feature vectors by the descriptor Haar. Then the artificial neural network receives a test database consists of extracts a feature vector to classify them into two classes: normal and sick.

The performance analysis of this classification system was performed by varying a very influential parameter in network multilayer perceptron type artificial neuron, which is the number of neurons in the hidden layer. And for each number of selected neuron, a result set is extracted and gives the overall error, the execution time, the rate of correct detection and false alarm rate. The following figures illustrate the results obtained during this test done in C ++ on PC platform type characteristics (Intel® Core™ i3 CPU (2,40GHZ), RAM 4 Go, Linux Mint):

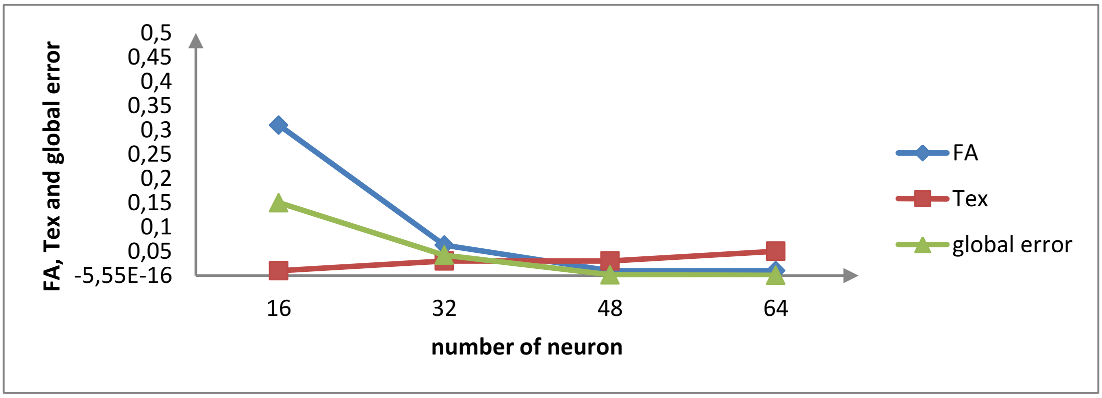

Fig.7.The comparison of the FA, execution time and global error.

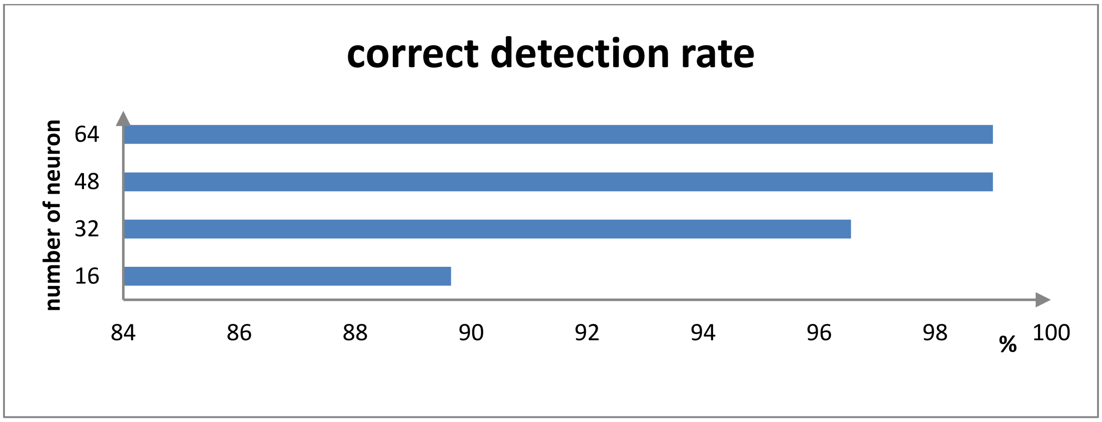

Fig.8.The DC results.

The experimental results illustrated in Figures 2 show two essential points:

The first point is that the ECG classification system is a robust system. This robustness is manifested through the good high detection rate fig.8 reached 99% correct classification and the false alarm rate fig.7 is very low factor of 0.01.

The second point is the speed of the system. Despite the size of the vector 2432 features and the number of neurons in the hidden layer, the system permits the classification of the ECG in an extremely small time fig.7, which gives the system the possibility of real-time use.

5. Conclusion

This paper presented a combination of efficient algorithms to build a decision support system for cardiologists to facilitate the classification task ECG images. This combination has exploited the accuracy of haar like feature extraction algorithm and the power of artificial multilayer perceptron type neural networks. The results obtained during tests have given a robust and quick decision support system.

However, the future works will examine the improvements that can be made to the proposed system of classification of ECG image normal or abnormal, to make it evolve into a system to classify images according to the nature ECG abnormalities (tachycardia, bradycardia, etc ...).

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