ECG arrhythmias classification using wavelet transform and neural networks

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***Abstract*—** In this research, a new method for heart Arrhythmias classification based on Wavelet Transform and Neural Networks has been proposed. Discrete Wavelet Transform (DWT) is normally used for processing and extracting the time and frequency characteristics (specifications) of ECG records. In this work, the obtained features from Wavelet Transform and morphological features of the ECG is combined with time of features this signal in order to use its results as final features to teach and test a Multi Layer Perceptron (MLP) Neural Network. In this research, 189 heart signal samples existed in MIT-BIH data base are utilized in order to teach and test the classifier. The best accuracy of 97.33 percent have been achieved for three different class of ECG signals including; Normal rhythm RBBB and LBBB.

***Keywords*— ECG, Heart Arrhythmias, Morphological Features, Neural Networks, Wavelet Transformation.**

I. Introduction

Bioelectrical signals represent human different organs electrical activities and Electrocardiogram or ECG is one of the important signals among bioelectrical ones that represent heart electrical activity. Deviation and distortion in any parts of ECG that is called Arrhythmia can illustrate a specific heart disease.

These signals carry crucial information about heart operations and conditions that should be extracted and analyzed. The process of extracting and analyzing of ECG can be done by human. In this method, Amplitude and time distances among waves are considered by an operator so that, is a limited and time wasting method, and potentially can have errors. In order to remove mentioned disadvantages, automatic analysis way of ECG has been proposed. Today, variety of methods is introduced for classification and diagnosis of heart arrhythmias. The main differences among them are the way of characteristics extraction and the type of their classifier.

In [1] Chi et al using 3 neural networks, have classified the arrhythmias with accuracy of 95.1 percent. In [2] Karlik et al using neural network, have classified 10 types of arrhythmias with the accuracy of 91.3 and 90.3 percent. In [3] Yu et al using 2 RVQ neural networks, have classified the arrhythmias with the accuracy of 91.3 and 90.3 percent.

Manuscript received October 29, 2010. This work was supported in part by the Islamic Azad University Lahijan Branch.

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The common problem in all these proposed methods is that they have used ECG signal itself for heart arrhythmia (HA) classification. In this work, to solve this problem, in addition to extract time and morphology features of ECG signal, wavelet transformation (WT) is used to extract ECG signal features and then the signals are classified by a MLP Neural Network.

II. Methods and Techniques

The block diagram of the utilized method is shown in Fig.1. As it can be seen, it has 3 stages. Firstly, the ECG signal should be pre-processor in order to eliminate existed noises of ECG and preparing a processed signal for the next stage. Secondly, there is main processor that extracts feature and produces a feature vector for the next usage. Finally, there is a classifier that determines the type of arrhythmia.

A. Achieving Needed Data

In order to teach and test the neural network some ECG signals have been downloaded from MIT-BIH data base [4] and 17 files of them, with time length of 30 minutes and sample frequencies of 300 Hz, have been utilized in this work. 186 sample signals from different times of these files have been chosen incidentally to provide needed data. Table.1 shows utilized files and their classifications.

B. Pre-Process of ECG Signal

In this stage, it is necessary to eliminate noises from input signals using WT. This pre-process of ECG signal before extracting its feature can resulted in better extracted features which in turn can resulted in a increase of system efficiency in HA diagnosis.

C. Main Processor (Characteristics Extraction)

After noise elimination, it is necessary to extract the features from the signal in order to use it in the next stage. Pattern identification is a basic step in features extraction and classification parameters. There are varieties of feature extraction ways.

In this work two categories of features are extracted from ECG signals; 1- features resulted from WT applying 2- time and morphology features of ECG signal itself. Utilized WT in this work is DWT [5-7] that will be described in section 3.

Fig.1 block diagram of the arrhythmia diagnosis system

TABLE I
UTILIZED FILES AND THEIR CLASSIFICATIONS THAT ARE OBTAINED FROM MIT-BIH DATA BASE [4]

Class	Records
Normal	100-101-103-112-115-117-121-123-202-220-222-234
RBBB	212-118-124
LBBB	109-111

D. Classifier

A part of researches in this work is devoted to consideration of different neural networks in order to determine their accuracy in identification and separation of categories or classes. Among all neural networks MLP, which is illustrated in Fig.2, has been chosen based on the below mentioned reasons:

1. It has 3 layers including; input, hidden and output layer.
2. As result of this fact that the numbers of existed neurons in hidden layer is an effective parameter for improvement of learning results, variety of neuron numbers was chosen in order to achieve the optimum number based on output results.
3. Tansig and Purelin function and also their combination function have been compared as transfer function of network neurons and finally, the effective one has been chosen.

For teaching of mentioned neural network, mean square error criterion was utilized in which error of 0.0001 was the stopping point of teaching and maximum repetitions was 500 times.

III. SIMULATION ENVIRONMENT

The simulations have been done by MATLAB software [8] because of its various capabilities in recognition of the pattern. As it mentioned before, firstly, the ECG signal should be pre-processed to eliminate its noise that is done by Wavelet. In this research Discrete Wavelet transformation (DWT) have been utilized. In the case of Signal processing using wavelet, the type of wavelet is important, as an instance, for a ECG signal, one of the best choices is Daubechies wavelet [9]. Among all Daubechies types of wavelet, 6db is selected based on its similarities to ECG signal. DWT can be utilized as a bank filter [10]. Fig. 3 shows a sample of a bank filter proportional to 2 stages Wavelet Transformation.

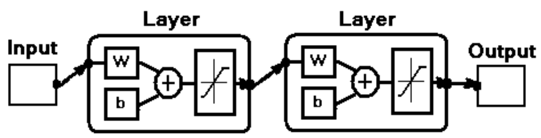

Fig.2 illustrates the structure of the utilizes neural network

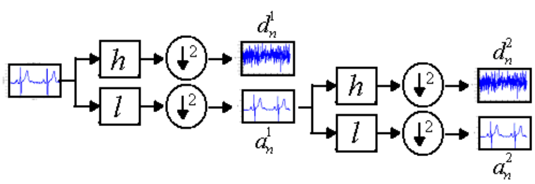

Fig.3 bank filter proportional to two stages WT

In above mentioned bank filter h is a high pass filter or is the wavelet, l is a low pass filter or scaling function. It should be mentioned that in this work, in order to achieve better results, a 8 stage wavelet have been used to eliminate signal noise. After noise elimination signal features should be extracted. Here, two groups of features are extracted and their combination had used as feature vector for neural network.

A. Characteristic Vector Resulted from Applying Wavelet

In this stage, by the use of DWT signal has been divided in to 8 levels, and in each level low frequency coefficients and high frequency, is obtained. Direct applying of wavelet coefficient as neural network inputs has resulted in an increase in neuron numbers in hidden layer which in turn has a negative impact on network operation. Thus, in this stage, variance, maximum and minimum of the signal in each level and for each high frequency and low frequency coefficient has been calculated. Finally for each of signals 48 feature have been obtained.

B. Time and Morphology Characteristics of ECG Signal

Time and morphology extracted features of ECG signals include; variance, maximum, minimum, standard deviation and R-R distance in 5 beats of the ECG signal.

By extracting these features, five feature of a signal will be achieved. These 5 time and morphology feature are combined with 48 obtained feature of applied DWT and finally 53 feature are assumed as total feature vector of neural network. This total vector is normalized to obtain optimum results and also is used to recognize three categories of heart arrhythmias. First category is people with normal heart operation. Second category is people who suffer from Right Bundle Branch Block (RBBB) and third category is people who suffer from Left Bundle Branch Block (LBBB).

As it is mentioned before to classify this three categories of arrhythmias three MLP neural network is utilized this has 8 neurons with Tansig transfer function in hidden layer and Purelin transfer function in its output layer. Total feature vectors of some signals are used to teach the neural network and some others are accidentally chosen to test it.

IV. SIMULATION RESULTS

To simulate and teach the network, 36 data, 12 data for each class, are used and two groups of feature have been extracted from them. Combining these feature based on mentioned descriptions in last section, a 53×36 matrix has been obtained as teaching input data and also 150 data, 50 data for each classified categories, is used for testing. Then, simulation has been done by different numbers of neurons in hidden layer. Using try and error method has given us 8 numbers of neurons in hidden layer as optimum state.

Table.2 shows the results of applying two groups of features to neural network in accuracy state of 100% for teaching stage. In this state of 100% teaching accuracy, when testing data are applied, test results will give us the best accuracy result of 97.33%. Defining the percentage of efficiency and correct recognition of arrhythmia by neural network is done by below parameter:

ISBN: 978-960-474-252-3

TABLE II
RESULTS OF APPLYING TWO GROUPS' CHARACTERISTICS TO NEURAL NETWORK AND THEIR CAMPARISON

Type of feature	Classified categories	Number of teaching data	Number of testing data	Number of correct classified samples	Network Efficiency %
Combination of time and morphology feature with ECG from WT	Normal	12	50	49	98
	RBBB	12	50	48	96
	LBBB	12	50	49	98
	Total	36	150	146	97.33
Feature resulted from applied wavelet	Normal	12	50	47	94
	RBBB	12	50	46	92
	LBBB	12	50	47	94
	Total	36	150	140	93.33

$$A = \frac{N_c}{N_t} \times 100 \tag{1}$$

In which A is percentage of efficiency, N_c is the number of correct classified samples and N_t is number of total samples. In table.2 percentage of efficiency is shown for each classified categories.

V. CONCLUSION

In this paper, utilizing different signal processing techniques and re-determining pattern, a powerful method has been achieved for diagnosis of HA. The crucial point that should be considered in this method is that it needs more data for expanding its decisions. Based on experiments results, it has been understood that determining feature vector, activity (transfer) function type and hidden layer neurons are the main influential factors in teaching and testing of the network in order to classify HA. In this work it is shown that combining the time and morphology features of ECG signal with features obtained from WT, results in network efficiency.

ACKNOWLEDGMENT

This work is supported by Electrical group, department of engineering, Islamic Azad university Lahijan branch, Lahijan, Iran.

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