NEURAL NETWORK ARCHITECTURE DESIGN FOR FEATURE EXTRACTION OF ECG BY WAVELET

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Abstract :
This paper deals with the designing of feed forward neural network (FFNN) with the effect of ANN parameters for feature extraction of ECG signal by employing wavelet decomposition. Extraction of ECG features has a significance role in disease diagnosis of heart.ECG signal is decomposed in to it's higher and lower frequency components by using Daubechies wavelet then statistical features of all components are given as input of neural network. A Multi-layer Feed forward Neural Network (MFNN) employing back propagation algorithm is used for learning and to train the ANN. The ANN is designed and trained by MATLAB software. Effect of ANN parameters on error is also found out. Two different type of ECG signals has been taken from MIT-BIH: Normal rhythm(128 Hz) and Atrial fibrillation(250 Hz).

Keywords: ECG; Wavelet decomposition; Features ; Neural Network.

1. Introduction

The ECG is nothing but the recording of the heart's electrical activity. It is graphical tracing of the electrical activity that is generated by depolarization and re-polarization of the atria and ventricles. ECG is one of the important signals among bioelectrical ones that represent heart electrical activity. The signal is constructed by measuring electrical potentials between various points of the body using a galvanometer. A typical ECG of a normal heartbeat (or cardiac cycle) consists of a P wave, a QRS complex and a T wave. A small U wave is normally visible in 50 to 75% of ECGs. Typical ECG waveform is shown in Fig .1. Analysis of ECG is the gold standard for the evaluation of cardiac arrhythmias.

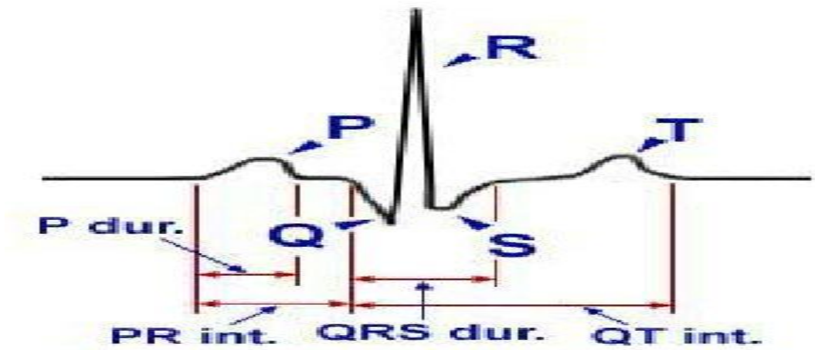

Fig .1. EGG Waveform

Its analysis has been widely used for diagnosing many cardiac diseases. Most of the clinically useful information in the ECG is found in the intervals and amplitudes defined by its features (Statistical and morphological features). Change in shape in any main section of ECG represent arrhythmia [1].The development of accurate and quick methods for automatic ECG feature extraction is of very important, especially for the analysis of long term ECG. Features can also be analyzed by operators but it is time taken and error may also be introduced. The objective of computer aided digital signal processing of ECG signal is to reduce the time taken by the cardiologists in interpreting the results.ECG feature extraction system provides fundamental features which are used in automatic detection. Various ECG feature extraction techniques have been developed so far which have their own merits and demerits [2]. The main differences among them are the way of characteristics extraction of features. The common problems in all earlier proposed method is that ECG signal itself was utilized to extract the features but in this paper, Wavelet Transform (WT) is used to extract the features and neural network is used to minimize the error.

2. Materials Required

2.1. *Discrete Wavelet Transform*

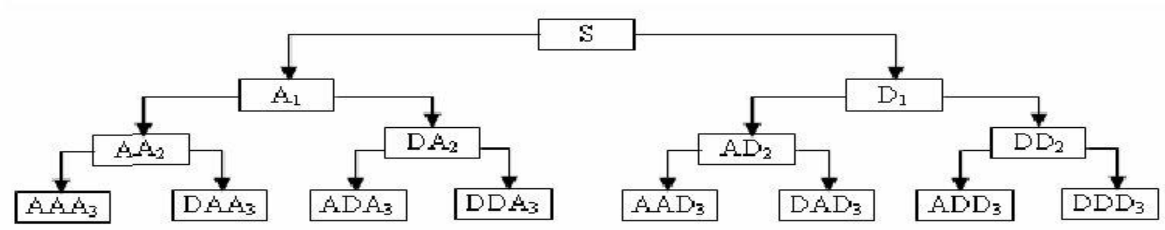

Fig .2. Process of decomposition of signal by DWT

As a result of the infinite extent of the Fourier integral, analysis of signal is time averaged as it contains only globally averaged information. A number of time–frequency methods are now available for signal analysis out of which Wavelet Transform has been proved as a powerful and favored tool in the field of science and engineering for analyzing non-stationary signals. Wavelet method of signal processing is found to be superior to the conventional FFT method in detecting the small changes in ECG signals. Recently wavelets have been used in a large number of biomedical applications and the time and frequency localization of wavelets makes it into a powerful tool for feature extraction [3].It is popular because it satisfies energy conservation law and original signal can be reconstructed [4] .In wavelet transform, a linear operation transforms the signal to decompose it at different scales .It is based on a set of analyzing wavelets allowing the decomposition of ECG signal in a set of coefficients [5]. The wavelet coefficient resulting from the wavelet transformation corresponds to a measurement of the ECG components in this time segment and frequency band. In case of discrete wavelet transform (DWT), filters of different cut-off frequencies are used for analyzing the signal at different scales. For this purpose, the signal is passed through a series of high pass and low pass filters in order to analyze low as well as high frequencies in the signal as shown in Fig .2. It allows signal S to be represented as A1 + AAD3 +DAD3 + DD2.Different types of wavelet are Bi-orthogonal , Coiflet , Harr , Symmlet ,Daubechies wavelets.

2.2. *Neural Network*

An Artificial Neural Network (ANN) is an information processing model that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this model is the novel structure of the information processing system. ANN is usually formed from many hundreds or thousands of simple processing units called neurons, connected in parallel and feeding forward in several layers. ANN's, similar to people, learn by examples. An ANN is configured for a specific application, such as pattern recognition, control and feature classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. Using neural network terminology, the strength of an interconnection is known as its weight. The perceptron is the neural computational model.ANN has a function f(x) which shows the relation between the inputs, weights, bias and the activation function. The activation function relates the output of a neuron to its input based on the neuron's input activity level.

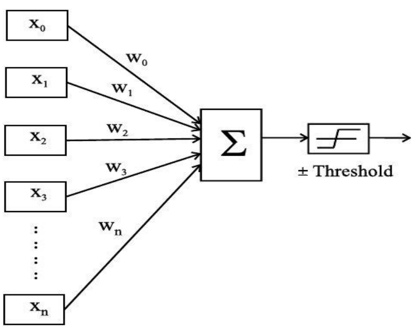

Fig .3.Perceptron

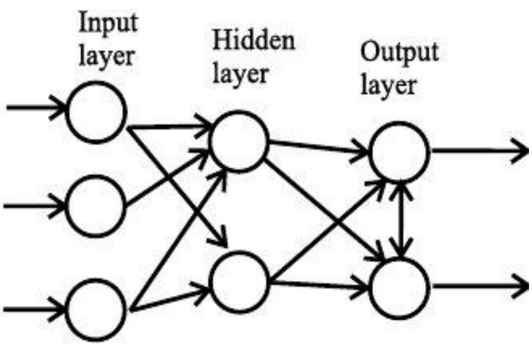

Fig .4.Structure of Feed Forward Neural Network

Some of the commonly used functions include: the threshold, piece-wise linear, sigmoid, tangent hyperbolic, and the Gaussian. It is a single layer neuron that contains the adjustable weight & some threshold values. The inputs are more than one & their weight should be more. The inputs are (x1, x2 ,..., xn) corresponding weights are (w0 , w1,..., wn) as shown in Fig .3.Neural networks are trained and adjusted until network output matches a specific target. Typically many such input/target pairs are needed to train a network. There are varieties of kinds of network structures. In a feed forward network, links are unidirectional and there are no cycles. The importance of the lack of cycles is that computation can take place uniformly from input to output units [6].In this paper feed forward neural network has been used shown in Fig .4.

2.3. *MATLAB Environment*

MATLAB is a powerful, comprehensive, and easy to use environment for technical computations. It provides engineers, scientist, and other technical professionals with a single interactive system that integrates numeric computation, visualization and programming .It includes a family of application specific solutions called toolboxes. In this paper, Wavelet and ANN analysis of ECG signal is performed using MATLAB R2009a Software. It is provided with Wavelet and ANN tool box [7]. It is a collection of functions built on the MATLAB technical computing environment. It provides tools for the analysis and reconstruction of signals and images using wavelets within the MATLAB domain. Customized special functions and programs can be easily created in MATLAB code.

2.4. *Data Acquisition*

For analysis of ECG signal, it is necessary that a standard database must be chosen. ECG signals required for analysis in this paper are downloaded from Physionet MIT-BIH arrhythmia database available online [8] where annotated ECG signals are described by- a text header file (.hea), a mat file (.mat) and a binary annotation file (.atr).Header file consists of detailed information such as number of samples, sampling frequency, format of ECG signal, type of ECG leads and number of ECG leads, patients history and the detailed clinical information. Two types of ECG signal has been taken: MIT BIH Normal (16265) and Atrial fibrillation (05091) Data Base having sampling frequency 128 Hz and 250 Hz respectively of time duration of 1 min then data has been divided in to group of 512 samples.

3. Description Of Algorithm

Preprocessing of ECG signal, decomposition of ECG, feature extraction and then training of features by variation of different parameters takes place in following given steps:

3.1. *Selection of Wavelet*

The selection of relevant wavelet is an important task before starting the detection procedure. It's depends upon the type of signal to be analyzed [9].Wavelet having similar look to the signal being analyzed is usually or One of the key criteria of selection of wavelet is its ability to fully reconstruct the signal from the wavelet decompositions. In this paper, **db6** has been chosen because it has highest correlation coefficient with ECG waveform and its energy spectrum is also concentrated around low frequencies.

3.2. *De-noising of ECG and R peak detection*

- De- noising of ECG signal before extracting its feature can be resulted in better extracted features which in turn can be resulted in an increase in efficiency of system. By using DWT, frequency domain filtering is implicitly performed, making the system robust and allowing the direct application over raw ECG signals. DWT may also be also considered as decomposition by wavelet filter banks.
- After the noise elimination from ECG signal, R peaks are identified by writing a suitable MATLAB code. Specific details of the signal are selected. R peaks are the largest amplitude points which are greater than threshold points are located in the wave. Those maxima points are stored which denotes R peak locations. De-noised ECG signal (Normal and Atrial Fibrillation) and their R wave positions are shown in Fig. 5. and Fig .6 by star.

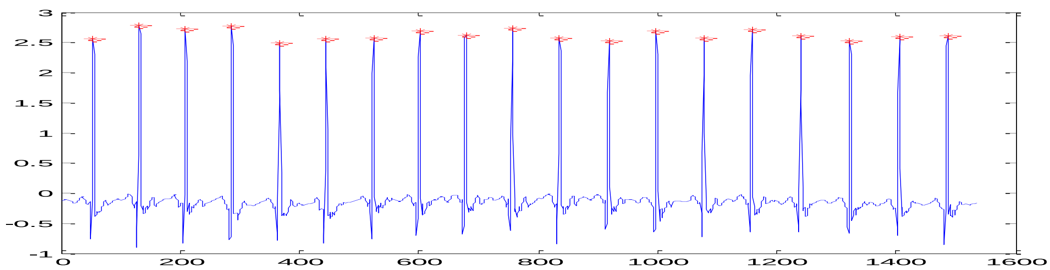

Fig .5. De-noised normal ECG and R wave positionn

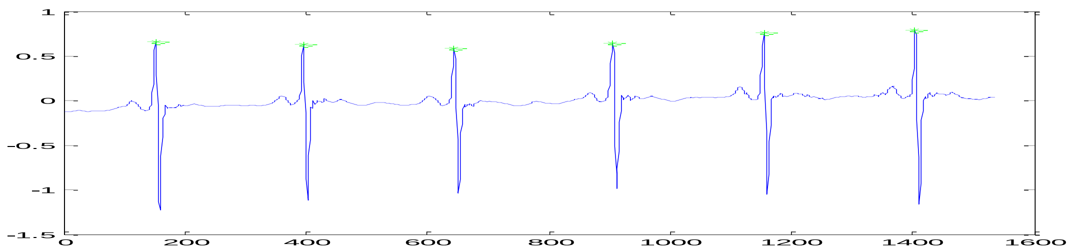

Fig .6. De-noised Atrial Fibrillation ECG and R wave positions

3.3. *Decomposition of ECG Waveform*

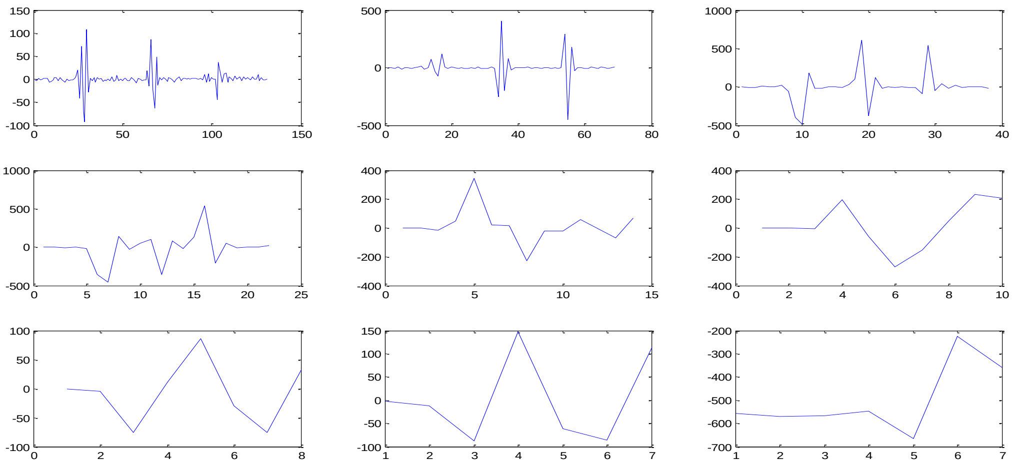

Fig .7 Decomposition of ECG waveform in to wavelet coefficients: Lower Frequency coefficients (d1-d8) and higher frequency Coefficient (a8)

3.4. *Feature Extraction and Normalization*

As ECG waveform has been decomposed in to 8 levels so statistical features like variance, maximum, minimum and standard deviation is found out of each high and low frequency component and also ECG signal. Thus total 68 features are obtained [10]. Feature vector is a matrix of 68x1.This total vector is normalized as shown by "Eq. (1) to obtain the optimal results and given as input of MFFNN (multi layer feed forward network). This is done to prevent the simulated neurons from being driven too far into saturation.

$$\text{Nor.} = 0.1 + \{(\text{Act.}-\text{Min.})*0.8\}/\{\text{Max.}-\text{Min.}\} \quad (1)$$

Where Act. = actual value of the parameter and Min. = minimum value of the parameter.
Max. =maximum value of the parameter and Nor. = normalized value of the parameter.

3.5. *Selection of Algorithm*

Back propagation algorithm (BPA) is supervised learning algorithm. It permits experiential acquisition of input/output mapping knowledge within multi-layer networks. It reduces mean square error between input and output by adjustment of weights. It is highly accurate for most classification problems because of the property of the generalized delta rule. The Multi-Layer Feed-forward Neural Network (MFFNN) falls into this category. It is found that the best architecture of the ANN consists of three layers (an input layer, one hidden layer and output layer) using feed-forward BPA.

4. Results And Discussions

Total feature vectors of some signals are used to teach the neural network and some others are accidentally chosen to test it. In order to simplify the architecture of ANN, data is divided in two groups (normal and atrial fibrillation ECG).Each group consists of a matrix of 68x3.The mean squared error (MSE) is employed as the error function. The ANN is trained under three conditions:

- Keeping the error goal, learning rate and no. of iterations constant and varying the momentum factor.
- Keeping the learning rate, no. of iterations, momentum factor constant and varying the no. of iterations
- Keeping the error goal, no. of iterations and momentum factor constant and varying learning rate.
- Keeping the momentum factor, learning rate, no. of iterations constant and varying the error goal.

The Mean Square Error (MSE) is a good performance measure for judging the accuracy of the ANN System. Effect of different ANN parameters on MSE has been evaluated. Results for training and testing data set are shown from Table .1. to Table .4

Table .1. Variations in MSE by varying momentum factor in normal and atrial fibrillation ECG ANN system

Momentum factor	Learning Rate	Error Goal	Iterations	MSE
0.5	0.5	10^{-5}	1000	$2.9x10^{-5}$
0.6	0.5	10^{-5}	1000	$8.6x10^{-5}$
0.7	0.5	10^{-5}	1000	$4.98x10^{-6}$

Momentum factor	Learning Rate	Error Goal	Iterations	MSE
0.5	0.5	10^{-5}	1000	$4.7x10^{-5}$
0.6	0.5	10^{-5}	1000	$6.1x10^{-5}$
0.7	0.5	10^{-5}	1000	$7.8x10^{-5}$

Table .2. Variations in MSE by varying no. of iterations in normal and atrial fibrillation ECG ANN system

Momentum Factor	Learning Rate	Error Goal	Iterations	MSE
0.5	0.5	10^{-5}	500	$2.47x10^{-5}$
0.5	0.5	10^{-5}	800	$4.9x10^{-6}$
0.5	0.5	10^{-5}	1000	$7.95x10^{-6}$

Momentum Factor	Learning Rate	Error Goal	Iterations	MSE
0.5	0.5	10^{-5}	500	$4.9x10^{-5}$
0.5	0.5	10^{-5}	800	$6.93x10^{-5}$
0.5	0.5	10^{-5}	1000	$4.95x10^{-5}$

Table .3. Variations in MSE by varying learning rate in normal and atrial fibrillation ECG ANN system

Momentum Factor	Learning Rate	Error Goal	Iterations	MSE
0.5	0.4	10^{-5}	1000	$2.5x10^{-4}$
0.5	0.55	10^{-5}	1000	$4x10^{-5}$
0.5	0.7	10^{-5}	1000	$9.19x10^{-5}$

Momentum Factor	Learning Rate	Error Goal	Iterations	MSE
0.5	0.4	10^{-5}	1000	$4.4x10^{-5}$
0.5	0.55	10^{-5}	1000	$6.65x10^{-5}$
0.5	0.7	10^{-5}	1000	$6.9x10^{-5}$

Table .4. Variations in MSE by varying error goal in normal and atrial fibrillation ECG ANN system

Momentum Factor	Learning Rate	Error Goal	Iterations	MSE
0.5	0.5	10^{-4}	1000	$6.6x10^{-5}$
0.5	0.5	10^{-2}	1000	$2.3x10^{-3}$
0.5	0.5	10^{-1}	1000	$1.2x10^{-2}$

Momentum Factor	Learning Rate	Error Goal	Iterations	MSE
0.5	0.5	10^{-4}	1000	$4.8x10^{-5}$
0.5	0.5	10^{-2}	1000	$2.5x10^{-3}$
0.5	0.5	10^{-1}	1000	$2.2x10^{-2}$

Above results show that mean square error varies from 10^{-4} to 10^{-6} indicating that overall MSE consideringall cases is low so proposed ANN model is effective. In this paper, it has been shown that by combining features of ECG and its coefficients leads to higher network efficiency as MSE is low. Based on experiments results, it has been shown that determining feature vector, learning rate, momentum factor, no. of iterations and error goal are the main influential factors in learning and testing of the network.

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