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Dwt - Based Feature Extraction from ecg Signal

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Abstract: Electrocardiogram is used to measure the rate and regularity of heartbeats to detect any irregularity to the heart. An ECG translates the heart electrical activity into wave-line on paper or screen. For the feature extraction and classification task we will be using discrete wavelet transform (DWT) as wavelet transform is a two-dimensional timescale processing method, so it is suitable for the non-stationary ECG signals(due to adequate scale values and shifting in time). Then the data will be analyzed and classified using neuro-fuzzy which is a hybrid of artificial neural networks and fuzzy logic.

Keyword: *Electrocardiogram (ECG), DWT, Neuro Fuzzy.*

I. INTRODUCTION

To attain a progressive sustainable development in all regions of the world, attention should be diverted to the health of a population. All sciences contribute to the maintenance of human health and the practice of medicine. Medical physicists and biomedical engineers are the professionals who develop and support the effective utilization of this medical science and technology as their responsibilities to enhance human health care with the new development of the medical tools such as electrocardiogram (ECG). Heart disease is a broad term that includes several more specific heart conditions which are Coronary Heart Disease, Heart Attack, Acute Coronary Syndrome, Aortic Aneurysm and Dissection, Ischemia, Arrhythmias, Cardiomyopathy, Congenital Heart Disease, Peripheral Arterial Disease (PAD).The most common heart condition is coronary heart disease, which can lead to heart attack and other serious conditions [22] and the Myocardial Ischemia is the most common cause of death in the industrialized countries [9].

The electrocardiogram (ECG) is a noninvasive and the record of variation of the biopotential signal of the human heartbeats. The noninvasive technique meaning that this signal can be measured without entering the body at all. Electrodes are placed on the users skin to detect the bioelectric potentials given off by the heart that reach the skins surface. The ECG detection which shows the information of the heart and cardiovascular condition is essential to enhance the patient living quality and appropriate treatment. It is valuable and an important tool in the diagnosing the condition of the heart diseases.

In recent year, numerous research and algorithm have been developed for the work of analyzing and classifying the ECG signal. The classifying method which have been proposed during the last decade and under evaluation includes digital signal analysis, Fuzzy Logic methods, Artificial Neural Network, Hidden Markov Model, Genetic Algorithm, Support Vector Machines, Self-Organizing Map, Bayesian and other method with each approach exhibiting its own advantages and disadvantages.

The ECG features can be extracted in time domain [5][4] or in frequency domain [8][9]. Some of the features extraction methods implemented in previous research includes Discrete Wavelet Transform [4], Karhunen-Loeve Transform [11], Hermitian Basis and other methods [10].

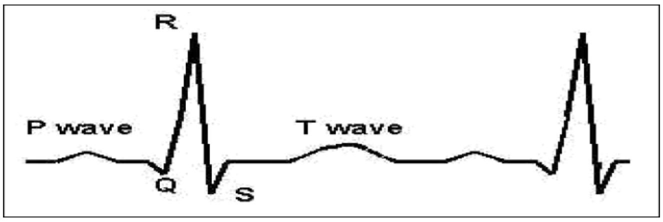

Figure 1: An example of normal ECG trace

All of the ECG waveforms pattern and variability must be determine accurately to get the better diagnostic result that will shown the correct heart disease of the patient. Figure 1 shows the normal ECG traces which consist of P wave, QRS complex and T wave. The P wave is the electrical signature of the current that causes atrial contraction, the QRS complex corresponds to the current that causes contraction of the left and right ventricles and the T wave represents the repolarization of the ventricles.

This research is mainly aimed to extract important parameters from the ECG signal through the DWT technique. By applying this signal analysis technique, the most important parameter of the ECG signal can be taken as the analysis data. Then, the data will be used as an input to the classifier to identify the heart disease. The idea of the ECG analysis and classification using Neuro Fuzzy has been start around 1990, yet it remains one of the most important indicators of proper heart disease classification today.

The most difficult problem faced by an automatic ECG analysis is the large variation in the morphologies of ECG waveforms, it happen not only for different patients or patient groups but also within the same patient. So the Neuro Fuzzy is the most suitable technique because it is more tolerance to morphological variations of the ECG waveforms. This project is useful for the medical application enhancement such as in hospital, clinic which can automatically help to increase the patient health care.

II. . RELATED RESEARCH

The Wavelet transform is a two-dimensional timescale processing method for non-stationary signals with adequate scale values and shifting in time [17]. The wavelet transform is capable of representing signals in different resolutions by dilating and compressing its basis functions [18]. The researcher Cuiwei Li et al [4] use the Wavelet transforms method [19][20][21] because the results indicated that the DWT-based feature extraction technique yields superior performance. Neuro-fuzzy is a hybrid of artificial neural networks and fuzzy logic [1]. Fuzzy Neural Network as in the literature [1] incorporates the human-like reasoning style of fuzzy systems through the use of fuzzy sets and a linguistic model consisting of a set of IF-THEN fuzzy rules. The learning process of FNN consists of three phases which are fuzzy membership, fuzzy rule identification and supervised fine-tuning.

Neuro-Fuzzy approach consist of a five-layer neural network called input linguistic layer, condition layer, rule layer, consequent layer, output linguistic layer. The fuzzification of the inputs and the defuzzification of the outputs are performed in the input linguistic stage and output linguistic layers performed by the fuzzy rule identification.

The performance enhancement using proposed method in Neuro-Fuzzy using autoregressive model coefficients, higher-order cumulant and wavelet transform variances as features had been used by Mehmet Engin [15]. It used self-organizing layer which responsible for the clusterization of the input data which is feature vector and the outputs of the membership values form the input vector to the second sub-network (MLP).

This research use the output of DWT technique as features vector and Neuro-Fuzzy as the classifier for the ECG analysis, because based on the previous research, the accuracy rates achieved by the combined neural network model presented for classification of the ECG beats were to be higher than stand alone classifier model.

III. PROPOSED SYSTEM

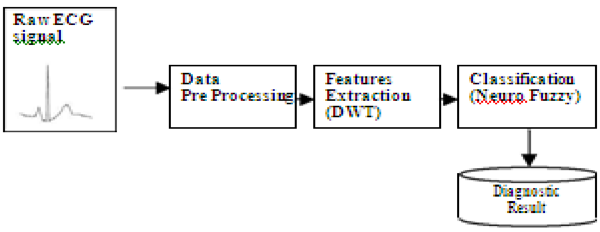

Figure 2: Block diagram of the system

Various methodologies of automated diagnosis have been done. The ECG data analysis techniques are reviewed in and evaluate proposed methods of the classification methods. In our proposed, the process of ECG analysis can be generally subdivided into a number of disjoint processing modules have been identified which are:

1. Data acquisition
2. Pre-processing beat detection
3. Feature Extraction
4. Classification

A. Data acquisition

1. Data Collection

The heart sound using ECG will record simultaneously from patients. The ECG Database in PhysioBank also being used as a data of ECG input signal for features extraction part processing.

2. Preparation of Data

Partitioning the ECG signal into cardiac cycles, and detection of the main events and intervals in each cycle. Major features such as the QRS amplitude, R-R intervals, waves slope of ECG signal can be used as features to create the mapping structure.

B. Preprocessing

The first step of signal pre processing is filtering the ECG signal because as any other measured signal, ECG is also contaminated with high frequency noise. The unwanted noise of the heart biopotential signal must be removing. ECG were filtered using a bandpass filter between 0.05HZ-100Hz to eliminate the motion artifact, baseline wander and 50Hz notch filter to eliminate power line noise.

C. Features Extraction using DWT

The Wavelet Transform (WT) is designed to address the problem of non-stationary ECG signals. It derived from a single generating function called the mother wavelet by translation and dilation operations. The main advantage of the WT is that it has a varying window size, being broad at low frequencies and narrow at high frequencies, thus leading to an optimal time-frequency resolution in all frequency ranges.

The WT of a signal is the decomposition of the signal over a set of functions obtained after dilation and translation of an analyzing wavelet [13]. The ECG signals which consisting of many data points, can be compressed into a few features by performing spectral analysis of the signals with the WT. These features characterize the behavior of the ECG signals. Using a smaller number of features to represent the ECG signals is particularly important for recognition and diagnostic purposes [14].

The ECG signals were decomposed into time-frequency representations using Discrete Wavelet Transform (DWT). The DWT technique has been widely used in signal processing tasks in recent years. The major advantage of the DWT is that it provides good time resolution. Good resolution at high frequency and good frequency resolution at low frequency. Because of its great time and frequency localization ability, the DWT can reveal the local characteristics of the input signal.

The DWT represents a 1-Decompodition signal s(t) in terms of shifted versions of a low pass scaling function φ(t) and shifted and dilated versions of a prototype bandpass wavelet function ψ(t).

$$\Psi_{j,k}(t) = 2^{(-j/2)}\, \psi\,(2^{-j}\, t - k) \qquad (1)$$

$$\varphi_{j,k}\,(t) = 2^{-j}\, \varphi\,(2^{-j}\, t - k) \qquad (2)$$

where: j controls the dilation or translation
k denotes the position of the wavelet function

Discrete Wavelet Transform is also referred to as decomposition by wavelet filter banks. This is because DWT uses two filters, a low pass filter (LPF) and a high pass filter (HPF) to decompose the signal into different scales. The output coefficients of the LPF are called approximations while the output coefficients of the HPF are called details. The approximations of the signal are what define its identity while the details only imparts nuance.

The DWT can be calculated at different resolutions using Mallat-algorithm to utilize successive lowpass and highpass filters to compute DWT.

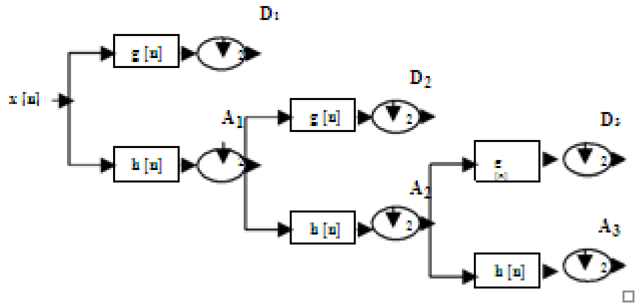

Figure 3: Decomposition of DWT

The procedure of DWT decomposition of a input signal x[n] is schematically shown in the Figure 3 above. Each stage consists of two digital filters and two downsamplers by 2 to produce the digitized signal. The first filter, g[n] is the discrete mother wavelet, which is high-pass filter, and the second, h[n] is low-pass filter. The downsampled outputs of first high pass filters and low-pass filters provide the detail, D1 and the approximation, A. The first approximation, A1 is decomposed again and this process is continued. The decomposition of the signal into different frequency bands is simply obtained by successive highpass and lowpass filtering of the time domain signal. The signal decomposition can mathematically be expressed as follows:

$$y_{hi}[k] = \Sigma\, x[n].g[2k - n] \qquad (3)$$

$$y_{lo}[k] = \Sigma\, x[n].h[2k - n] \qquad (4)$$

D. ECG Classification using Neuro Fuzzy

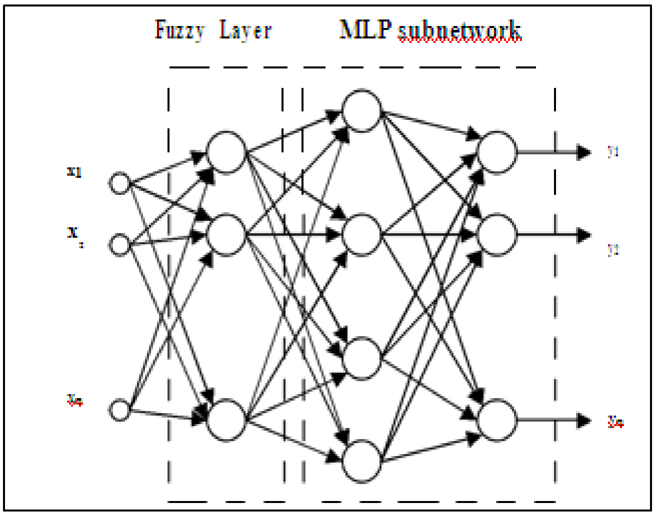

Figure 4: Structure of the Neuro Fuzzy adapted from [2]

In the classifier stage, the idea to apply fuzzy hybrid neural network which composed of two subnetworks connected in cascade. The cascading of the fuzzy self-organizing layer performing the pre classification task and the Multilayer Perceptron (MLP) of Neural Network working as the final classifier which is the fuzzy rules are modeled by artificial neural networks (ANNs)

In the fuzzy self-organizing layer, it is responsible to analyze the distribution of data and group the data into the different membership values. This membership value is applied as the input vector to the MLP Neural Network classifier. The membership value also representing the parameter of each heart beat class. The used of Fuzzy neural network has a number of advantages when compared to ordinary learning of neural networks class. The fuzzy neural network is more tolerant to the noise and less sensitive to the morphological changes of the ECG characteristics.

E. Neuro Fuzzy Model

A Neuro Fuzzy model contains three main components, which are fuzzification stage, the rule base and the defuzzification stage.

1. The first layer represents the direct input layer. Each node represents one ECG feature and sends this input variables from the features extraction to next layer directly.
2. The second layer is the fuzzification layer. In this layer, each extracted ECG feature is fed to fuzzy nodes. These nodes perform to transform the crisp values of the input variables into fuzzy membership values. It represent the membership degree of the input ECG feature to its linguistic description.
3. The third layer represents the fuzzy rules stage. Each node in this layer represents one fuzzy if-then rule.
4. The last layer is the neural network connecting layer. The

linguistic description will shows the ECG classification result of each lead group. Based on the Mamdani model [16], the fuzzy system by existing knowledge described as:

Rule i, R^i: IF x_1 is A^i_1 and x_2 is A^i_2 …and x_n is A^i_n,
THEN y^i is C^i (5)

Where R^i (I =1,2…,n) denotes the ith fuzzy rules. $x=(x_1,x_2,..,x_n)$ is the input vector,
y^i is the output of the fuzzy rule R^i
$A^i j$ (j=1,2, ..., n) are fuzzy membership function (linguistic description)

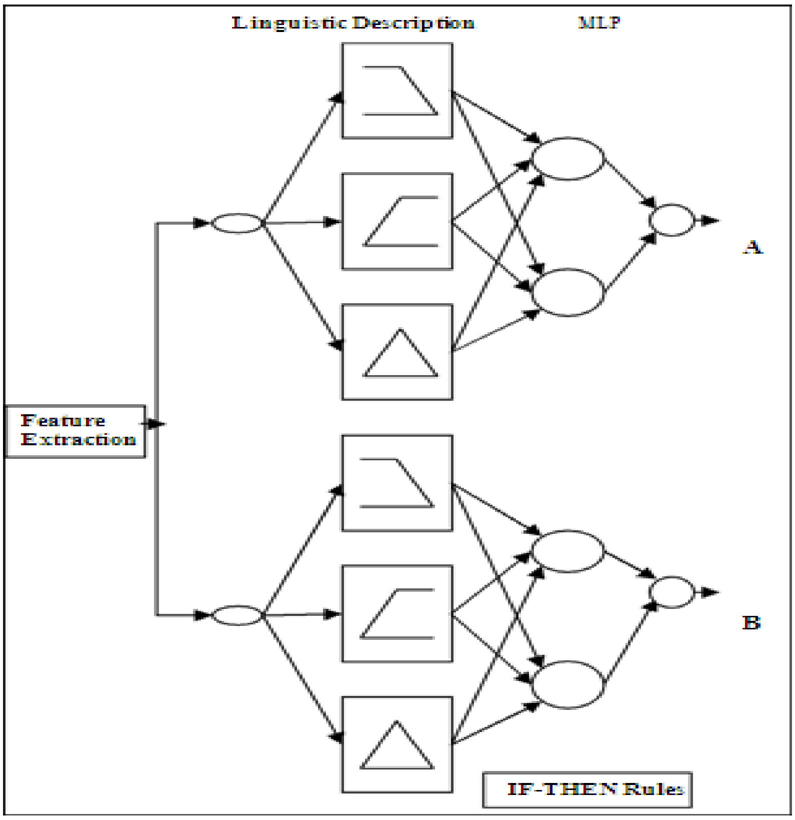

Figure 5: Feedforward Neuro-Fuzzy

The performance measures used to evaluate the performance of the classifiers were accuracy, sensitivity, specificity.
(i) Specificity = number of correct classified normal Number of total normal beats
(ii) Sensitivity =number of correct classified heart disease Number of total heart disease
(iii) Accuracy = Number of beats correctly classified Total number of beats tested

IV. RESULT

The experiment result of ECG analysis using MATLAB programming has been done to show the preprocessing of biosignal analysis before the features extraction process. The ECG Database from Holy Hospital has been used for ECG input signal of the preprocessing stage.

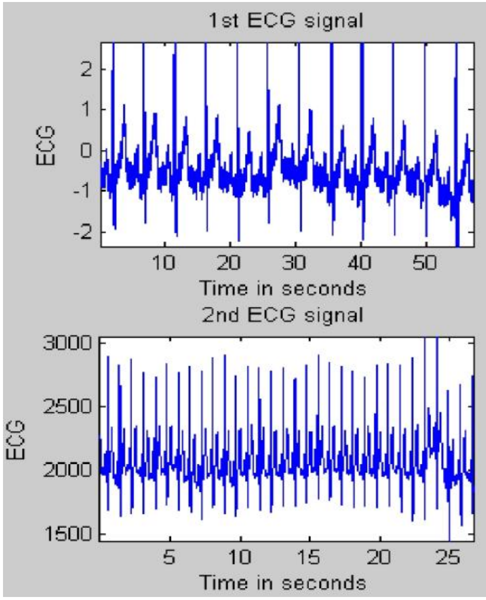

Figure 6: Original ECG signal

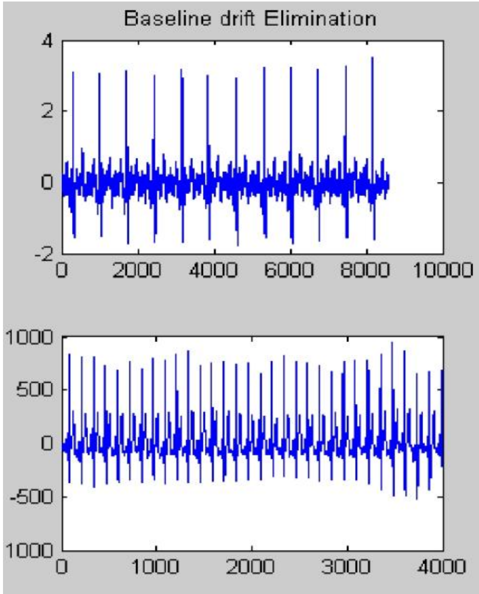

Figure 7: Baseline Elimination of ECG signal

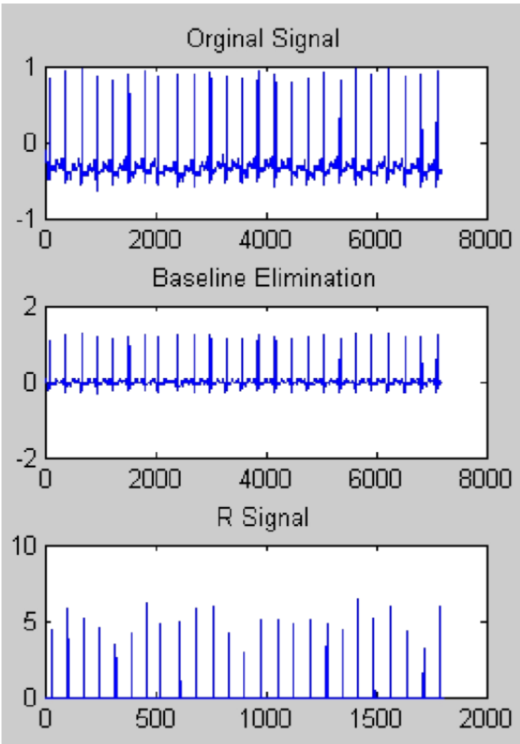

Figure 8: Flow of ECG signal process

V. CONCLUSION

This paper has presented the system which based on the application of Neuro Fuzzy network for reliable heartbeat classification on the basis of the ECG waveform. The DWT characterization will delivers the stable features to the morphology variations of the ECG waveforms. The potential of accuracy rate for Neuro Fuzzy system as ECG diagnostic decision aid is very high.

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