Performance Evaluation of ANFIS for Classification of PCG Signal Using Wavelet Transform

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***Abstract*— Heart is the most important part of any living being, and hence for the humans also. In recent years, it has been seen that the deaths have been highly increased due to heart disease all over the world. The need of fast and accurate detection of heart disease has been increased and acquires the highest importance in the field of research. There has been a lot of work done for the ECG signal for its segmentation, and classification, but it does not fulfill the requirement of heart disease detection so accurately. The discovery PCG signals gave a great hope, and hence a lot of work has also been done of PCG Signal segmentation and feature extraction. In continuation, the experimental results from different literatures need to be studied and to be used for detection of heart disease. The PCG signal has been analyzed and the feature has been extracted based on the best method shown in the literature. Further, these feature features has been used for the classification of the PCG signal for different heart disease acquired by the patient. ANFIS is the tool used for the classification and on training the system it proves to be the best for classification of heart disease.**

Index Terms*— *ANFIS, Wavelet, kNN, PCG, Membership Function (MFs).

I. Introduction

The heart is the most important part of any living being, and hence for the humans also. In recent years, it has been seen that the deaths have been highly increased due to heart disease all over the world [1]. The requirement of accurate detection of heart disease has forced researchers to develop a system which can help to detect the disease and cure it as soon as possible. The discovery of PCG signal is a pave to drag the concentration towards this topic. In recent years a lot of work has been done on ECG signal and a lot of information has been extracted and has been used for different purposes. Although ECG signal has been analyzed to a greater level, it is not sufficient to detect the heart disease because it deals with the electrical behavior of the heart, while abnormalities in heart are mostly due to change in shape of the chambers of the heart. The blood flow from heart to lungs and then from lungs to heart and different parts of the body, this flow of bloods with specific pressure and volume, produces the heart sound. These heart sounds are called as Phonocardiogram signal. Phonocardiogram signal is non-stationary signals with a frequency of 10 KHz and provide the experienced doctors a path to find the disease acquired by a person. Hearing to PCG signal the experienced doctors understand the disease and cure accordingly. There is always exists a chance of wrong detection of disease because of the doctor's inability to hear the sound properly, his perseverance and his experience. Hence there is a need of developing a decision support system that can support doctors independent of their experience and any unfavorable physical conditions. The system includes the feature extraction of signal, here PCG signal, using discrete wavelet transform specially dabocious wavelet as this can provide better information than other wavelets like her, simulate, coiflet etc. Phonocardiogram signal is a nonstationary signal and hence discrete wavelet transform is the best to analyze [2]. Then for the purpose classification of PCG signal, Adaptive Neuro Fuzzy Inference System (ANFIS) has been used. The training of the system is done by the heart sound available in various website of medical sciences on the World Wide Web. ANFIS system is powered with the feature of Neural Network as well as Fuzzy Inference System both and hence can classify the PCG signal more accurately compared to other type of classifier like kNN classifier or NN classifier. Despite the recent developments on echocardiography for heart examinations are now available, cardiac auscultation remains the most important and screening, diagnostic method for early diagnosis of heart valve diseases. The necessity of early detection is to give a warning sign for further investigations before the serious pathological conditions of heart diseases occur. In addition, detection of heart sounds can be obtained by a technique known as phonocardiography. Phonocardiography displays the graphical representation of the heart sounds. It is easy to use and non-invasive. It provides the diagnostic information for detection of the abnormal function of the cardiac valves in clinical practice.

II. PROBLEM IDENTIFICATION AND SOLUTIONS

Phonocardiogram signal is the nonstationary signal, hence a perfect tool is required to analyze the signal. Various methods of feature extraction are available like Fourier Transform, Fast Fourier Transform, Discrete Fourier

Manuscript received July, 2014.
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ISSN: 2278 – 909X

Transform, Wavelet Transform, Discrete Wavelet Transform etc. the selection of appropriate feature extractor is a big challenge for the system. Literature suggests that DWT provides better feature compared to other feature extractor with no loss in data [3]. Signal varies much in its length and contains many redundant information, these signals needs to be reshaped to get it in the required format. Deciding the length of the signal which can provide better results in feature extraction plays an important role. Variation in length of the signal misguides the system at the time of training which leads to wrong detection. On analysis a length of 85525 has been observed to produce better results. After deciding the feature extraction method, the database is prepared so as to use it to train the ANFIS system. There exists a number of classifier again deciding the best one is beg challenge. Literature suggests that fuzzy systems produce better results compared to other classifier and ANFIS which incorporates the feature of neural network and fuzzy inference system produces the best results compare to other type of classifier. Then the input signal which needs to be detected for disease are given as an input to the system, and here again the feature of the input signal is extracted and passed to the trained system for matching the signal with the database so as to produce the output as the name of the disease acquired by the patient. During input we again have to take care of the signal that it should not have greater length, which may lead to misclassification of the signal.

III. METHODOLOGY

The detection of the heart disease via a decision support system is a tool for the doctors and especially for the novice doctors who know about the disease and their remedy, but due to lack of experience they are not able to detect the disease particularly. The system is developed using MATLAB 2012a. This system takes as an input the heart sound, processes it and then produces the output as the name of the disease acquired by the person whose heart sound is under test. The processed output is the name of disease acquired by the patient. The process is highly reactive and as soon as the disease is identified by the doctors they can soon take the corrective measures to prevent the further losses that can happen to the patient due to the long term acquisition of the disease by the patient. The data flow diagram shown below presents the process followed by the system in the detection of the heart disease.

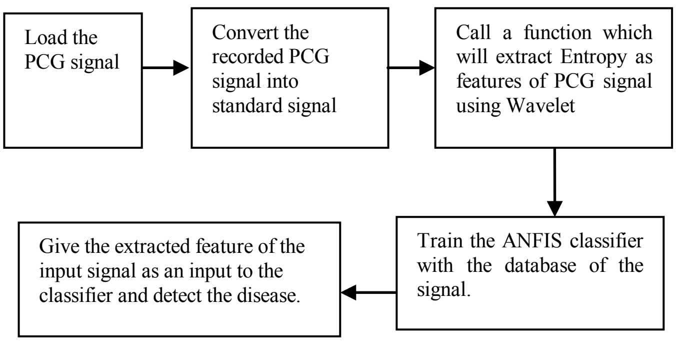

Fig -1: Block diagram representation of whole process

The process involves five different stages in the development of the system. Initially the PCG signal is loaded to the system. The signal is then converted into the standard format, i.e. in the desired form and then it is given as in input to a function which extracts the feature of the PCG signal using db10 wavelet. The Mitral Regurgitation signal is analyzed by Daubechies Wavelet (db10) at a level of 5 and the analyzed signal can be obtained as below.

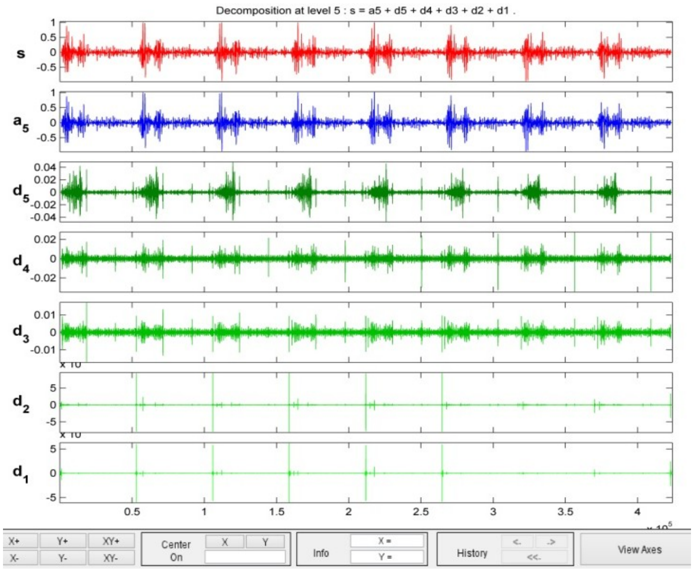

Fig -2: Signal analysis using db10 at level5

The graph shown in red color is the input signal; the graph in blue color represents the approximate information through approximate coefficient while graph in green color represents the detailed information through detailed coefficient. Through this technique the system analyzes the input signal and features like Entropy, Energy and Variance of the signal can be extracted. Entropy provides better information about the PCG signal and hence can be used for the classification of signal. For the purpose of classification ANFIS (Adaptive Neuro-Fuzzy Inference System) has been used. The architecture of ANFIS includes five layers; Layer1 (Inputs Layer), Layer2 (Fuzzy AND Operation), Layer3 (Normalization), Layer4 (Normalization of Each Rule Firing Strength), and Layer5 (Output Layer), which follows the process as shown below.

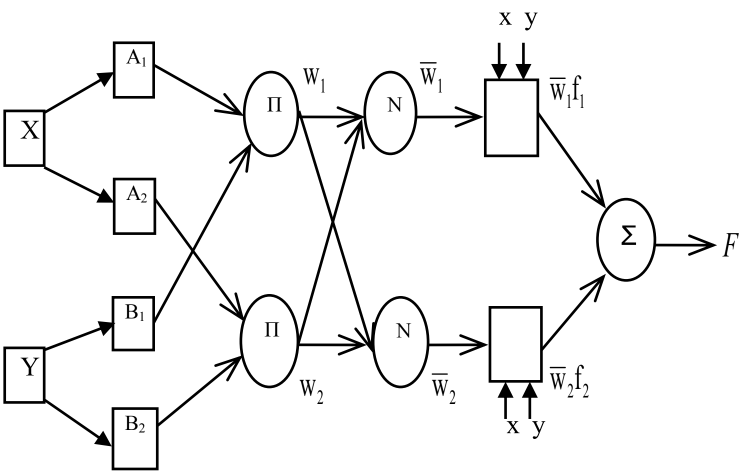

Fig -3: Architecture of ANFIS system

A Two Rule Sugeno Type ANFIS has rules of the form:

ISSN: 2278 – 909X

$$If\ x\ is\ A_1\ and\ y\ is\ B_1\quad THEN\ f_1 = p_1x + q_1y + r_1$$
$$If\ x\ is\ A_2\ and\ y\ is\ B_2\quad THEN\ f_2 = p_2x + q_2y + r_2$$

For the training of the network, there is a forward pass and a backward pass. The forward pass propagates the input vector through the network, layer by layer. In the backward pass, the error is sent back through the network in a similar manner to Backpropagation network.

At Layer1 the output of each node is:

$$O_{1,i} = \mu_{A_i}(x) \qquad for\ i = 1,2 \quad \text{.......................... (1)}$$

$$O_{1,i} = \mu_{B_{i-2}}(y) \qquad for\ i = 3,4 \quad \text{.......................... (2)}$$

So, $O_{1,i}(x)$ the is essentially the membership grade for x and y. The membership functions could be anything but here a bell shaped function is used which is given by:

$$\mu_A(x) = \frac{1}{1 + \left|\frac{x - c_i}{a_i}\right|^{2b_i}} \quad \text{.......................... (3)}$$

where a_i, b_i, and c_i are the premise parameters.

At Layer2, every node is fixed. This is where the t-norm is used to 'AND' the membership grades given by:

$$O_{2,i} = w_i = \mu_{A_i}(x)\mu_{B_i}(y), \quad i = 1,2 \quad \text{...................... (4)}$$

At Layer3 fixed nodes are present, which calculates the ratio of the firing strengths of the rules given by:

$$O_{3,i} = \overline{w_i} = \frac{w_i}{w_1 + w_2} \quad \text{.. (5)}$$

At Layer4 the nodes are adaptive and perform the consequences of the rules:

$$O_{4,i} = \overline{w_i} f_i = \overline{w_i}(p_i x + q_i y + r_i) \quad \text{...................... (6)}$$

The parameters p_i, q_i and r_i in this layer are to be determined and are referred to as the consequent parameters.

At Layer5 there is a single node that computes the overall output, which is given by:

$$O_{5,i} = \sum_i \overline{w_i} f_i = \frac{\sum_i w_i f_i}{\sum_i w_i} \quad \text{............................ (7)}$$

This is how, typically, the input vector is fed through the network layer by layer.

The process discussed above shows the process how an ANFIS system works. In the proposed work the system is trained by the database. The database is prepared by collecting many heart murmurs from different places and then those signals are processed to obtain the entropy of the signals. The set of entropy information of all the murmurs forms a database. The number of values of entropy i.e. the number of values among all the values extracted by decomposing the signal using db10 should be chosen appropriately. Here highest eight values are taken into account to give as an input to the system to train it. The ANFIS system is trained by defining the following parameters along with the database.

Table 5.1: ANFIS architecture and training parameters

Modeling Description	Setting
Number of inputs	8
Number of outputs	1
Type of input membership functions	gaussmf
Number of input membership functions	2
Type of output membership functions	Linear
Number of Rules	256
Learning rule (Optimization Method)	hybrid
Max. Epochs (Stopping Criterion)	50
Error tolerance (Training Error Goal)	0.01
Initial step size	1

As mentioned above, eight values are chosen for input and the number of membership functions is two hence the number of rules formed is 256 ((8×2)2). However, if the number of membership function and the number of input increases, more number of rules will be prepared, which is good in one way, but the problem is the computation complexity and so the system will take more time to train itself moreover the software may run out of memory. Hence we have to choose an optimum value to tradeoff between number of inputs and number of membership functions. A good pair for the same has been obtained as eight inputs with two membership function which is used in the proposed system. The structure and rule base of the system is shown below.

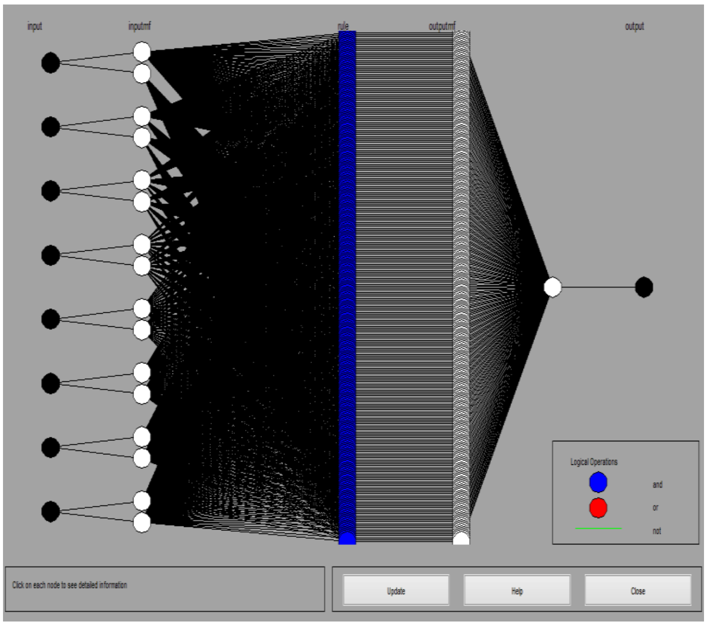

Fig -3: Structure of ANFIS system

ISSN: 2278 – 909X

Fig -3: Structure of ANFIS system

As soon as the system is trained it is ready to accept the test input signal. The test signal is also processed to attain its entropy and then the system, according to the fuzzy logic developed after training, identifies the disease represented by the test signal. Here at the point of inputting the test signal it should be taken into consideration that the test signal should also be changed to standard format according to the requirement of the system; a very short signal may not be able to provide sufficient information for classification while a very lengthy system may confuse the system in the course of detection of the disease. Under these considerations, the system is developed and produces the output as the name of disease acquired by the patient.

IV. RESULTS AND DISCUSSION

The validity of the proposed procedure is proven by means of extensive computer simulations. The results obtained for Aortic Stenosis, Aortic Regurgitation, Mitral stenosis, Mitral Regurgitation and Normal Heart Sounds is illustrated in this section. The figure below shows the ANFIS structure which is generated in MATLB while simulation of the system. The database is prepared in required format and is passed on to the system for training purpose. The figure below shows there are eight input feature for the system which are the entropy extracted as feature by db10 at level5 with 2 membership function, 256 rules and one constant output which is particularly the name of the disease conceived by the patient.

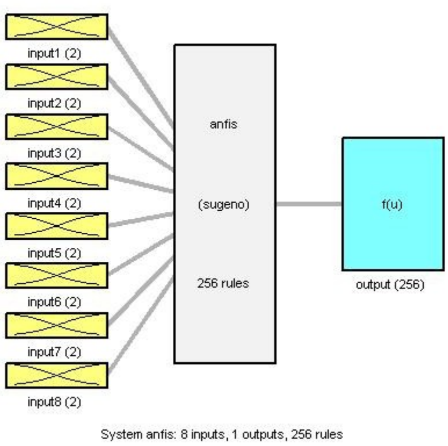

Fig -4: System Architecture

The input signal is taken and then it is processed to get it into the desired form so any extra information that does not disinfect the output. The figure below shows one of the signals, and then the processed signal, the entropy of which is given as an input to the ANFIS system.

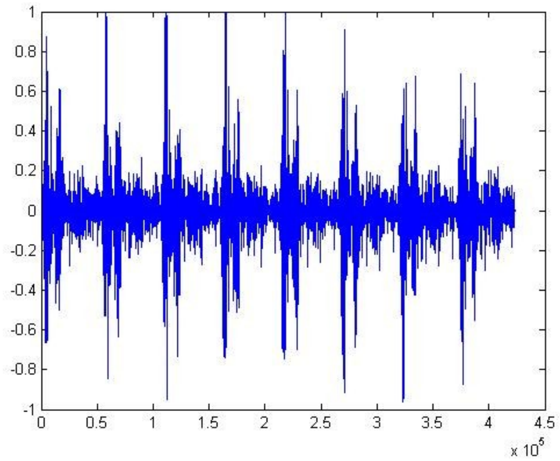

Fig -5: Input signal (Mitral Regurgitation)

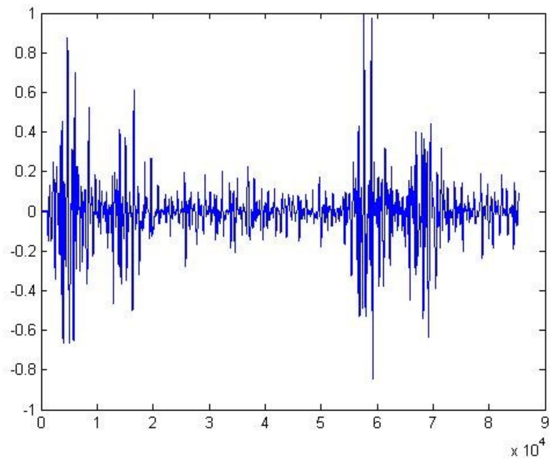

Fig -6: Transformed input signal

The input signal is fuzzified with two membership functions which are represented below. The MF (Membership Function) can be increased more than two, but with the increase in MF, the rules get increased and in turn it is observed that with large MFs MATLAB may run out of memory.

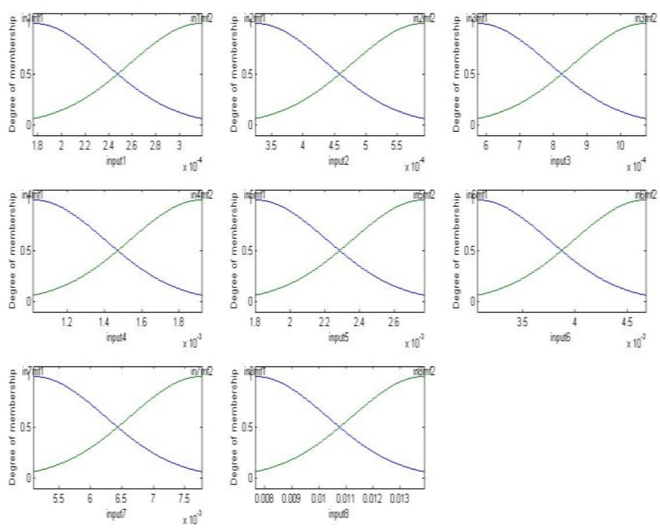

Fig -7: Membership grade of inputs with 2 MF

ISSN: 2278 – 909X

These membership functions after fuzzificaton gives the values to the next level of normalization and for the application of rules formed by the system which leads to train the ANFIS system and to provide the result as the detected disease. While training the system, various errors have been incurred by the system at each epoch of training. The RMSE with respect to training epochs has been shown below.

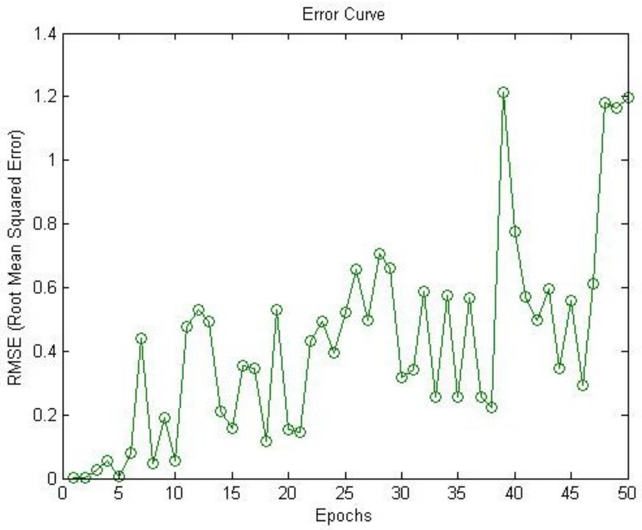

Fig -8: Error output while training the system

The graph above shows that the error is increasing and decreasing with the number of epochs selected, and has minimum error at the initial point. The advantage of using ANFIS is that it uses the parameter with respect to the minimum error, no matter whether it occurs in the first or last or at any epoch in between. The training epochs can be increased to any level, but it has been observed that the computing complexity and time required increases significantly with increase in training epochs.

V. CONCLUSIONS

The simulation results show that the developed system performs better with the method adopted for feature extraction, and classification of the signal. While analyzing the result, it has been observed that the system is working perfectly for the signal which is 30 to 40 second long, but it produces 99% results for the signal which mismatches the desired signal length. One percent deviation is due to the inappropriate signals which are either very noisy of whose signal feature could not be extracted at the desired level. The developed system produces a very effective and accurate decision support system for the novice doctors to cure the patient which are in urgent need of auscultation for detection of pathological condition of the heart. It can also be used at the home premise for early detection of the pathological condition of the patient by any person with some knowledge of medical background whenever it felt to be so necessary.

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ISSN: 2278 – 909X