



Detection of Normal ECG and Arrhythmia Using Adaptive Neuro-Fuzzy Interface System

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Abstract-Now a day we have various intelligent computing tools such as artificial neural network (ANN) and fuzzy logic approaches are proving to be dexterous when applied to a range of problems. In this paper we applied the ANFIS (Adaptive Neuro-Fuzzy Interface System) tool for detecting the normal and abnormal signal. Here the designed ANFIS model contained both approaches the neural network adaptive potential approach and the fuzzy logic qualitative approach. Hybrid method is used as an optimization method. The Electrocardiogram (ECG) dynamic and nonlinear signal characteristic requires an accurate and precise detection and recognition system. This paper describes the detection of a MIT-BHI normal sinus ECG database signal and MIT-BHI Supraventricular ECG database signal based on ANFIS approach. Some conclusions regarding the classification of the ECG signals is obtained through analysis of the ANFIS. The proposed ANFIS modal gives the 100% accuracy for normal ECG detection and 91% accuracy for abnormal ECG detection. Classification accuracies and the results created by the ANFIS confirmed that the proposed ANFIS model is very efficient in classifying the normal and abnormal ECG signals. but in our research we have taken the 1 min complete ECG include of many ECG bits is taken for analysis.

Keywords: Adaptive Neuro-Fuzzy Interface System (ANFIS), Electrocardiogram (ECG) , Fuzzy logic, MIT-BHI database.

I- Introduction

Cardiac problems are increasing day by day. ECG is one of the most commonly used tests to diagnose the heart problem. Detection and treatment of arrhythmias have become one of the cardiac care unit's major functions. Few of the arrhythmias are Ventricular Premature Beats, a systole, Couplet, Bigeminy, Fusion beats. [1], the objective of ANFIS is to integrate the best features of fuzzy systems and neural networks. The advantage of fuzzy set is the representation of prior knowledge into a set of constraints to reduce the optimization research space is utilized.[2] for getting the best result toward the unknown and unseen data the size of the training database should be at least as large as the number of modifiable parameters in ANFIS. Electrocardiogram (ECG) represents the electrical activity of the heart. When the ECG is abnormal, it is called arrhythmia. Millions of ECGs are taken for the diagnosis of various classes of patients, where ECG can provide a lot of information regarding the abnormality in the concerned patient are analyzed by the physicians and interpreted depending upon their experience. The interpretation may vary by physician to physician. Hence this work is all about the automation and consistency in the analysis of the ECG signals so that they must be diagnosed and interpreted accurately irrespective of the physicians.[3] the recorded ECG waveform which is made of distinct electrical depolarization and repolarization patterns of the heart. Any disorder of heart rate or rhythm, or change in the morphological pattern, is an indication of an arrhythmia, which could be detected by analysis of the recorded ECG waveform. A typical cycle of an ECG is shown in Fig. 1. Physicians first locate such fiduciary points as Q points, R points, and S points in the ECG from which they locate the P-complexes, QRS-waves, T-complexes, and U-waves in the ECG. These waves and complexes are defined in Fig. 1. Physicians then interpret the shapes of those waves and complexes. They calculate parameters to determine whether the ECG shows signs of cardiac disease or not. The parameters are the height and the interval of each wave, such as RR interval, PP interval, QT interval, and ST segment (Figure 1).[4]

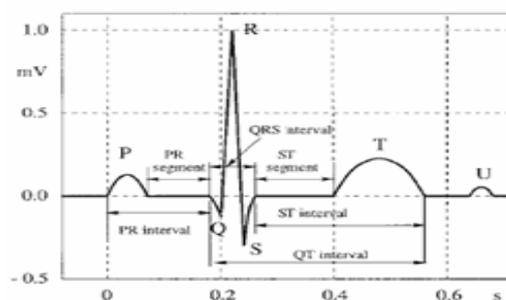


Figure 1 The ECG signal and its different components

In this paper we applied normal sinus ECG database and Supraventricular Arrhythmia database, the normal sinus rhythm not only give you an idea about the rhythm is normally generated from the sinus node and wandering in a normal manner in the heart. In most of the research paper single ECG bit taken for analysis, but in our research we have taken the 1 min complete ECG include of many ECG bit is taken for analysis which has taken a great care in case of heart beat variability. The normal value of heart bit rate depends upon age it is not same for all the normal people, normal heart rate for an infant is 150 beats in one minute maximum, even the heartbeat rate of child of five year age may 100 beats in a minute, the heart rate of adult is slower than the child, it is about 60-80 beats in one minute. In normal sinus rhythm of heart p-waves are pursued after a short gap by a QRS complex followed by a T-wave of ECG the cause of Supraventricular Arrhythmia is a quick heart rhythm of the upper chambers of the heart. In Supraventricular Arrhythmia electrical signals or the electrical potential move through the upper chambers to lower chambers of the heart. Supraventricular Arrhythmia are usually 150-250 beats per minute but it can be both slower or faster. The most common types of supraventricular tachycardia are caused by a reentry phenomenon producing accelerated heart rates. Normally, Supraventricular Arrhythmia results in symptoms such as frequent heart beating, dizziness, shortness of breath and chest discomfort.

The image of the normal sinus rhythm database (16265) and supraventricular Arrhythmia (801) duration of 10 Sec and 128 Hz sampling rate of MIT-BHI is shown in the figure-(2-a,b).[5]

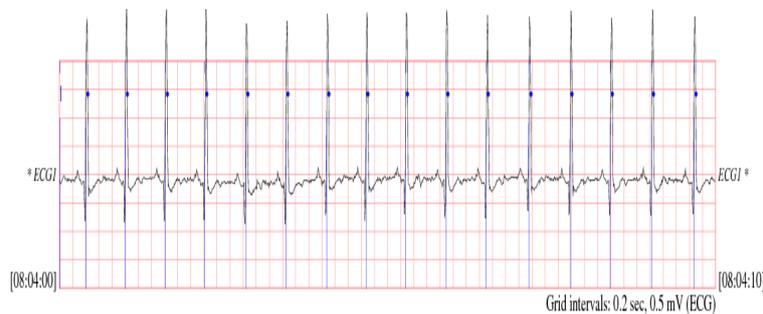


Figure 2-a normal sinus 16265 signal of MIT-BHI



Figure 2-b Supraventricular Arrhythmia 800 signal of MIT-BHI

II- ANFIS

In this paper we use adaptive Neuro-fuzzy interface tool for training and testing the database, here ANFIS is an adaptive network which uses neural network topology and fuzzy logic together; ANFIS uses the characteristics of both methods. The combination of both methods removes the some disadvantage of both the method. Actually, ANFIS is like a fuzzy inference system but in ANFIS feed-forward back propagation to minimize the error. Mamdani type and Takagi-Sugeno type is commonly used system in ANFIS. In our analysis, we use zero-order Takagi-Sugeno fuzzy inference system.

The ANFIS first introduced by Jang in 1993, It is a model that maps inputs through input membership Functions (MFs) and associated parameters, and then through output MFs to outputs. The initial membership functions and rules for the fuzzy inference system can be designed by employing human expertise about the target system to be modeled. ANFIS can then purify the fuzzy if-then rules and membership functions to describe the input-output behavior of a complex system. Jang showed that even if human expertise is not available it is possible to intuitively set up practical membership functions and employs the neural training process to generate a set of fuzzy if-then rules that approximate a desired data set[6-7].

Five layers are used to create this inference system. Each layer involves several nodes described by node function. The output signals from nodes in the previous layers will be accepted as the input signals in the present layer. After manipulation by the node function in the present layer will be served as input signals for the next layer. Here square nodes, named adaptive nodes, are adopted to represent that the parameter sets in these nodes are adjustable. Whereas, circle nodes, named fixed nodes, are adopted to represent that the parameter sets are fixed in the system. For simplicity to explain the procedure of the ANFIS, we consider two inputs x , y and one output f in the fuzzy inference system. And one degree of Sugeno's function is adopted to depict the fuzzy rule.[6-7]

ANFIS gives a powerful tool for data classification.
for example:

Rule 1: If x is A1 and y is B1 then $f_1 = a_1 x + b_1 y + c_1$

Rule 2: If x is A2 and y is B2 then $f_2 = a_2 x + b_2 y + c_2$.

The given figure 3 is the ANFIS architecture of 5 layer.[6-7]

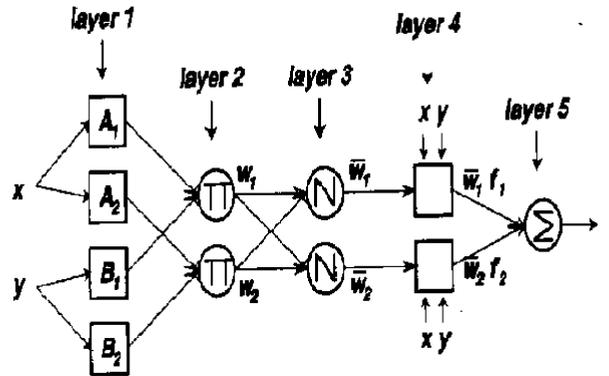
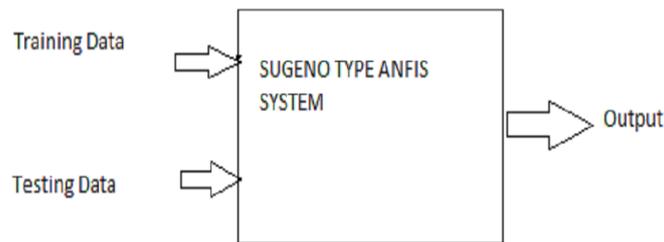


Figure 3 ANFIS Architecture

The block diagram of the ANFIS system is shown in the figure-4, two arrows indicate the training data and testing data that applied to the sugeno type ANFIS system. Training data used for preparing the network architecture and decide the input and output range according to the training function, number of epoch, the method used for optimization and number of membership functions is used for training. After this test data is applied, on the basis of proposed ANFIS network output is determined in the form of number.



ANFIS system for Detection normal and abnormal ECG Signal

Figure 4

The coding sugeno type network is done with the help of book MATLAB “An Introduction with Applications” written by Amos Gilat on MATLAB 7.10.0 (2010a) software.[8]

III- Methodology

The MIT-BIH Database contains 48 half-hour excerpts of two-channel ambulatory ECG recordings, obtained from 47 subjects studied by the BIH Arrhythmia Laboratory between 1975 and 1979. The recordings of normal sinus ECG (ECG1) database and Supraventricular ECG (ECG1) database were digitized at the rate of 128 samples per second per channel with the resolution of 11-bits over a span of 10 mV.[5] In our method we use 18 ECG Signal of normal sinus database, out of 18 we use 14 in training and 4 in testing. The duration of one ECG is 60 Sec with sampling rate 128 Hz and total sample of an ECG signal is 7680 some of the abnormal ECG is called arrhythmia in our paper we have taken supraventricular database. In abnormal database we take supraventricular arrhythmia database of 61 ECG signal out of 61 ECG signal 14 signal used for training and 47 used for testing. The sampling rate of supraventricular ECG signal is same as a normal ECG signal.

Sugano type system is used for training and testing, total number of input membership functions used is 2, total number of output membership functions used is 2,2 num rules is used, input range is [-2890 4690] and output range [0 1]. We use a hybrid method which is a grouping of both least-squares estimation method and back-propagation Method, as an optimization method.

IV- Input Data

The input database is given in the matrix from shown in the table

Name	Total	Training	Testing
Normal ECG Database	18	14	4
Supraventricular ECG database	61	14	47

From the above table the total 79 ECG signal is used for analysis, out of 79, 28 is used for training and remaining 51 used for testing.

V- Analysis

A membership function is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The trapezoidal membership function, Trapmf, has a flat top and really is just a truncated triangle curve. These straight line membership functions have the advantage of simplicity.[9] We applied the above input database to ANFIS tool of MATLAB-2010a , the Trapezoidal-shaped built-in membership function is used as an input membership function and output membership function is linear type. There are two membership functions for input and two for output and number of epochs is 10.testing data of both ECG is given is given in the table.

VI- Trapmf

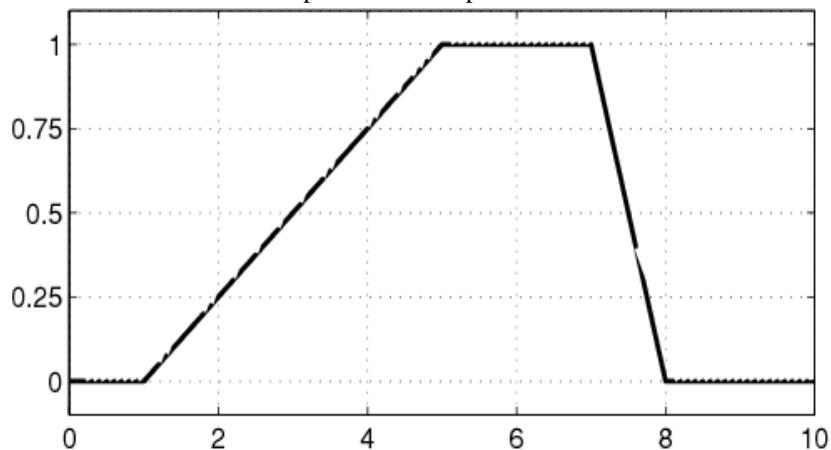
The trapezoidal curve is a function of a vector, x , and depends on four scalar parameters a, b, c , and d , as given by

$$f(x; a, b, c, d) = \begin{cases} 0, & x \leq a \\ \frac{x-a}{b-a}, & a \leq x \leq b \\ 1, & b \leq x \leq c \\ \frac{d-x}{d-c}, & c \leq x \leq d \\ 0, & d \leq x \end{cases}$$

or, more compactly, by

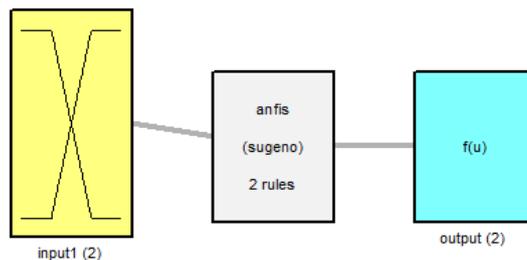
$$f(x; a, b, c, d) = \max \left(\min \left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c} \right), 0 \right)$$

The parameters a and d locate the "feet" of the trapezoid and the parameters b and c locate the "shoulders." [10]



trapmf. P = [1 5 7 8]
Figure 5 trapezoidal curve

The figure 6 sugeno type ANFIS system is shown the relation between the input and output there are two input function and two output functions and two rules is used for the training and testing. here $f(u)$ is the function of the output and the figure 7,8 show rule applied for training and testing.



System anfis: 1 inputs, 1 outputs, 2 rules

Figure 6 ANFIS system

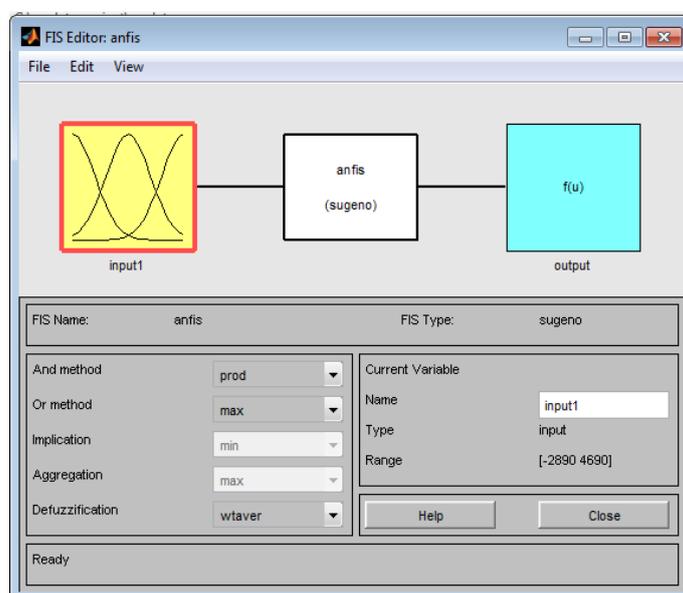


Figure 7 ANFIS FIS editor

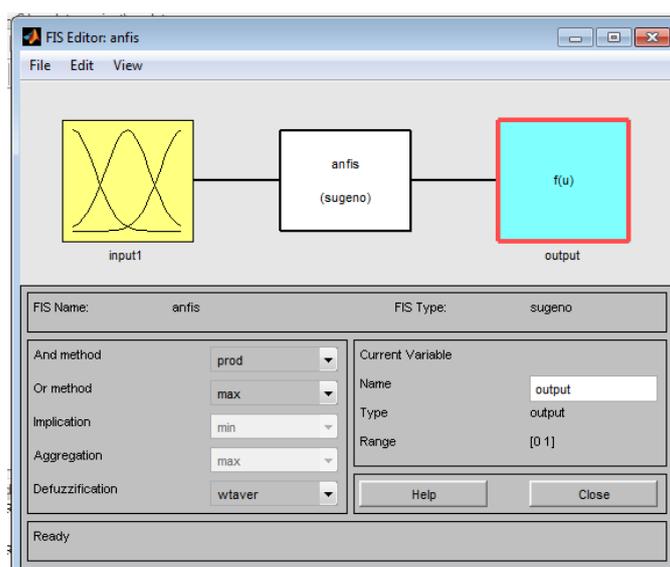


Figure 8 ANFIS editor

Figure 9 is the graph between the input and the degree of membership (lies between 0 and 1). here inmf1 and inmf2 are the INMFLabels. The degree of membership for in1mf1 is varies 1 to 0 to the input range [-2890 4690] and for the in2mf2 degree of membership varies 0 to 1 to the input range [-2890 4690].

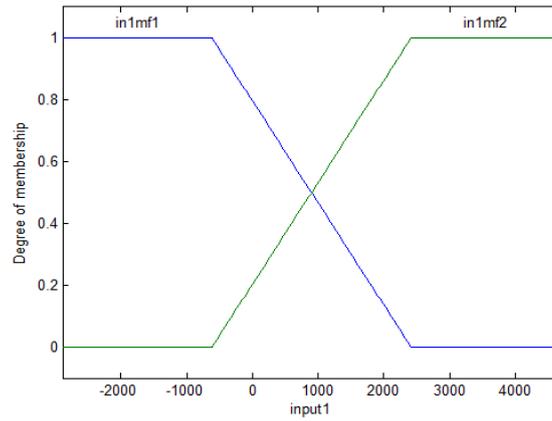


Figure 9 ANFIS Plot of membership function

Fig-10 show the ANFIS rule viewer, where the left part indicates the input in yellow colour and right part indicate the output in blue colour correspond to the input.

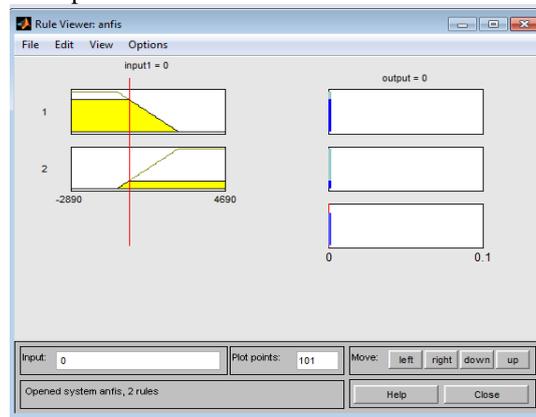


Figure 10 ANFIS Rule Viewer

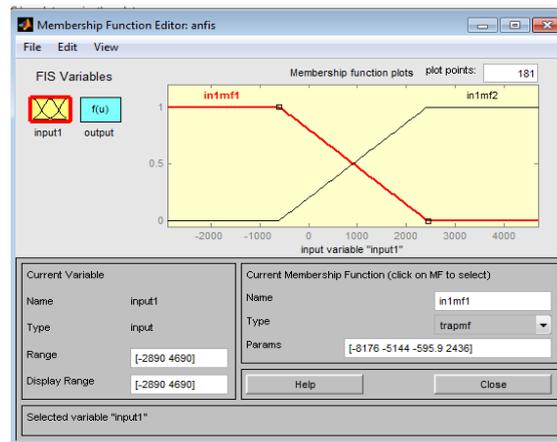


Figure 11 ANFIS membership Function editor for in1mf1

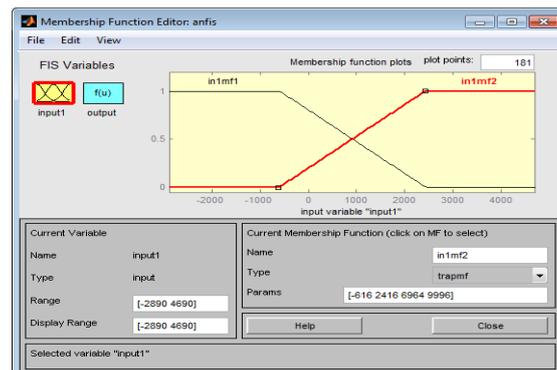


Figure 12 ANFIS membership Function editor for in1mf2

Fig-11, 12 are the membership function editor that shows detail information about the membership function.

VII- Results

Result of processing of normal and abnormal ECG signal is shown in tabular form

Name	Testing signal number	Testing Result	Overall Test Accuracy				
Normal sinus database	19093	Verified	100%	Supraventricular Arrhythmia database	858	Verified	91.48%
	19140	Verified			859	Verified	
	19539	Verified			860	Verified	
	19830	Verified			861	Verified	
Supraventricular Arrhythmia database	822	Verified	91.48%		862	Verified	
	825	Verified			863	Verified	
	826	Verified			864	Verified	
	827	Verified			874	Verified	
	828	Verified			875	Verified	
	829	Verified			876	Verified	
	840	Verified			877	Verified	
	844	Verified			878	Verified	
	845	Verified			879	Verified	
	846	Verified			880	Not Verified	
	847	Not Verified			881	Verified	
	848	Verified			882	Verified	
	849	Not Verified			883	Verified	
	850	Verified			884	Verified	
	851	Verified			885	Verified	
	852	Verified			887	Verified	
	853	Verified		888	Verified		
854	Verified	889	Verified				
855	Verified	890	Not Verified				
856	Verified	891	Verified				
857	Verified	892	Verified				
				893	Verified		

VIII- Conclusion

The conclusion resulting from this work is that, by using MATLAB based the adaptive Neuro-fuzzy interface system design and simulation. [11] Some better networks can be prepared which have the capability to understand all types of ECG database. In most of the research paper single ECG bits taken for analysis, but in our research we have taken the 1 min complete ECG include of many ECG bits is taken for analysis which has taken a great care in case of heart beat variability. This type of network can be very reliable as ANFIS provides a better and understandable set of tools so that the network parameters can be adjusted and precisely easily, such type of network can handle a large amount of database and can work easily with unseen database. The accuracy obtained by such network is comparatively good. The above ANFIS method for analysis of ECG signal gives 95.5% average percentage of correct classification without using the any feature extraction techniques. Proposed ANFIS model used for detection normal ECG and arrhythmia is proving to be a very reliable precise method of analyzing each signal.

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