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A Hybrid AI approach based on Genetic Algorithm and ANFIS for Heart Disease Diagnosis

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Abstract*: The accurate and immediate diagnosis of heart disease is very essential. AI based techniques play a vital role in the prediction of heart related problems. The aim of this work is to develop a hybrid method using adaptive neuro_fuzzy inference system (ANFIS) and genetic algorithm (GA) for heart attack prediction. This work has been carried out on two datasets: 1. Online available dataset obtained from UCI repository with seven input fields (features) and one output field (disease). 2. Primary heart disease dataset obtained from Government Medical Collage (GMC) srinagar consisting of eleven input fields (features) and one output field (disease). Genetic algorithm is used for filtering purpose to screen out the less important features. Both datasets are modeled in a way to make them suitable for training and initial FIS model structure is generated. The initial ANFIS Model structure is created using a training heart disease dataset, trained using a checking heart disease dataset and then tested and validated using testing dataset. The proposed work has been done using all features and then only selected features for both datasets and it is seen that using selected features as inputs to the trained model the testing error reduces , training time gets reduced and the anfis model structure is less complex. Besides the combination of simplified anfis and genetic algorithm, this work has also been carried out on a hybrid of GA-ANFIS-KFCM that shows better results than simplified ANFIS in terms of testing error.

Index Term: ANFIS; Genetic Algorithm; KFCM; datasets; Heart Disease.

I. INTRODUCTION

Heart disease has become one of the leading causes of death all over the world. Diseases that involve heart and blood vessels are termed as cardiovascular diseases (CVD). Most common CVDs related to blood vessels, also known as vascular diseases, include coronary artery disease, peripheral arterial disease, cerebrovascular disease, renal artery stenosis and aortic aneurysm. some of the CVDs that involve heart include cardiomyopathy, heart failure, hypertensive heart disease, pulmonary heart disease, cardiac dysrhythmias, inflammatory heart disease, valvular heart disease, congenital heart disease and rheumatic heart disease. A substance called plaque builds up in the walls of arteries due to which these blood vessels shrink that hinders the blood flow through them. This whole process is known as atherosclerosis. The most common causes of atherosclerosis are high blood pressure, diabetes, obesity, lack of exercise, high blood cholesterol, smoking, excessive consumption of alcohol and many more. According to World Health Organization report more than 80% of people in low middle income countries die every year due this disease; around 17.7 million people all over the world loss their lives as a result of this disease that comprises 31% of all deaths. Hence, prior prediction and diagnosis of this disease is essential in order to decrease the mortality rate due to heart failures. Traditionally, a large number of tests were required to predict this disease since it is based on many parameters that is a very hectic and costly procedure that some people cannot afford. Now-a-days, different AI based techniques such as neural networks, fuzzy logic, machine learning, support vector machines, genetic algorithms, etc, assist in the detection and diagnosis of CVDs. The vast availability of heart disease data and rapid development of big data analytic methods enable the applications of various AI techniques in the prediction of heart diseases that will overcome the rapid surge in healthcare costs facing the community. The hybrid AI techniques in particular are indispensible in this field as standalone AI techniques are not capable of capturing the inherent uncertainty in the heart disease diagnosis which is based on numerous parameters. Recently, researchers are combining various AI tools in order to maximize performance of the AI system; by doing so they are able to remove the limitations of one AI system by cascading it with another AI tool. Some of the hybrid AI tools include neuro-fuzzy (neural networks and fuzzy logic), fuzzy-SVM (fuzzy logic and support vector machines), neuro-SVM (neural networks and support vector machines), neuro-fuzzy-genetic algorithm. According to the proposed work, first we have used a hybrid combination of genetic algorithm and advanced neuro-fuzzy inference system (ANFIS). In this work, genetic algorithm has been used for feature selection which selects more important features from a given heart disease dataset so that we need only a few tests to diagnose this disease. The selected features are then used as input fields to the anfis model structure due to which it takes lesser time in the training process and gives better results. Advanced neuro-fuzzy inference system (ANFIS) is a hybrid combination of artificial neural networks and fuzzy logic that combines the advantages such as adaptability property from neural networks and smoothness property from fuzzy principle. on the other hand genetic algorithm is a heuristic approach based on natural evolution and helps to make the given heart disease data set less bulky by screening out the less important features (attributes) from it. The filtered datasets obtained after the application of genetic algorithm have also been tested on a simplified ANFIS model which further improves results. Similarly the given data sets have been tested on the combination of genetic algorithm, advanced neuro-fuzzy inference system and kernel based fuzzy C means classifier (KFCM). FCM is an unsupervised clustering algorithm, which allows one piece of data to belong to two or more clusters. Fuzzy clustering is a class of algorithm in cluster analysis wherein the allocation of data points to clusters is not „hard‟ but „fuzzy‟ in the same sense as fuzzy logic. Fuzzy logic is a multi-valued logic derived from fuzzy set theory, proposed by Lofti Zadeh to deal with reasoning that is approximate rather than precise. KFCM is an improvement over the standard FCM based on the use of kernel functions. This work has been carried on the heart disease dataset available in the UCI repository as well as on a primary heart disease dataset. In this work, results obtained from the hybrid combination of genetic algorithm and anfis for both the primary and UCI heart disease datasets are better in comparison when only ANFIS is used for testing and training. Similarly, when both datasets after filtering are used on a simplified ANFIS, it further improves the result.

II. RELATED WORK

During the investigation of literature, it can be seen that there exists diverse studies on the use anifis, fuzzy logic, ANN, GA in the medical field. In 2014, Negar and Iman [1] introduced adaptive neuro-fuzzy inference model (ANFIS) to classify the cleveland heart disease dataset with seven input variables obtained from UCI machine learning repository. In this, they have used k-fold cross validation technique to check the ability of trained anfis model in diagnosing the disease. This model shows an accuracy of 92.30% in forecasting the degree of disease in a patient. The training and testing errors are 0.01 and 0.15 respectively for UCI heart disease dataset. In [5], Santhanam and Ephzibah [5] designed a hybrid genetic-fuzzy heart disease diagnosis system using UCI learning machine repository heart disease dataset with 297 samples. In this case, the UCI data comprised of 13 attributes age, sex, cp, trestbps, chol, fbs, restecg, thalach, exang, oldpeak, slope, ca and thal out of which 7 attributes sex, serum cholesterol (chol), maximum heart rate achieved (thalach), Exercise induced angina (exang), ST depression induced by exercise relative to rest (oldpeak), number of major vessels coloured (ca) and thal value are selected by genetic algorithm. the classification model was generated using fuzzy inference system for the resultant dataset obtained after the application of genetic algorithm resulted in a classification accuracy, sensitivity and specificity of 86% , 0.80 and 0.90 respectively using the stratified K-fold technique. In 2017, Folasade, Jumoke and Olayinka [6] developed a mobile-based neuro fuzzy expert system for diagnosing cardiovascular diseases. They developed an interactive interface through Programs like PHP, XML, JAVA(Android) along with tools like PhpStorm, XAMPP, and Android O/S to integrate all these techniques. it provides an interactive interface; a user can input values of various attributes through ‘ heartup ’ application and it gives the status of disease. In 2016, Aamir, Rao, Zheng, Wang and Aristides [13] proposed a fuzzy logic based home healthcare system that is an intelligent decision making system based on the experiments and observations of a healthcare practioner. This system can be used for out-of-hospital monitoring of a chronic disease patient and for timely diagnosis of disease especially for those patients who live alone at their homes. In 2013, Manjusha, Tijare and Sawalkar [10] proposed a multilayer feed forward network with back propagation algorithm for the classification of a heart disease dataset. In 2012, Obanijesu and Emuoyibofarhe [21] developed a neuro-fuzzy system (ANFIS) for heart disease detection by using a dataset with 8 input fields exercise, heart rate, blood pressure, cholesterol, age, chest pain type, sex, and blood sugar and one output field (status of disease) classified into four : high, very high, low, very low; extracted from the collection of databases at the University of California.. In [3] A.V Senthil Kumar used the cleveland dataset presented an advanced fuzzy resolution mechanism for the diagnosis of heart disease in MATLAB. In 2013, Chitra1 and Seenivasagam [20] developed a fuzzy C means classifier (an unsupervised classifier algorithm) to detect heart disease in a patient. In this, they used a heart disease dataset comprising of 270 samples with 13 attributes to test the efficiency of FCM classifier; has an accuracy of 92%. In 2017, Sagir and Sathasivam [16] designed and compared the classification performance of two discrete ANFIS models on a Stalog-Cleveland Heart Disease dataset, one is ANFIS_LGSD; the Maylab’s built-in ANFIS model and another is ANFIS_LSLM; a newly ANFIS model with Levenberg-Marquardt algorithm. Both models included classification with grid partioning, the first one trained with least square method and backpripagation algorithm while as the second trained with Levenberg-Marquardt algorithm that uses the finite difference method to compute a jacobian matrix. There, the ANFIS_LSLM model proved better compared to ANFIS_LSGD in predicting the degree of heart disease in a patient with more reliable and more accurate results due to its index membership function; it computes the unique membership functions and indexes them into a row wise vector. In 2015, Purusothaman and Krishnakumari [17] compared the

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classification performance of various data mining techniques such as decision tree, association rule, K-NN, artificial neural network, SVM, navie bayes and hybrid approach in the risk prediction of heart disease using the cleveland heart disease dataset from UCI repository. Applying hybrid techniques has revealed better outcomes in the prediction diagnosis of heart disease. In 2017, Omisore , Samuel, Atajeromavwo [18] proposed a hybrid technique using a genetic-neuro-fuzzy inferential (GENFIS) system for the intelligent diagnosis of tuberculosis(TB) that integrates together GA, FL and NN components to handle the imprecise and uncertain TB data. This decision support system will assist the medical practitioners in timely, accurate and cost effective treatment of TB.

In 2017, Choubey, Paul and Kumar [19] proposed a hybrid technique using navie bayes-genetic algorithm for the classification of pima Indian diabetes (PIDD) dataset obtained from UCI repository. In first case, they used only navie bayes for classification of PIDD dataset and in second case, they initially used genetic algorithm for PIDD attribute selection and then used navie bayes on the selected attributes which decreases the computational time, computational cost and maximizes the classification accuracy.

III. ANFIS

ANFIS is a hybrid of artificial neural networks (ANN) and fuzzy inference system (FIS) introduced by Jang. ANFIS is used to model, control and estimate parameters in complex systems. This combination of ANN and fuzzy-set theory can provide advantages and remove the limitations in both techniques. ANFIS possess the advantages of ANN such as data classification and identification of patterns and it is more transparent to the user and causes less memorization errors compared to ANN. Several other advantages of ANFIS model include its adaptability, nonlinear ability, rapid learning capacity and it can be trained without relying on expert knowledge sufficient for a fuzzy logic model. it has numerical and linguistic knowledge as well. ANFIS being an adaptive neuro-fuzzy inference system possess the learning capability to optimize the performance based on finding the best parameters for the fuzzy rules within its rule base. ANFIS architecture employs two fuzzy if –then rules that are based on first order suegno model :

If t_1 is C_1 and t_2 is D_1 then $f_1 = l_1t_1 + m_1t_2 + n_1$

If t_1 is C_2 and t_2 is D_2 then $f_2 = p_2t_1 + q_2t_2 + r_2$

Where t_1 and t_2 are inputs, C_i and D_i are fuzzy sets f_i are the outputs within the fuzzy region specified by the fuzzy rule, l_i ,m_i and n_i are the design parameters that are determined during the training process.

Figure1 shows the Anfis architecture with five layers of nodes out of which first and fourth layer has adaptive nodes while as second, third and fifth consists of fixed nodes. The adaptive nodes connected with their respective parameters get appropriately updated with subsequent iteration on the other hand fixed nodes are devoid of any parameters.

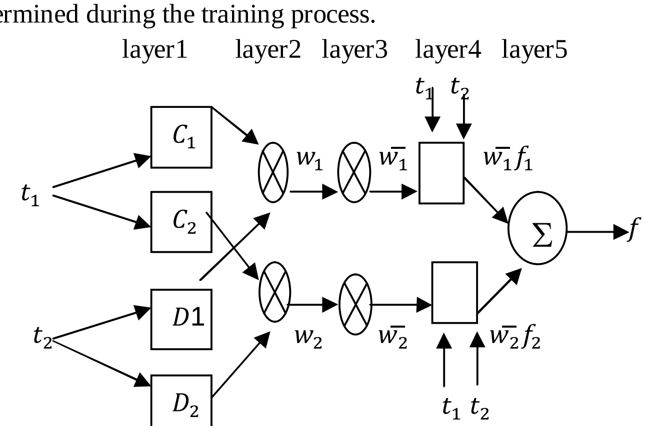

Figure 1. ANFIS architecture

functioning details of each layer of the ANFIS are as below:

Layer 1: The first layer is the input fuzzification layer in which every node consists of adaptive node functions. Each node has an output equal to fuzzy membership grade of inputs given by :

$$O_{i,1} = \mu_{Ci}(t_1) \quad \text{for } i = 1,2 \qquad (1)$$

$$O_{i,1} = \mu_{Di-2}(t_2) \quad \text{for } i = 3,4 \qquad (2)$$

Various types of membership function can be used, like triangular function gauss function, the bell-shaped function etc.Layer 2: Rule layer : In this layer each node M computes the product of incoming signals which represents the firing strength of the rule. Mathematically, the output is given by :

$$O_{i,2} = wi = \mu_{Ci}(t_1) \times \mu_{Di}(t_2) \text{ , for } i = 1,2 \qquad (3)$$

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Layer 3: In this layer each k-th node calculates the ratio of the k-th rule's firing strength to the sum of all rule's the firing strengths, that is the normalized firing strength output :

$$O_{k,3} = \bar{w}_k = \frac{w_k}{w1+w2}, \quad k = 1,2 \qquad (4)$$

Layer 4: Nodes in this layer are adaptive and output of each node is the product of normalized firing strength and a polynomial (first order polynomial for first order sugeno model). Output is given by:

$$O_{i,4} = \bar{w}_i f_i = \bar{w}_i (l x_1 + m_i x_2 + n_i) \quad \text{for } i=1,2 \qquad (5)$$

Where w_i is the output of layer 3 and {li,mi,ni} is parameter set called consequent parameter set

Layer 5: This layer consists of a single node that computes the overall output as the sum of all incoming signals:

$$O_{i,5} = \sum_i \bar{w}_i f_i = \frac{\sum_i w_i f_i}{\sum_i w_i} \quad \text{for } i = 1,2 \qquad (6)$$

Where $O_{5,1}$ is the obtained output available to user.

We can either use back propagation or hybrid learning algorithm to optimize the fuzzy rule base of ANFIS. The hybrid learning algorithm is mostly preferred; it identifies the optimal consequent parameters by LSE and updates the premise parameters of fuzzy rules by gradient descent method.

IV. GENETIC ALGORITHM

Genetic algorithm is a heuristic optimization technique that relies on natural evolution procedures; yields an approximation that fits properly in an objective function by applying its generate and test paradigm. It creates an initial population of candidate individuals (chromosomes) of size N and operates on them to produce better solutions. Nature of an objective function decides the level of fit of the individual chromosome. If fitness value is better, an individual will get closer to the target. Evaluation process stops when a stopping criterion is attained which can be maximum number of generations, maximum time elapsed, etc,. In this work, genetic algorithm is used to optimize the generalization performance of ANFIS predictive model on a dataset that is not used in training it by selecting the most relevant features from heart disease dataset. For the primary heart disease dataset; it ranks the attributes and then selects 6 highly ranked out of 11 attributes. Optimal and feasible solution depends upon the genetic operators like selection (individuals that will contribute in next generation), crossover (process of recombination to produce new individual) and mutation (changing value of features at random).

V. DATASET

In this work, two datasets have been used; one is online available Heart Disease dataset obtained from UCI repository and another is a primary heart disease dataset obtained from government medical collage (GMC) srinagar. The information contained in the primary dataset consists of 200 cases, 11 input fields (attributes listed in table1) and one output field that is presence or absence of disease. On the other hand the online available dataset (secondary data) contains 210 cases, 7 attributes (listed in table2) which are effective in the detection of this disease and one output field that represents presence or absence of disease in a patient.

Table 1: attributes of primary dataset

Attribute	Abbreviation
age in years	AGE
sex (1 = male; 0 = female)	SEX
blood sugar	BS
chest pain	CP
cholesterol	CHO
LDL cholesterol	LDL
triglyceride	TG
resting electrocardiographic	RESTECG
systolic	systolic
diasystolic	diasystolic
problem	problem

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Table 2: attributes of secondary dataset

Attribute	Abbreviation
age in years	age
chest pain type	chest_pain
resting blood pressure (in mm Hg)	Rest_bpress
fasting blood sugar (true if> 120 mg/dl; false otherwise)	blood_sugar
maximum heart rate	max_heart-rate
resting electrocardiographic results	restelectro
exercise induced angina	exercise_angina

VI. EXPERIMENTAL RESULTS

The proposed experiment for heart disease diagnosis was implemented with MATLAB. The experimental datasets have been divided randomly into training data, checking data and testing data. For the primary heart disease dataset the relative proportion of three subsets is: training dataset -- 47.74% (95 samples), checking and testing datasets -- 26% (52 samples each). In case of online available heart disease dataset training subset comprises of 99 samples (47.37%) , checking and testing subsets comprise of 55 samples each (26.34%). In both cases, training data was used to create the initial fuzzy model then checking data used to train the initial fuzzy model for 200 epochs and then testing data was used to test the effectiveness of anfis model. When feature selection is done with genetic algorithm in primary data set it selects 6 out of 11 features or inputs and in case of secondary dataset it selected 4 out of seven attributes.

dataset	Number of attributes	Test error
primary	11	0.57585
primary	6	0.36057
Secondary	7	29.2323
secondary	4	7.1882

Table 3. prediction on test data

First the simplified anfis structure model is trained and tested by giving all attributes as input to the model and after that using only the selected features as input to model. Table 3 shows the results of test error in anfis with various number of attributes. Primary dataset shows 0.57585 test error with eleven attributes and 0.36057 error with 6 selected attributes by genetic algorithm. Similarly, in case of secondary heart disease dataset, with 7 features testing error is 29.2323 and for 4 selected features testing error reduces to 7.1882. . It is clear from the results that the due to the application of genetic algorithm the accuracy of ANFIS for the prediction of heart disease on these data sets can be improved. Gaussian membership function has been used for all inputs. Figures given below show the membership functions before training and after training for input variables chest-pain and cholesterol in primary heart disease dataset with 11 features (fig. 2. and fig. 3.) and for same dataset with only 6 selected features (fig. 4. and fig. 5.) respectively. Fig. 6. and fig. 7. Shows the surface view of two parameters (cholesterol and chest-pain) to one output (disease); a 3D curve that represent mapping with two input parameters to one output. Figure 8 shows the rule view for 6 selected features and one output that is disease.

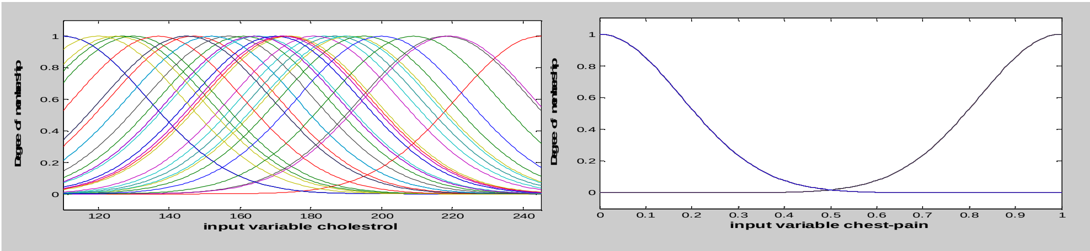

Figure 2. Membership functions before training

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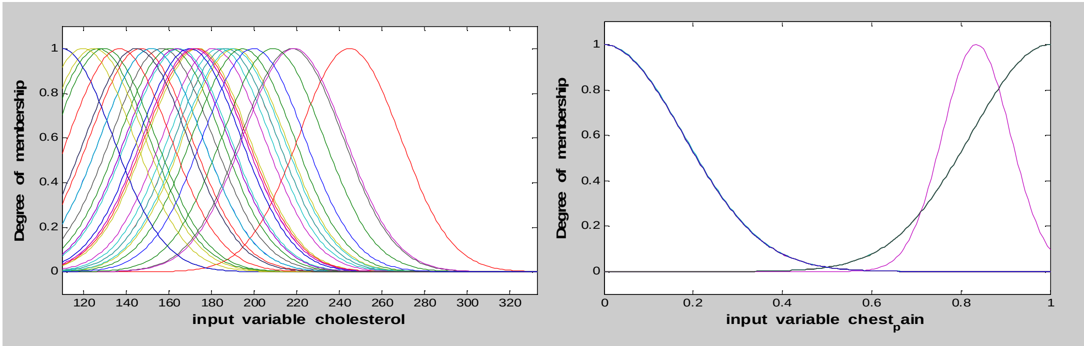

Figure 3. Membership functions after training

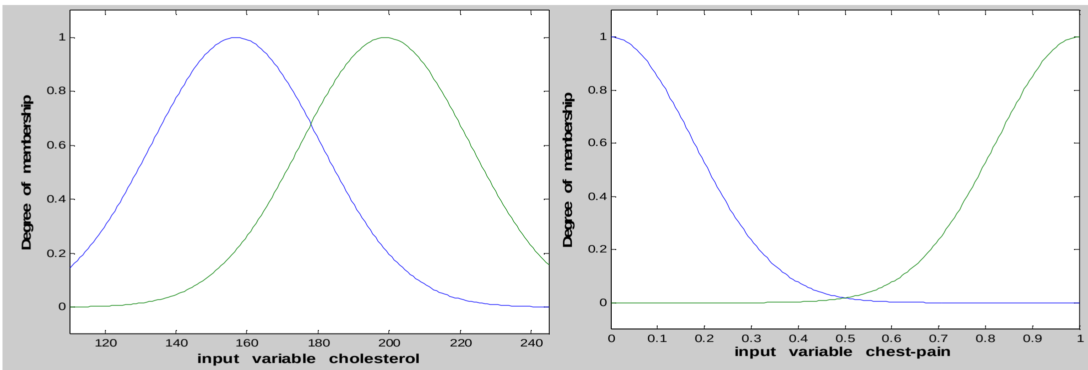

Fig 4. Membership function before training

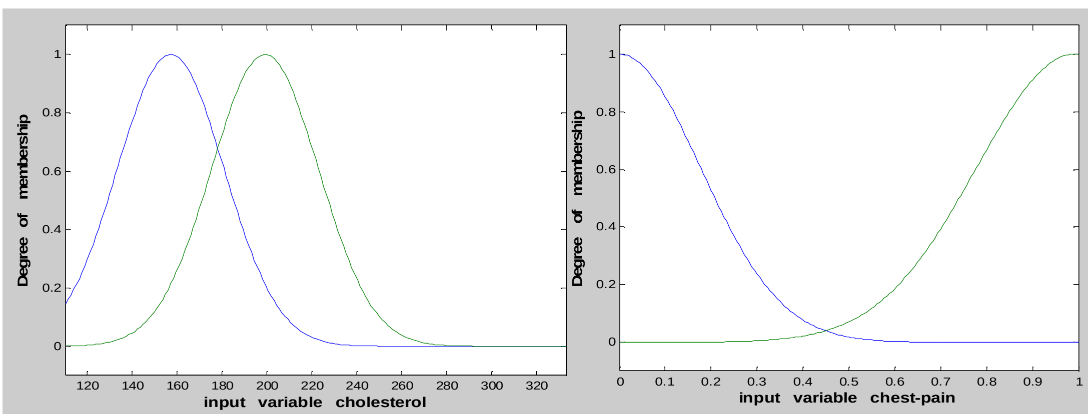

Fig 5. Membership function after training

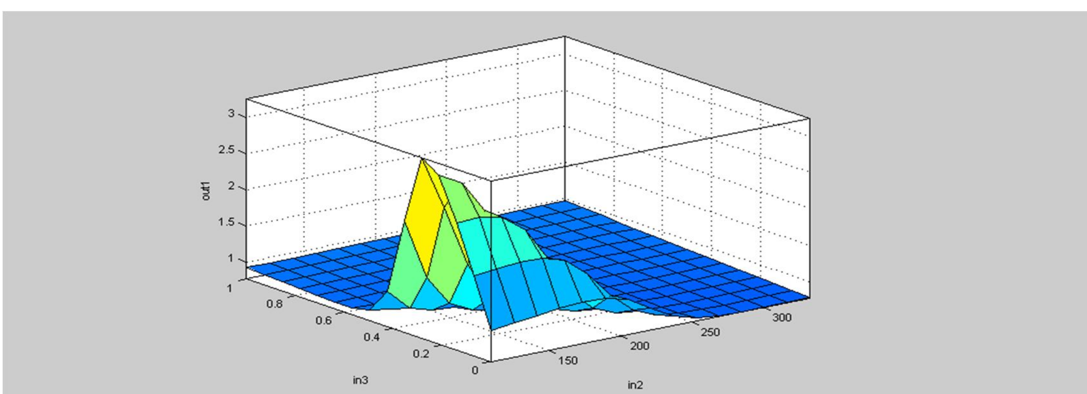

Fig.6 surface view of cholesterol versus chest-pain in 11 feature primary dataset

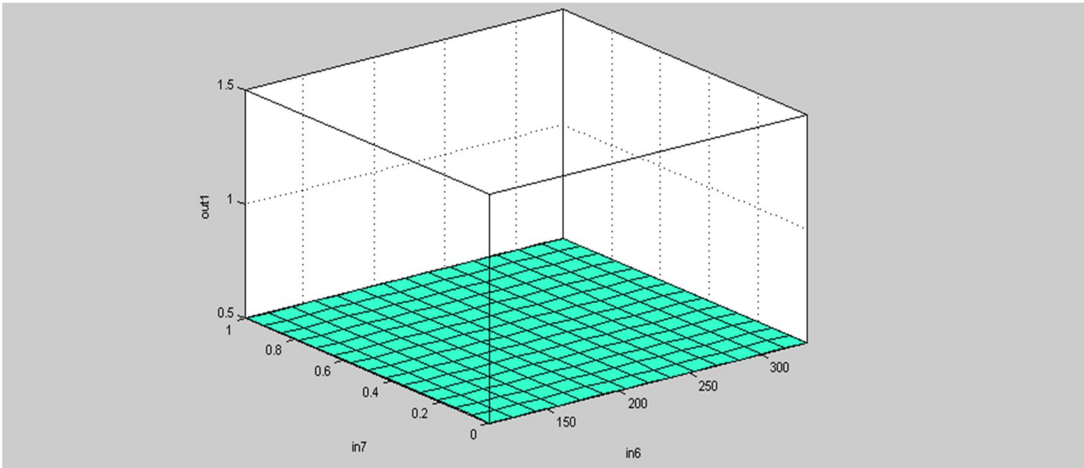

Fig.7. surface view of cholesterol versus chest-pain in 6 feature primary dataset

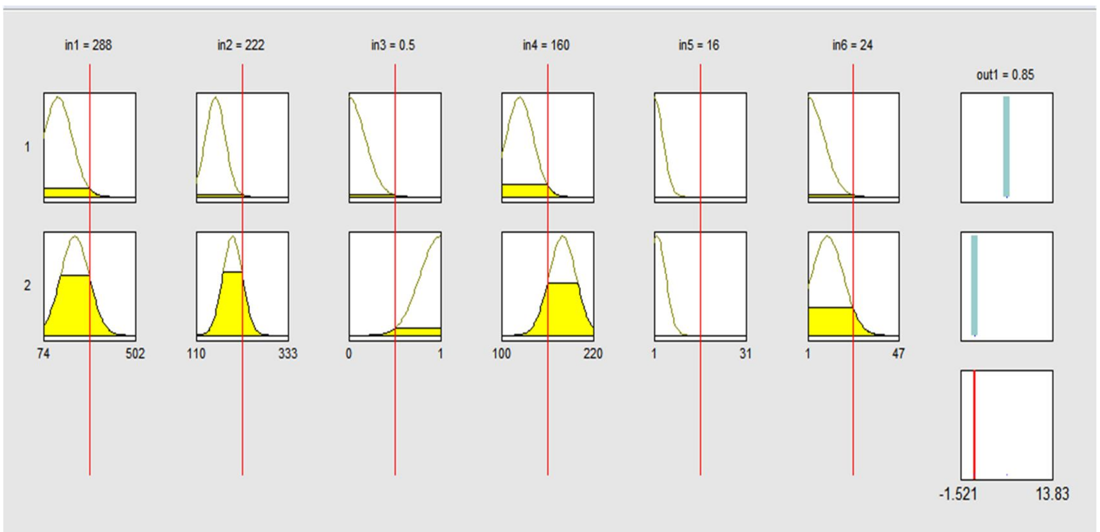

Fig. 8. Rule viewer for 6 selected attributes

dataset	Number of attributes	Test error
Primary	6	0.28414
secondary	4	1.951

Table 4. prediction on test data

The reduced datasets (primary and secondary) have also be tested on kernel FCM (KFCM) based ANFIS the results of which are shown in the table 4 . From table 3 and table 4 it can be seen that there is much improvement both in case of primary as well as secondary datasets. In case of primary reduced dataset with 6 selected attributes the test error decreases from 0.36057 to 0.28414 and in case of secondary dataset with 4 selected attributes the test error decreases from 7.1882 to 1.951. Membership functions before training and after training for inputs cholesterol and chest pain of primary reduced datasets and for inputs age and chest pain in secondary datasets are in case of KFCM based ANFIS using genfis3 are shown in figure 9 and figure 10 respectively. Similarly, in case of reduced secondary heart disease dataset, figure 11 and figure 12 shows the membership function before and after training for the input variable chest-pain.

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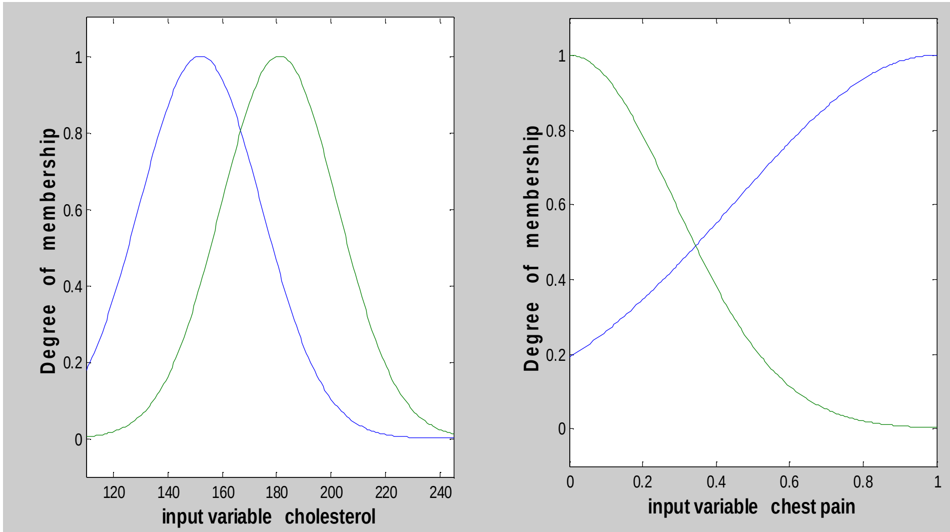

Fig 9. Membership function before training

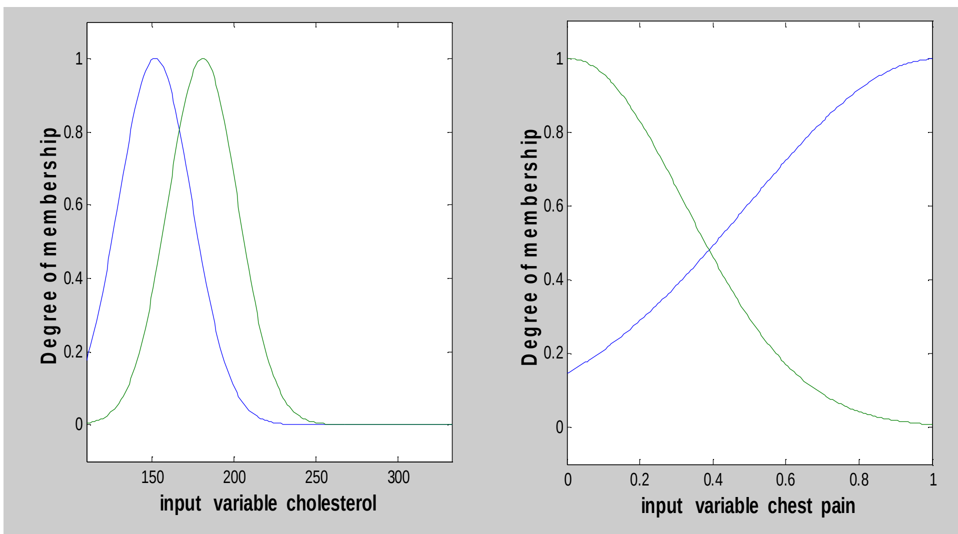

Fig 10. Membership function after training

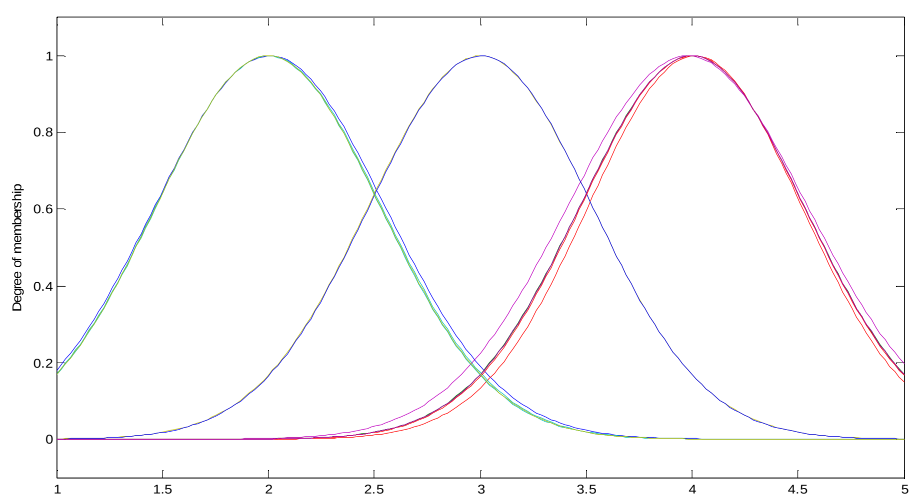

Fig 11. Membership function before training

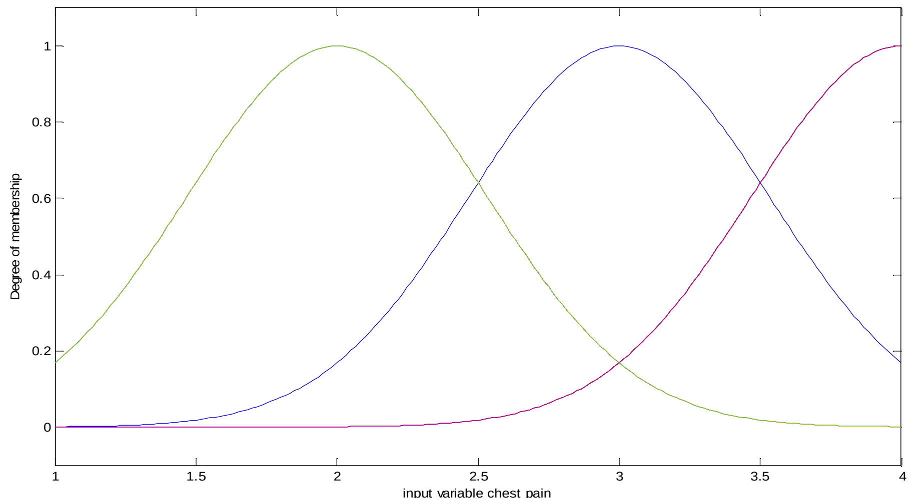

Fig 12. Membership function after training

VII. CONCLUSION

This paper suggests a hybrid technique in which patients need not carry out large number of costly tests to find presence or absence of heart disease or in other sense this method decreases the number of tests a patient have to perform for the detection of heart disease; reduces the heart disease datasets in terms of number of features thus helping patients in its early prediction and reliable diagnosis with minimal costs. Genetic algorithm and Adaptive Neuro-Fuzzy Inference System (GA-ANFIS) have been used for building a hybrid model structure (simplified ANFIS model structure) using the primary as well as the secondary heart disease datasets which combines the advantages of genetic algorithm, neural network and fuzzy logic in the prediction of heart disease. In this work, it can be seen that the performance of a hybrid model of GA and simplified ANFIS is better than hybrid of neuro-fuzzy (ANFIS) model. Similarly, a hybrid of GA and KFCM based ANFIS (GA-KFCM-ANFIS) performs better than a hybrid model of GA and simplified ANFIS. The experimental results show that the proposed hybrid techniques (GA-ANFIS and GA-KFCM-ANFIS) have a high accuracy in terms of testing error in predicting the heart disease on the primary as well as secondary heart disease dataset. We can use such hybrid techniques for other heart disease datasets. Similarly, these techniques can be used for other health care issues too.

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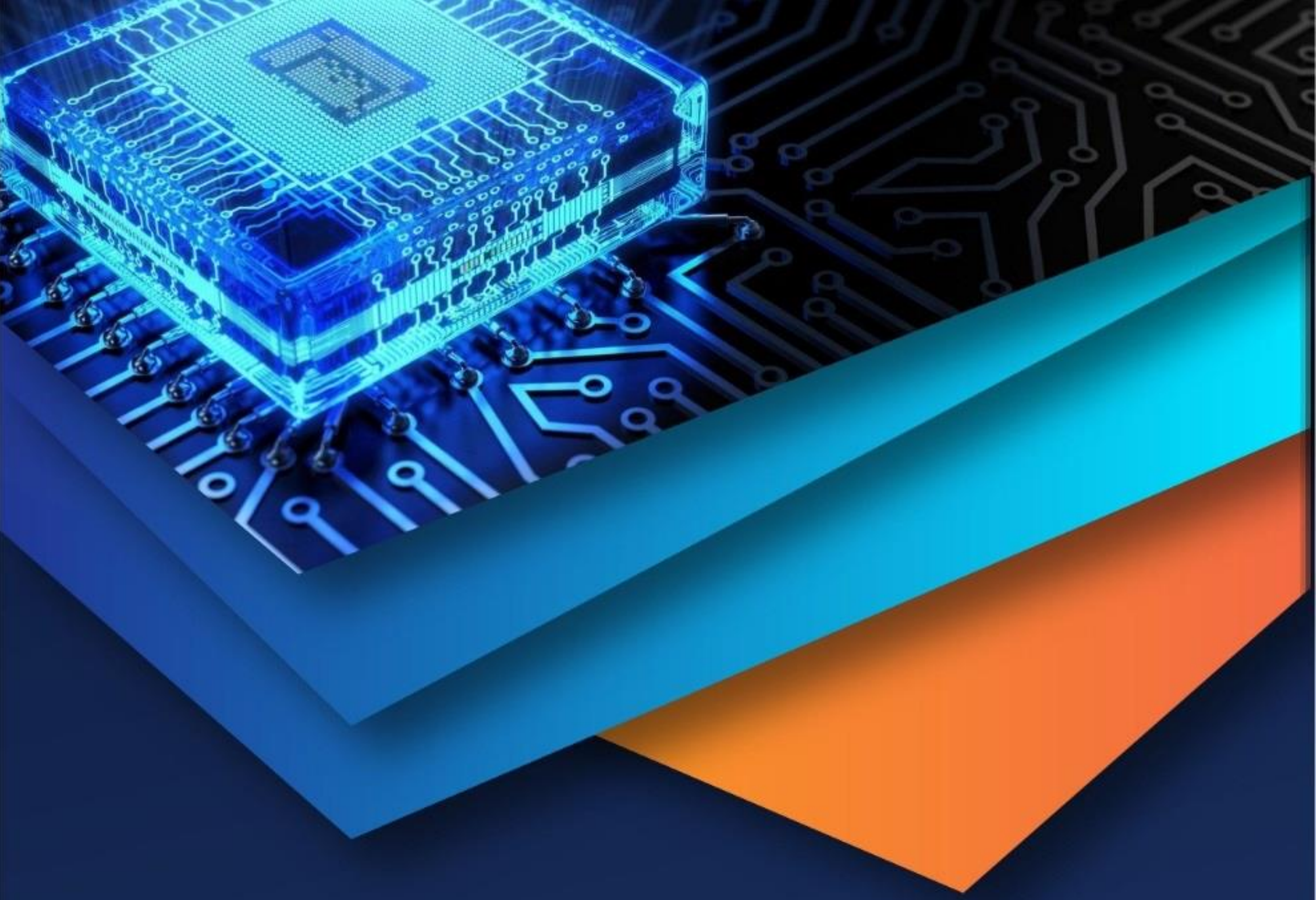

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