A Frame work for the Neuro Fuzzy Rule Base System in the diagnosis of heart disease

Manisha Barman, J Paul Choudhury, Susanta Biswas

Abstract— Now a day's prediction of a heart disease is a great challenge to modern technology. Use of intelligent system in this context is a real challenge. In this paper fuzzy rule based system and artificial neural network system have been presented for the diagnosis of the heart disease. The developed system has seven inputs .These are Chest pain type, resting blood pressure in mm(Trestbps),Serum cholesterol in mg(Chol),Numbers of Years as a smoker(years), fasting of blood sugar(fbs), maximum heart rate achieved(thalach), resting blood rate(trestbpd). The angiographic disease status of heart of patients has been recorded as output. It is to state that the diagnosis of heart disease by angiographic disease status is assigned by a number between 0 to 1 that number indicates whether the heart attack is mild or massive, The Cleveland database has been used to make this study. Various membership functions have been used as input. Here an effort has been made to compare the performance of neural network with fuzzy rule based system using certain membership functions. for proper diagnosis of heart disease. Three types of membership functions viz gaussian, triangular and trapezoidal membership functions have been attempted. Based on the minimum value of absolute residual, the particular membership function can be decided for the fuzzy rule base system and the output data from fuzzy rule base system has been applied to the neural network for the proper diagnosis of heart disease of a patient.

Index Terms— Fuzzy Logic, membership function, Fuzzy Rule base System, Artificial neural network, Feed Forward Back propagation neural network.Absolute residual .

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1 Introduction

Heart disease, sometime define as coronary artery disease (CAD), is a well-known term that can be referred to any condition that affects the heart. Most of the people with heart disease have symptoms such as chest pain, blockage and fatigue, as many as 50% have no symptoms until a heart attack occurs.

R.Das,Ibrahim Turkoglu b, Abdulkadir Sengur[1] have used a neural network based model for the diagnosis of heart disease from the available data. Initially the data have been partitioned for the purpose of the usage of the neural network and for the validation of data sets. Three types of neural networks have been used. The authors have made a comment that a multilayer feed forward neural network has shown the excellent performance among the three types of neural networks.

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Ali.Adeli, Mehdi.Neshat[4] have used a fuzzy expert system for the diagnosis of heart disease. The authors have used several variables viz as chest pain type, blood pressure, cholesterol, resting blood sugar, resting maximum heart rate, sex, electrocardiography (ECG), exercise, old peak (ST depression induced by exercise relative to rest), thallium scan and age as inputs. The status of the patients as healthy or sick has been used as output. Four types of sickness has been used as output. These are Sick s1,Sick s2, Sick s3, Sick s4.
Priti Srinivas Sajja,Dipti M Shah[3] have used a knowledge-oriented decision support system for the diagnosis of abdomen pain .They have used a modified Prolog rule format, for their decision making process and have created awareness in the area especially where trained manpower is in scarce.

Narendra S. Chaudhari and Avishek Ghosh [5] have used a projection algorithm with an objective to map p-dimensional patterns to q-dimensional space such that the structure of the data is preserved. They have implemented an extension of Sammon's algorithm using fuzzy logic approach. Finally they have shown that their result was excellent.
Vanisree K,Jyothi Singaraju[2] have used a Decision Support System for the diagnosis of Congenital heart disease from the available database .They have used backpropagation neural network which contains one input layer, one output layer and one or more hidden layers. As the name implies the input layer receives signals from the external nodes and transmits these signals to other layers without performing any computation at that layer. The output layer receives the signals from an input layer through a weighted connection links, performs computations at that layer and produces output of the network
It has been trained using a supervised delta learning rule. The

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dataset used in this study are the signs, symptoms and the results of physical evaluation of a patient. The proposed system has achieved an accuracy of 90%.

K. Usha Rani[12] have used a classification approach based on neural network. They have used single and multilayer neural network mode for classification of heart disease dataset. For training the network, they have used back propagation algorithm and parallelism technique at the same time at each neuron in all hidden and output layers to speed up the learning process. They have proved that neural network based technique has given satisfactory result.

K.Rajeswari, V.Vaithiyanatham,,P.Amirtharaj[13] have proposed a Decision support system for reliable heart disease risk prediction of Indian patients using machine learning technique. They have used genetic algorithm to determine high impact pattern and their optimal value. They have used theoretical approaches to implement the machine learning algorithm.

Ersin Kaya, Bulent Oran and Ahmet Arslahn[14] have used a fuzzy rule based classifier for diagnosis of congential heart disease which defines structural and functional disease of heart. They have used weighted vote method and single winner method . The result has shown that the weighted vote method generally has increased the classification accuracy of congenital heart disease.

Shradhanjali Rout[16] have used a Fuzzy Petri net based system instead of fuzzy expert system and have analyzed the system through fuzzy rule based reasoning algorithm. They have used 11 attributes for input and 1 attribute as output for diagnosis of the heart disease. They have shown that their result was excellent by using their proposed petri net based fuzzy system.

E.P.Ephzibah1, V. Sundarapandian[15]have proposed a neuro fuzzy expert system that finds a solution to diagnose the disease using some of the evolutionary computing techniques like genetic algorithm, fuzzy rule based learning and neural networks. Their proposed neuro-fuzzy method refers to the combination of artificial neural network and fuzzy logic based system in which the 13 attributes have been taken from UCI Machine learning repository. The result has helped the doctors to arrive at a conclusion about the presence or absence of heart disease in patients.

Ranjana Raut, S. V. Dudul[6] have used a neural network based approach for intelligent system in the diagnosis of heart disease. They have used classifiers based on various neural networks namely multilayer perceptron, Jordan recurrent neural network, generalized feed forward neural network, Modular Radial Basic Function, Self Organizing Feature Map, other techniques like Support Vector Machine and conventional statistical techniques such as Data Analysis and CART. They have proposed Muitilayer Perceptron Neural Network based classifier which has shown the excellent result as compared to others.

Various authors ([1][2][3][4][6][12]) have used several neural network models like back propagation neural network, multilayer perceptron neural network, radial basis neural network etc. Their effort was to detect the heart disease using fuzzy expert system and artificial neural network, but they have not shown how much accuracy they have achieved in their result. That is the reason for taking this work as described in this paper.

In this paper an effort has been made to diagnose the heart disease by using fuzzy rule base and artificial neural network . Initially 7 attributes of patients have been used as input values from the Clevand database[11]. The data values used have been partioned into several intervals based on certain intermediate values of the available data values. Thereafter fuzzy rule base has been applied on the partitioned input data values. Based on the neural netwotk tested value of the output variable, the heart disease can be ascertained.

In this context various membership functions have been used for each input variable and output variable. Finally absolute residual and mean absolute residual have been calculated using the output value produced by fuzzy rule base and neural network based system in comparison to the actual output value as available in the database [11]

2 METHODOLOGY

2.1 Expert System

The components [20] of an expert system have been furnished in figure 1. The knowledge base stores all relevant information, data, rules, cases, and relationships used by the expert system. A knowledge base can be formed by combining the knowledge of multiple human experts. A rule is a conditional statement that links given conditions to actions or outcomes. A frame is another approach used to capture and store knowledge in a knowledge base. It relates an object or item to various facts or values. A frame-based representation is ideally suited for object-oriented programming techniques. Expert systems making use of frames to store knowledge are also called frame-based expert systems.

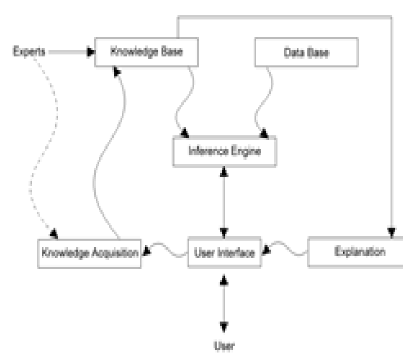

Figure 1

The purpose of the inference engine is to seek information and relationships from the knowledge base and to provide answers, predictions, and suggestions in the way a human expert would provide. The inference engine must find the right facts, interpretations, and rules and assemble them correctly. Two types of inference methods are commonly used –

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back chaining and forward chaining. Backward chaining is the process of starting with conclusions and working backward to the supporting facts. Forward chaining starts with the facts and works forward to the conclusions.

2.2 Fuzzy membership function

Fuzzy membership functions determine the membership functions of objects to fuzzy set of all variables. A membership function provides a measure of the degree of similarity of an element to a fuzzy set. There are different shapes of membership functions; triangular, trapezoidal, piecewise-linear, Gaussian, bell-shaped, etc.

2.2.1 Triangular membership function

Let p, q and r represent the three vertices of the X coordinates and $\mu_A(x)$ represents the Y coordinate in a fuzzy set A. Where A is the membership value .In this equation p: lower boundary and r: upper boundary where membership degree is zero, q: the centre where membership degree is 1.

$$\mu_A(x) = \begin{cases} 0 & if\ x \le p \\ \dfrac{x-p}{q-p} & if\ p \le x \le q \\ \dfrac{r-x}{r-q} & if\ q \le x \le r \\ 0 & if\ x \ge r \end{cases}$$

2.2.2. Trapezoidal Membership function

The trapezoidal curve is a function of μ_A of vector x, and depends on four scalar parameters p, q, r and *s* where p and s allocate the "feet" of the trapezoid and the parameters q and r allocate the "shoulders."

$$\mu_A(x:p,q,r,s) = \begin{cases} 0 & if\ x \le p \\ \dfrac{x-p}{q-p} & if\ p \le x \le q \\ \dfrac{r-x}{r-q} & if\ q \le x \le r \\ 0 & if\ x \le r \end{cases}$$

2.2.3. Gaussian Membership function

The gaussian curve is a function of μ_A of vector x, and depends on three scalar parameters p, q and *s* where p: center and q:width and s:fuzzification factor(in expression s=2).The gaussian membership function μ_A of vector x have been represented by

$$\mu(x:p,q,s) = exp\left[-\frac{1}{2}\left|\frac{x-p}{q}\right|^s\right]$$

2.3 Absolute residual

The absolute residual is represented by

$$|(Estimated\ cost - Actual\ cost)/n|$$

Mean absolute residual is $\sum_{i=1} \frac{absolute\ residual_i}{n}$

2.4 Artificial neural network:

Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the network function is determined largely by the connections between elements. A neural network can be trained to perform a particular function by adjusting the values of the connections (weights) between elements. The components [1] of an artificial neural network have been furnished in figure 2.

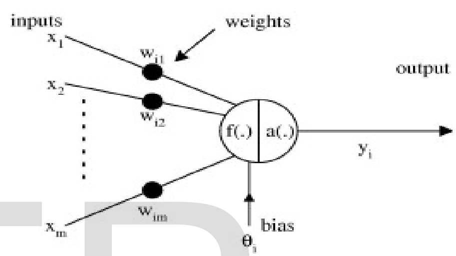

Figure 2

3 IMPLEMENTATION

Step 1:

From Clevand database [11],out of 76 attributes, 7 attributes have been taken as input and 1 attribute has been used as output. The input attributes are chest pain type, resting blood pressure in mm(Trestbps),serum cholesterol in mg(Chol),numbers of years the person behaves as a smoker(years), fasting of blood sugar (fbs), maximum heart rate achieved (thalach), resting blood rate(trestbpd). The output attribute is the angiographic disease status of heart of patients.

Step 2:

The first input field “Chest pain type” comprises of four types as denoted by numerical value. The value 1 indicates” typical angina”, 2 indicates “atypical angina, 3 indicates “non-angina” and 4 indicates “asymptomatic angina ” .The second and third input fields are resting blood pressure measured in mm and serum cholesterol measured in mg respectively. The fourth input field is the number of years the person behaves as a smoker that denoted by numeric value. The fifth input field indicating the contents of fasting blood sugar. When fasting blood sugar is greater than or equal to 120 mg, the level of fasting blood sugar is 1 otherwise 0.The sixth and seventh input fields are maximum heart rate achieved and resting blood rate respectively. The output field refers to the angiographic disease status of heart of patients. It is to state that diagnosis of heart disease is made by the angiographic disease status which is a number between 0 to 1.Where 0 indicates the di-

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ameter of coronary arteries is less than 50% of original diameter and 1 indicates the diameter of coronary arteries is more than 50% of its original diameter.

Step 3:

The following data items (7 attributes per patient) have been used as input.

The input data items have been furnished in table 1:-

.

Table1. Input data values

Patients No	Chest pain type	blood pressure (t restbps)	Serum cholesterol (chol)	Years as a smoker (years)	Fasting of blood sugar (fbs)	heart rate achieve (thalrest)	Resting blood rate (tpeakbps)
1	1	145	233	20	1	60	90
2	4	120	229	35	0	78	140
3	3	130	250	0	0	84	195
4	2	130	204	0	0	71	160
5	2	120	236	20	0	73	165
6	4	120	354	0	0	84	165
7	4	140	203	25	1	86	185
8	4	140	192	25	0	86	180
9	2	140	294	0	0	85	204
10	2	120	263	30	0	70	165
11	3	172	199	35	1	91	220
12	3	150	168	40	0	60	192
13	2	110	229	0	0	75	175
14	4	140	239	30	0	86	180
15	3	130	275	20	0	62	165
16	2	130	266	22	0	82	135
17	1	110	211	20	0	58	170
18	1	150	283	9	1	75	210
19	2	120	284	0	0	69	170
20	3	120	219	8	0	71	160

Step4:

Thus input and output variables have been classified based on their interim values, which have been furnished in table2, table3, table4, table5, table6, table7, table8, table9 respectively.

Table 2. Chest pain type classification

Chest pain type	Numeric value in fuzzy set
Typical angina	1
Atypical angina	2
Non typical-angina	3
Asymptomatic angina	4

Table 3. Resting blood pressure classification

Resting blood pressure: The input variable measured in mm, having different values

Resting blood pressure(t restbps)	Fuzzy set value
t restbps<=145(from 110 -145)	min
t restbps>145(from 145 -above)	max

Table 4. Serum cholesterol classification

Serum cholesterol: The input variable measured in mg having different values.

Serum cholesterol (chol)	Fuzzy set value
chol<=240(from 168 -240)	minlevel
chol>240(from 240 -above)	maxlevel

Table 5.Number of Years as a smoker classification

Number of Years as a smoker: The numbers of years the persons behave as a smoker that denoted by numeric value

Number of years as smoker(years_input4)	Fuzzy set value
years_input4<=30(from 0-30)	Low possibility
years_input4>30(from 30 -above)	High possibility

Table 6.Fasting blood sugar classification

Fasting blood sugar(fbs): . The input variable is measured in mg.

Fasting blood sugar (fbs)	Fuzzy set value
fbs=0,(fbs<=120mg)	Sugar _level_no
fbs=1,(fbs>120mg)	Sugar _level_yes

Table7.Maximum heart rate classification

Maximum heart rate: The six input fields are maximum heart rate achieved

Maximum heart rate achieved (thalrest)	Fuzzy set value
thalrest< =70,(from50-70)	Min_heart_rate
thalrest,>70(from 70-above)	Max_heart_rate

Table 8. Resting blood rate classification

Resting blood rate: The seven input fields are resing blood rate achieved

Resting blood rate achieved (tpeakbps)	Fuzzy set value
tpeakbps < =140,(from90-140)	low_blood_rate
tpeakbps >140(from 140-above)	high_blood_rate

Table 9.Angiographic disease status classificationOutput field angiographic disease status

Angiographic disease status (Heart disease)	Fuzzy set value
0(diameter of coronary arteries is less than 50% of original diameter)	mild
1(diameter of coronary arteries is more than 50% of its original diameter)	massive

Step5:

The fuzzy rules have been applied on the data to estimate the angiographic status of heart of the patients using fuzzy rule base. The fuzzy rules have been furnished in table 10

Table 10. Rule base

1.if(Chest_pain_type is typical angina) and (trestbps is min)and(chol is minlevel) and(years_input4 is low_possibility)and(fbs is sugar_level_no) and (thalrest is min_heart_rate)and(tpeakbps is low_blood_rate) then (heart_disease is mild)
2.if(Chest_pain_type is asymptomatic_angina) and (trestbps is min)and(chol is maxlevel) and(years_input4 is low_possibility)and(fbs is sugar_level_no) and (thalrest is min_heart_rate)and(tpeakbps is high_blood_rate) then (heart_disease is massive)
3.if(Chest_pain_type is nontypical angina) and (trestbps is min)and(chol is maxlevel) and(years_input4 is high_possibility)and(fbs is sugar_level_no) and (thalrest is min_heart_rate)and(tpeakbps is high_blood_rate) then (heart_disease is mild)
4.if(Chest_pain_type is atypical angina) and (trestbps is min)and(chol is maxlevel) and(years_input4 is low_possibility)and(fbs is sugar_level_no) and (thalrest is min_heart_rate)and(tpeakbps is high_blood_rate) then (heart_disease is mild)
5.if(Chest_pain_type is atypical angina) and (trestbps is min)and(chol is maxlevel) and(years_input4 is high_possibility)and(fbs is sugar_level_no) and (thalrest is min_heart_rate)and(tpeakbps is low_blood_rate) then (heart_disease is mild)
6.if(Chest_pain_type is asymptomatic angina) and (trestbps is max)and(chol is minlevel) and(years_input4 is low_possibility)and(fbs is sugar_level_no) and (thalrest is min_heart_rate)and(tpeakbps is low_blood_rate) then (heart_disease is mild)
7.if(Chest_pain_type is asymptomatic_angina) or (trestbps is max)or(chol is maxlevel) and(years_input4 is low_possibility)or(fbs is sugar_level_no) or (thalrest is min_heart_rate)or(tpeakbps is high_blood_rate) then (heart_disease is massive)
8.if(Chest_pain_type is asymptomatic angina) and (trestbps is max)and(chol is maxlevel) and(years_input4 is high_possibility)and(fbs is sugar_level_no) and (thalrest is min_heart_rate)and(tpeakbps is low_blood_rate) then (heart_disease is mild)
9.if(Chest_pain_type is atypical angina) and (trestbps is min)and(chol is maxlevel) and(years_input4 is high_possibility)and(fbs is sugar_level_no) and (thalrest is min_heart_rate)and(tpeakbps is low_blood_rate) then (heart_disease is mild)
10.if(Chest_pain_type is nontypical angina) and (trestbps is min)and(chol is maxlevel) and(years_input4 is high_possibility)and(fbs is sugar_level_no) and (thalrest is min_heart_rate)and(tpeakbps is low_blood_rate) then (heart_disease is mild)
11.if(Chest_pain_type is nontypical angina) and (trestbps is max)and(chol is maxlevel) and(years_input4 is high_possibility)and(fbs is sugar_level_yes) and (thalrest is max_heart_rate)and(tpeakbps is high_blood_rate) then (heart_disease is massive)

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Step 6
The fuzzy rule base toolbox of Matlab 7 has been applied and that has produced the estimated output as furnished in table 11.Initially triangular membership function has been applied to all input and output variables.

Step 7
Now Gaussian membership function has been applied to all input and output variables. The fuzzy rule base toolbox of Matlab 7 has been applied to produce the estimated output based on gaussian membership function as furnished in table 11.

Step 8
Thereafter Trapezoidal membership function has been applied to all input and output variables. The fuzzy rule base toolbox of Matlab 7 has been applied to produce the estimated output based on gaussian membership function as furnished in table 11.

Table 11 Original heart status and estimated heart status

Patients No	Original status(Available from the database)	Estimated Status (As calculated by triangular membership function Matlab)	Estimated Status (As calculated by trapezoidal membership function Matlab)	Estimated Status (As calculated by gaussian membership function Matlab)
1	0	0.415	0.433	0.276
2	1	0.575	0.510	0.845
3	0	0.515	0.415	0.276
4	0	0.515	0.400	0.276
5	0	0.415	0.478	0.233
6	0	0.515	0.478	0.278
7	1	0.575	0.628	0.833
8	0	0.515	0.500	0.313
9	0	0.515	0.500	0.313
10	0	0.515	0.500	0.278
11	0	0.415	0.478	0.276
12	0	0.515	0.500	0.276
13	1	0.575	0.535	0.833
14	0	0.515	0.478	0.276
15	0	0.515	0.500	0.276
16	0	0.415	0.500	0.278
17	0	0.515	0.500	0.276
18	0	0.515	0.500	0.276
19	1	0.575	0.535	0.845
20	0	0.515	0.500	0.278

Step 9
The absolute residual of the estimated output value with respect to the original status has been calculated for each membership function(triangular ,gaussian ,trapezoidal) as furnished in table12.Mean absolute residual value based on each membership function has been calculated and furnished in table 13.

Table 12.Absolute residual based on membership function

Patients no	Absolute residual values calculated by using triangular membership function	Absolute residual values calculated by using trapezoidal membership function	Absolute residual values calculated by using gaussian membership function
1	0.415	0.433	0.276
2	0.425	0.490	0.155
3	0.515	0.415	0.276
4	0.515	0.400	0.276
5	0.415	0.478	0.233
6	0.515	0.478	0.278
7	0.425	0.372	0.167
8	0.515	0.500	0.313
9	0.515	0.500	0.313
10	0.515	0.500	0.278
11	0.415	0.478	0.276

12	0.515	0.500	0.276
13	0.425	0.465	0.167
14	0.515	0.478	0.276
15	0.515	0.500	0.276
16	0.415	0.500	0.278
17	0.515	0.500	0.276
18	0.515	0.500	0.276
19	0.425	0.465	0.155
20	0.515	0.500	0.313

Table 13. Mean Absolute residual based on membership function

Membership function	Mean absolute residual
Triangular	0.4770
Trapezoidal	0.4726
Gaussian	0.2567

Step 10

From Table 13 it has been observed that the mean absolute residual values calculated using Gaussian membership function gives the minimum value as compared to other membership functions. Therefore Gaussian membership function is the suitable membership function as compared to other membership functions in fuzzy rule base. Thus the estimated output value based on Gaussian membership function has to be used for further processing. Rule editor and rule viewer using Matlab 7 have been furnished in figure 2 and figure 3 respectively.

Step 11

Artificial neural network has been used on the estimated data based on fuzzy rule base using Gaussian membership function to get the estimated output based on artificial neural network, which has been furnished in table 14. Here 7 noded input 2 noded hidden and 1 node output feed forward back propagation neural network has been used.

Table 14 Absolute status, actual status based on Gaussian membership function and neural network based status

Patients no	Original status(Available from the database)	Estimated status using gaussian membership function	values using Artificial neural network
1	0	0.276	0.22
2	1	0.845	0.845
3	0	0.276	0.22
4	0	0.276	0.22
5	0	0.233	0.198
6	0	0.278	0.22
7	1	0.833	0.833
8	0	0.313	0.22
9	0	0.313	0.22
10	0	0.278	0.22
11	0	0.276	0.22
12	0	0.276	0.22
13	1	0.833	0.833
14	0	0.276	0.22
15	0	0.276	0.22
16	0	0.278	0.22
17	0	0.276	0.22
18	0	0.276	0.22
19	1	0.845	0.845
20	0	0.278	0.22

Step 12

The absolute residual value using artificial neural network has been calculated and furnished in table 15. The mean of absolute residual value has been calculated as 0.142.

Table 15. Absolute status, absolute residual status based on Gaussian membership function and absolute residual status neural network based status

Patients no	Original status(Available from the database)	Absolute residual status using gaussian membership function	Absolute residual values using Artificial neural network
1	0	0.276	0.22
2	1	0.155	0.155
3	0	0.276	0.22
4	0	0.276	0.22
5	0	0.233	0.198
6	0	0.278	0.22
7	1	0.167	0.167
8	0	0.313	0.22
9	0	0.313	0.22
10	0	0.278	0.22
11	0	0.276	0.22
12	0	0.276	0.22
13	1	0.167	0.167
14	0	0.276	0.22
15	0	0.276	0.22
16	0	0.278	0.22
17	0	0.276	0.22
18	0	0.276	0.22
19	1	0.155	0.155
20	0	0.313	0.22

Step 13

The mean of the absolute residual function using artificial neural network and fuzzy rule base using Gaussian membership function has been calculated and furnished in table 16.

Table16.Mean absolute residual against fuzzy and neural network value

Function	Mean absolute residual
Fuzzy Logic(Gaussian membership function)	0.322
Neural Network	0.142

Step 14

From Table 16 it has been observed that the mean absolute residual value using artificial neural network has shown minimum value as 0.142 as compared to fuzzy rule base based on gaussian membership function as 0.322. The estimated output value using artificial neural network has to be used for diagnosis of heart disease.

Result

It has been observed that the feed forward neural network function is suitable for implementation of for heart disease diagnosis system. The estimated status of heart disease based on artificial neural network has been furnished in table 14.

4 CONCLUSION

It has been shown that feed forward neural network function is suitable for implementation of for heart disease diagnosis system.. For patient 1 with the characteristics:blood pressure during resting time as 145, serum cholesterol 233 mg, maximum heart rate as 60,blood rate during rest as 90 , the person is having fasting blood sugar, the person can be treated as a smoker for 20 years with a typical angina(chest pain type angina value 1), the output (angiographic disease status) has been observed as 0.22 using artificial neural network. The original status for patient 1 is 0. Thus for patients 1 ,the absolute residual (derivation from original) is 0.22.For patient 2, the observed output status using artificial neural network is 0.845 as against the original status as 1 with absolute residual (derivation from original) is 0.155.For patient 19, the observed status using artificial neural network is 0.845 as against the original status as 1 with absolute residual (derivation from original) is 0.155.Accordingly the output (angiographic disease status) for all the patients can be ascertained.

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