

Enhancement in Diagnosis of Coronary Artery Disease using Fuzzy Expert System

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ABSTRACT

Coronary Artery Disease (CAD) is one of the most dangerous diseases on the globe. If it is not treated and detected at an early stage then it may lead to death. According to Global Burden of Disease Report, released on 15 September 2017, CAD is still the leading cause of death in India, killing 1.7 million Indians. The main aim of this paper is to predict Coronary Artery Disease using fuzzy expert system and for database, we have used Cleveland database. The proposed fuzzy expert system consists of three major steps i.e. fuzzification, rule base and defuzzification. Centroid technique is used for defuzzification. This system uses 10 input parameters and 1 output parameter which is either healthy, low risk, high risk or very high risk. An output result depends upon fuzzy rule base, which are combinations of input parameters. MATLAB tool used as a development tool and we have achieved 94.5% accuracy of proposed system.

Keywords: Coronary Artery Disease (CAD); fuzzy expert system; matlab tool; Cleveland database, Centroid Technique

I. INTRODUCTION

As we all know, heart is one of the important organ of our body, our life completely depends on its efficient working. Other important parts of our body like liver, kidney, brain also effects due to improper working of heart. If working of heart is affected due to any disease, whole body gets disturbed. There are various factors, which increases the risk of heart disease. As computer technology grows in every area, medical diagnosis area is not an exception. The diagnostic decision depends upon expertise and use of proper method with powerful logical reasoning ability to work on disease. Fuzzy logic is a powerful reasoning method that can handle uncertainty of data very well. One of the most important causes of death worldwide is heart attack. Therefore, diagnosis

of the heart disease is important requirement in daily life but due to lots of uncertainty and risk factor sometimes, heart disease diagnosis is hard for experts. When a heart disease is identified, the speed of detection is highly essential to save the life of heart attack patient and to prevent heart damage. According to the World Health Organization, 12 million deaths occur each year due to heart attack diseases.

This paper organized as follows: Part 2 shows related work concerning heart disease diagnosis; Part 3, proposed algorithm and flowchart are given. In Part 4 reveals method and implementation of designing of fuzzy expert system. In the next part 5, Result analysis is given by the help of confusion matrix and

finally, we have concludes this study and scope for future.

II. Related Work

Baihaqi et al. [1] designed a review paper on fuzzy expert system and data mining technique with algorithm. In this paper, they also gave comparison between two techniques for accuracy. In this paper, they used UCI machine repository dataset for CAD. Agrawal-Chopde [2] presented a survey paper on CAD. In this paper, author mentions the entire possible attribute to determine heart condition with comparison of all the techniques. In this paper, they mentioned that ANFIS is better techniques to predict heart condition. Krishnasree-Rao[3] introduced a Bayesian regularization model, which is one of the statistical models for calculating nonlinear dataset. In this paper, they have implemented this model and achieved 91% accuracy. Muthukaruppan [4] presented a particle swarm optimization (PSO)-based fuzzy expert system for the diagnosis of heart disease. They have used decision tree (DT) for taking proper input attributes because dataset consist of lots of attributes. In this paper, they have given complete attribute information with their ranges and remarks.

Kasbe-Pippal [5] implemented a fuzzy expert system for diagnosis heart disease. In this paper, they have used 13 input attribute and 1 output attribute with UCI machine dataset. They have also compared a previous study with accuracy and in this paper, they achieved 93.33% accuracy. Nagar-Jain [6] presented a survey paper to diagnosis heart disease by expert system. In this paper, author gave all the important information like input variable with their values and how mamdani interface work, and dataset from UCI machine repository. Wagh-Paygude [7] implemented a heart disease diagnosis using Neuro-Fuzzy Expert System (NFES) with 90% accuracy. Author used MATLAB tool for implementation and given a table to compare Neuro fuzzy system with and without genetic algorithm. Rathod-Gawande [8] proposed a fuzzy expert system to diagnosis heart disease of any

patient. In this paper, author gave complete details of all 11 attribute with their membership functions and given a rules. They achieved 94% accuracy in this paper. Pathania-Ritika [9] implements a fuzzy controller for diagnosis. They used 6 Input parameter and 1 output attribute for identify risk level and also used UCI machine repository dataset. In this paper, they achieved 92% accuracy.

Kumar-Kaur [10] developed a fuzzy logic system for diagnosis from the database of Parvati Devi hospital, Ranjit Avenue and EMC hospital Amritsar and International Lab. In this paper, they have used 6 Input attribute with 1 output variable and achieved 90% accuracy. Abushariah et al. [11] proposed an adaptative Neuro-Fuzzy Inference System (ANFIS), which is the part of hybrid neuro-fuzzy inference expert systems. In this paper, they have used hybrid learning algorithm with MATLAB software. Venkatalakshmi- Shivsankar [12] designed a Naïve Bayes, Decision tree and Clustering algorithm to diagnosis heart disease diagnosis. They have used UCI machine database and also given performance comparison to above mention algorithm. Senthil Kumar [13] developed an expert system to diagnosis heart disease by using advance fuzzy resolution mechanism. In this paper, they have used MATLAB tool and Cleveland dataset for implementation process with 93.88% accuracy. Eswara Rao- Govinda Rao [14] implemented a fuzzy expert system using mamdani interface and UCI machine repository dataset. Author has used 11 input parameters with their membership functions and rules. Sen et al. [15] presented a paper on data mining techniques using neuro fuzzy expert system to diagnosis heart disease. In this paper, they have used MATLAB tool with 11 input parameter and UCI machine dataset.

Khatibi-Montazerac [16] proposed a hybrid interface engine to find out risk level and achieved 91.58%. Their prediction model was based on Dempster-Shafer theory of evidence and fuzzy sets theory. Chitra- Seenivasagam [17] designed a Supervised

Learning Algorithm is adopted for heart disease prediction. In this paper, they have used 270 patient databases from UCI with confusion matrix. Barman-Choudhury [18] implemented a fuzzy rule base for heart disease diagnosis. In this paper, they have used mamdani interface with UCI machine database. Baihaqi et al. [19] developed used a data mining techniques with 81.82% accuracy. For rule base, they have used C4.5, CART and RIPPER. In this paper, they have also given comparison among all three fuzzy rule based techniques and implemented their system on 411 data sets. Paul et al. [20] implemented genetic algorithm based fuzzy decision support system for the diagnosis of heart disease. In this paper, they have used FDSS based on the preprocessed datasets and the selected effective attributes generated by correlation coefficient by the help of required and WLS method. Sayad-Halkarnikar [21] presented a neural network approach. This paper consists of Multi-Layer Perception Neural Network (MLPNN) and used back-propagation algorithm. For diagnosis of heart disease, significantly 13 attributes are used in proposed system as per the medical literature with 94% accuracy.

Step 3: Built the fuzzy numbers for A1, A2, A3, A4,

A5, A6 A7, A8, A9, and A10 for input set

Step 3.1: Built the fuzzy number for DM for the output set.

Step 4: Fuzzy inference are executed by Mamdani's method.

Step 4.1: Input the rule as {Rule 1, 2...k}

Step 4.2: Matching degree of rule with OR fuzzy disjunction are calculated for fuzzy input set (A11, A12, A13,A14, A21, A22, A23,A24, A31, A32, A33, A41, A42, A43,A44, A51, A52, A53, A61, A62, A63, A64, DC1, DC2,DC3,DC4 and DC5).

Step5: Defuzzify into the crisp values by DC=

$$DC \leftarrow \frac{\sum_{i=1}^n Z_i \mu(Z_i)}{\sum_{i=1}^n \mu(Z_i)}$$

Where Zi means the weight for $\mu(Z_i)$ and $\mu(Z_i)$ means the number of fuzzy numbers of the output fuzzy variable DC.

Step6: Present the knowledge in the form of human nature language.

End.

III. PROPOSED ALGORITHM & FLOWCHART

INPUT

Input the fuzzy set for A1, A2, A3, A4, A5, A6, A7, A8, A9, A10

OUTPUT

Output the fuzzy set for DC

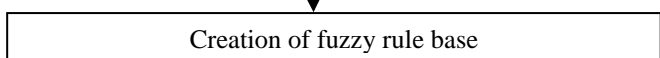
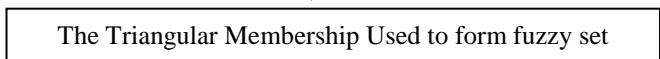
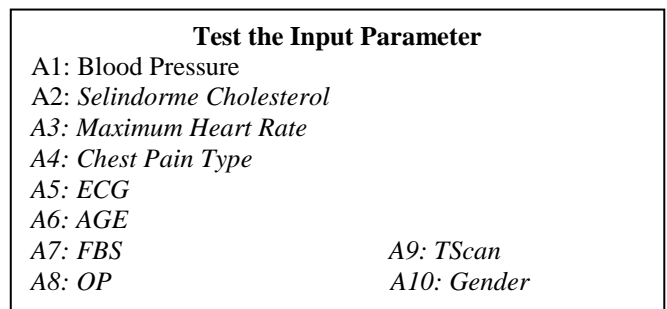
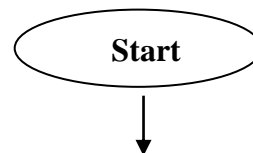
METHOD

Begin

Step1: Input the crisp values for A1, A2, A3, A4, A5, A6 A7, A8, A9, A10

Step 2: Set the triangular membership function for the fuzzy number with equation.

$$\mu_a(x) = \begin{cases} 0, & x \leq a \\ \frac{x-a}{m-a}, & a < x \leq m \\ \frac{b-x}{b-m}, & m < x < b \\ 0, & x \geq b \end{cases}$$



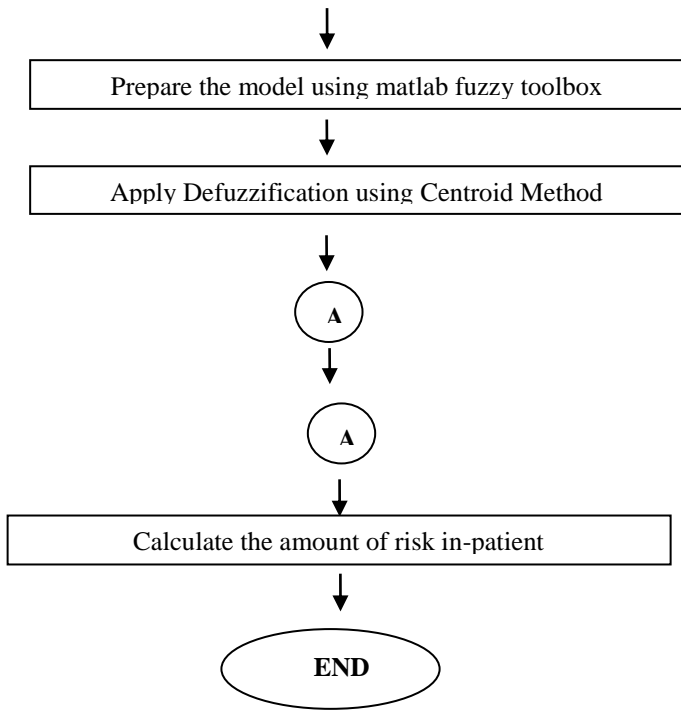


Figure 1. It shows 10 Input variables & 1 Output variable

Step 1:

In this step, we are providing ranges of input variable by using membership functions and providing ranges of output variable. We have used triangular and trapezoidal member functions [5] [8] [10].

Following are the table, in which we have mention all input variable with their range and fuzzy set values:

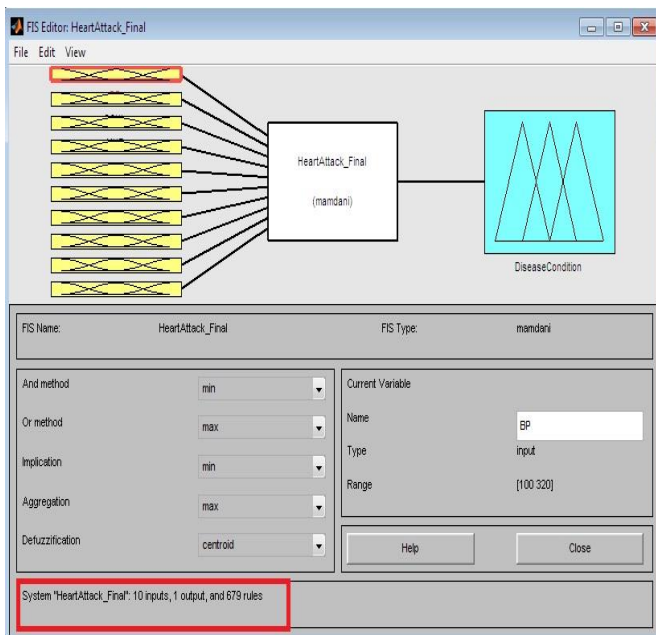
TABLE I: Input Attribute with their Ranges

Input Filed	Ranges	Fuzzy Set Value
BP	100 - 134	Low
	127 - 153	Medium
	142 - 172	High
	154 - 320	Very High
SCHL	40 - 197	Low
	188 - 250	Medium
	217- 307	High
	281 - 681	Very High
MHR	70 - 141	Low
	111 - 194	Medium
	152 - 400	High
CP	0 - 2	TAngina
	1 - 3	ATAngina
	2 - 4	NonAngina
	3 - 5	Asynpt
FBS	-1 - 1	False
	0 - 2	True
OP	0 - 2	Low
	1.5 - 4.2	Medium

IV. PROPOSED METHODS

We have used MATLAB R2008 tool, which is best tool for implementing fuzzy interface system. We have used 10 Input variables & one output variable for identification of disease risk level. Following images are used as a screenshots of MATLAB window while using fuzzy interface system and providing screenshot of input variables, fuzzy rules creation editor and view editor [5] [12].

MATLAB Window



	2.55 - 5	High
ECG	-0.5 - 0.4	Normal
	0.25 - 1.8	ST_T_abnormal
	1.4 - 2.5	Hypertrophy
ThaScan	1 - 5	Normal
	4 - 8	FixedDef
	5.5 - 10	RevDef
Gender	-1 - 1	M
	0 - 2	F
Age	20 - 38	Young
	33 - 45	Medium
	40 - 58	Old
	52 - 100	VeryOld

TABLE III: Output Attribute with their Ranges

Output Filed	Ranges	Fuzzy Set Value
DiseaseCondition	-1 - 1	Healthy
	1 - 2	LowRisk
	2 - 3	Risk
	3 - 4	HighRisk
	4 - 5	VeryHighRisk

Step 2:

After above step, we have created rules for all possible output, which is the most important part and contain any one of the output. Result accuracy is fully depends upon the combinations & strength of rule. If we have created rules with proper combination of input variable then surely we will get a good result. All the rules prepared with the help of AND & OR connection [22]. We have made **679 rules** for diagnosis of heart disease.

Fuzzy Rule Base

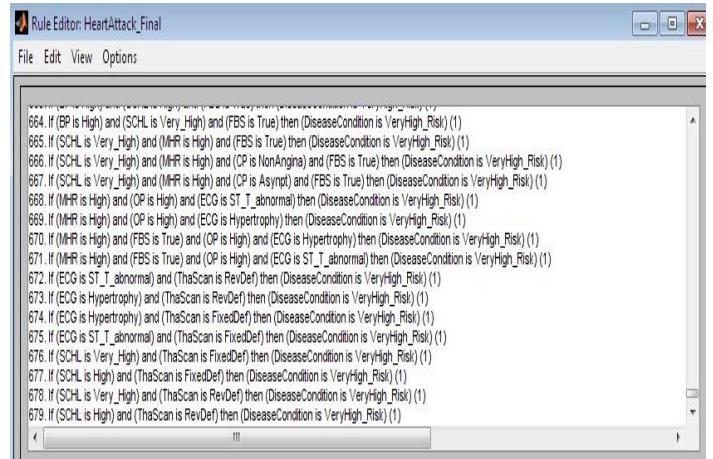


Figure 2. Rule Base Editor

Step: 3: Rule Viewer

By the help of rule viewer, we can check the disease condition (Risk Level) depends upon given input parameter. Rule Viewer is a place, where we will use all the input parameter from the UCI database [23] and result is displayed according to given input parameter. We are providing the screenshot of our implementation.

Rule Viewer

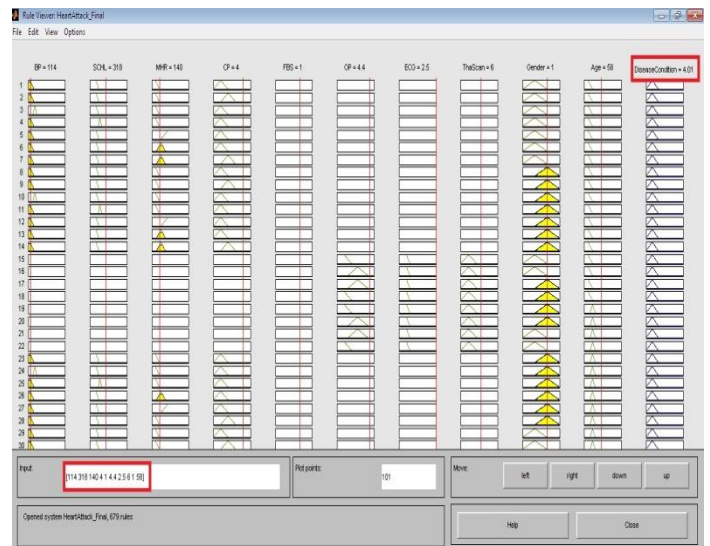


Figure 3. Rule Viewer

With the help of above matlab rule viewer, the result can tested easily. After testing on 200 patient databases (UCI) [25], 94.5% accuracy has been

achieved by the proposed diagnosis system. The experimental results are compared with earlier research in Table III and shows that the proposed system is more efficient and accurate as compare to other existing diagnosis systems.

TABLE IIIII: Comparisons of Previous Research

Diagnosis System	Accuracy
Rathod-Gawande [8], Sayad-Halkarnikar [21]	94%
Senthil Kumar [13]	93.88%
Kasbe-Pippal [5]	93.33%
Muthukaruppan [4]	93.27%
Pathania-Ritika [9] Kumar-Kaur [10]	92%
Khatibi-Montazerac [16]	91.58%
Proposed Method	94.5%

V. RESULT ANALYSIS AND DISCUSSION

The most important part of any expert system is input given by the user. In this proposed study, we have used Cleveland database from UCI machine repository [23]. We have used 200 patient data, and make fuzzy rule according to the input parameter given in the UCI. We have used all the 10 input variables which exist in UCI dataset [5] [10] [23]. After testing on this implementation system, accuracy & sensitivity of system is 94.5% & 90.1 %. We have measured the accuracy and sensitivity by the help of confusion matrix. The following table shows the confusion matrix:

TABLE IV. CONFUSION MATRIX

Total = 200	Predicated Value : NO	Predicated Value : YES
Actual Value: NO	TN=143	FP=6

Actual Value: YES	FN=5	TP=46
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True Positive (TP) = In this case, we have predicated a heart disease and according to database, actual it is.

True Negative (TN) = In this case, we have predicated a no heart disease and they do not have the disease.

False Negative (FN) = In this case, we have predicated a no heart disease and they have the heart disease.

False Positive (FP) = In this case, we have predicated a heart disease and they do not have the heart disease.

VI. CONCLUSION

In this paper, expert system is designed by the help of fuzzy logic toolbox and used mamdani interface system. We have used 10 input variables, 679 fuzzy rules and dataset from Cleveland database (200 dataset). We have used centroid technique for defuzzification. It is one of the most efficient methods to create an expert system and diagnosis the heart disease. The proposed implementation system has better performance and accuracy compared with the previous research to diagnosis heart disease. We have archived 94.5% accuracy, which is the highest accuracy using fuzzy expert system, so far. From the result accuracy, it can be concluded that the proposed system has highest accuracy but still it will require to get more accuracy.

VII. REFERENCES

[1] Wiga Maulana Baihaqi, Taqwa Hariguna, Tri Astuti, "Review on Fuzzy Expert System and Data Mining Techniques for the Diagnosis of Coronary Artery Disease", International Conferences on Information Technology, Information Systems and Electrical

- Engineering (ICITISEE), Indonesia, pp. 353-358, 2017.
- [2] Pallavi A. Agrawal and Nitin R. Chopde, "A Survey on Heart Disease Prediction using Soft Computing", *International Journal of Engineering Sciences & Research Technology*, Vol.5, No. 3, pp.582-587, 2016.
- [3] K.Sai Krishnasree and M.R.Narasinga Rao, "Diagnosis of Heart Disease Using Neural Networks-Comparative Study Of Bayesian Regularization With Multiple Regression Model", *Journal of Theoretical and Applied Information Technology*, Vol.88, No. 3, pp.638-643, 2016.
- [4] S. Muthukaruppan, "A hybrid particle swarm optimization based fuzzy expert system for the diagnosis of coronary artery disease," *Expert Systems with Applications*, vol. 39, no. 14, pp.11657-11665, 2012.
- [5] Tanmay Kasbe and Ravi Singh Pippal, "Design of Heart Disease Diagnosis System Using Fuzzy Logic", In *IEEE International Conference On Energy, Communication, Data Analytics, And Soft Computing (ICECDS-2017)*, Tamil Nadu, 2017.
- [6] Suresh Nagar and Arvind Kumar Jain, "Expert System for Diagnosis of Heart Disease: A Review", *International Journal of Computer Sciences and Engineering*, Vol.4, No.8, pp.45-47, 2016.
- [7] Rupali Wagh and S. S. Paygude," CDSS for Heart Disease Prediction Using Risk Factors", *International Journal of Innovative Research in Computer and Communication Engineering*, Vol. 4, No.6, pp. 12082- 12089-12089, 2016.
- [8] Anuradha B. Rathod, P. S. Gawande, "Design of Rule Based Fuzzy Expert System for Diagnosis of Cardiac Diseases, National Conference on Innovative Trends in Science and Engineering (NC-ITSE'16), Vol. 4, No. 7, pp.313-320 , 2016.
- [9] Neeru Pathania and Ritika, "Implementation of fuzzy controller for diagnose of patient heart disease," *International Journal of Innovative Science, Engineering and Technology*, vol. 2, no. 4, pp. 694-698, 2015.
- [10] Sanjeev Kumar and Gursimran Jeet Kaur, "Detection of heart diseases using fuzzy logic," *International Journal of Engineering Trends and Technology (IJETT)*, vol. 4, no. 6, pp. 2694-2699, 2013.
- [11] Mohammad A. M. Abushariah, Assal A. M. Alqudah, Omar Y. Adwan and Rana M. M. Yousef, "Automatic Heart Disease Diagnosis System Based on Artificial Neural Network (ANN) and Adaptive Neuro-Fuzzy Inference Systems (ANFIS) Approaches", *Journal of Software Engineering and Applications*, pp. 1056-1064, Vol.7 No.12, 2014
- [12] B.Venkatalakshmi and M.V Shivsankar,"Heart Disease Diagnosis Using Predictive Data mining", *International Conference on Innovations in Engineering and Technology (ICIET'14)*, Vol.3, No.3, pp. 1873-1877, 2014.
- [13] A.V Senthil Kumar," Diagnosis of heart disease using Advanced Fuzzy resolution Mechanism", *International Journal of Science and Applied Information Technology (IJSAIT)*, Vol.2 , No.2, pp. 22-30, 2013.
- [14] M. Eswara Rao and S. Govinda Rao," Expert System for Heart Problems", *International Journal of Computer Science Engineering and Technology(IJCSET)*, Vol. 4, No. 10, pp.266-271,2014.
- [15] Ashish Kumar Sen, Shamsheer Bahadur Patel,D. P. Shukla," A Data Mining Technique for Prediction of Coronary Heart Disease Using Neuro- Fuzzy Integrated Approach Two Level", *International Journal Of Engineering And Computer Science*, Vol.2, No.9, pp.2663-2671, 2013.
- [16] Vahid Khatibi and Gholam Ali Montazerac, "A fuzzy-evidential hybrid inference engine for coronary heart disease risk assessment," *Expert Systems with Applications*, vol. 37, no. 12, pp. 8536-8542, 2010.

- [17] R. Chitra and V. Seenivasagam, "Heart Disease Prediction System Using Supervised Learning Classifier", *Bonfring International Journal of Software Engineering and Soft Computing*, Vol. 3, No. 1, pp.1-7, 2013.
- [18] Manisha Barman and J Pal Choudhury, "A Fuzzy Rule Base System for the Diagnosis of Heart Disease", *International Journal of Computer Applications*, Vol.57, No.7, pp. 46-53, 2012.
- [19] Noor Akhmad Setiawan, Igi Ardiyanto and Wiga Maulana Baihaqi, "Rule extraction for fuzzy expert system to diagnose coronary artery disease," *International Conference on Information Systems and Electrical Engineering (ICITISEE)*, Indonesia, pp. 136-141, 2016.
- [20] Animesh Kumar Paul, Pintu Chandra Shill, Md. Rafiqul Islam Rabin and M. A. H. Akhand, "Genetic Algorithm Based Fuzzy Decision Support System for the Diagnosis of Heart Disease", *International Conference on Informatics, Electronics and Vision (ICIEV)*, pp.145-151, 2016.
- [21] A. T. Sayad and P. P. Halkarnikar, "Diagnosis of heart disease using neural network Approach," *International Journal of Advances in Science Engineering and Technology*, vol. 2, no. 3, pp. 88-92, 2014.
- [22] Tanmay Kasbe and Ravi Singh Pippal, "Design and Implementation of Fuzzy Expert System for Dengue Diagnosis", In *Springer International Conference on Advanced Computing, Networking and Informatics (ICANI-2018)*, Medi-Caps University, Indore, 2018.
- [23] <https://archive.ics.uci.edu/ml/datasets/Heart+Disease>.