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Research Article

Comparison of Proposed Intelligent Systems with Existing Models for Monitoring Heart Diseases

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ABSTRACT

These days, people are preoccupied with their everyday tasks, paying close attention to their work and other obligations while putting their health on the back burner. A growing number of individuals fall ill every day as a result of their hectic lifestyle and disrespect for their health. Hence, the majority of the population across the world affects by heart disease. Heart disease is one of the major causes of death globally, and early detection and monitoring are critical for effective treatment. Moreover, the use of machine learning is increasing quickly all around the world, particularly in the healthcare industry. Therefore, intelligent models can be developed or introduced by using machine learning approaches that predict the health of a patient's heart from its risk factors. This paper presents a comparative study in which models are proposed using fuzzy logic and hybrid system and also their performances are compared with each other as well as existing models. The comparison is made by considering the classification accuracy of each model. The model which has the highest percentage of accuracy is considered as the most accurate model for the monitoring of heart disease. According to the results, it is found that the neuro fuzzy methodology assists in implementing an intelligent model which has 98.90 percent accuracy of a classification and also outperforms other existing models.

Keywords: Comparative study, artificial intelligence, heart diseases, intelligent system, medical diagnostic systems, ANFIS, neuro fuzzy inference system, hybrid system, fuzzy logic, artificial neural network.

INTRODUCTION

In the human body, one of the most vital organs is the heart. The heart is a mechanism which is responsible for distributing blood that is enriched in oxygen to various bodily regions [1]. Any disruption in the heart's functions would have a negative impact on the proper functioning of other organs, which may be catastrophic [2]. The heart works continuously to ensure that all other organs receive the proper amount of oxygen-rich blood. Cardiovascular or heart disease is a serious as well as life threatening medical condition which is brought on by the heart's improper performance of its circulation related duties [3], [4]. Based on a poll done by W.H.O., seventy-five percent of people die from heart attacks annually and due to which this disorder becomes a rising and major problem in recent times [5]. Hence, it is true to say that one of the most serious and deadly human illnesses in the world today is heart disease [6]. Early signs of the illness that seem to be warning signs should not be ignored since there will be no time for recovery and the patient will finally pass away immediately [7],[8],[9]. This is referred to in medicine as a heart attack. It happens because the arteries' main role is to deliver blood with plenty of oxygen to the heart;

however, plaque builds up due to fat and additional compounds, interfering with that function and narrowing coronary arteries. Blood flow may thus be delayed or stopped completely [10].

Early diagnosis and prediction of cardiac disease are essential for effective treatment. More deaths of patients may be avoided and a good diagnosis would be known if heart disease could be predicted early [11], [12]. A medical diagnosis system needs to be improved every day. The main goals of medical diagnostics programmes are to lower costs while achieving effective results for more dependable outcomes [13]. Effective categorization combined with medical therapy lowers the death rate. Recently, machine learning has become increasingly important in the healthcare industry [14], [15]. It is a technique that makes it possible for machines to mimic human behaviour. Without being coded, it allows robots to gain knowledge from what they have experienced and forecast desired elements [16]. Decision support systems for mobile devices can also be incorporated using remote healthcare technology [17]. It can effectively deliver healthcare services and collect patient data in real time. Without having to attend hospitals or medical facilities, it helps monitor patients [18]. In contrast to the conventional method, the creation of a machine learning-based system for medical diagnostics that predicts cardiac problems results in a highly specific choice and lowers the cost of therapy [19], [20].

In the existing models for monitoring heart illnesses have a number of drawbacks. Firstly, the recent options of machine learning approaches have not been employed mostly, instead, the classical methodologies of machine learning is been used for the development of such models as regression modelling [21]. Secondly, the majority of models are created to only include a limited amount of key predictors that physicians may quickly access and can measure the risk assessment very easily to select the best type of therapy for a specific patient. This can also be explained as maybe they do not have the resources to acquire additional data beyond the regularly gathered health care data [22]. Last but not least, less emphasis has been given to developing a model for output that is crucial from the viewpoints of patients as well as payers [23]. The primary purpose of this study's analysis is to compare several machine learning methods in order to address the shortcomings of the earlier proposed models. This paper develops an intelligent model by using the most recent fuzzy logic and a hybrid approach of machine learning and also compares it with other models which are proposed earlier by other authors.

1.1. Main Contribution of Research

Many medical conditions can be identified, detected, and predicted using machine learning approaches. However, this study's main goal is to provide clinicians with a tool or an intelligent model for early detection and monitoring of heart disease. Due to this developed model, it will be simpler to offer top-notch and right care to the patient while minimizing negative consequences. This study utilizes fuzzy logic and a neuro-fuzzy approach to develop diagnostic systems and also evaluate the selected methodologies with other existing methodologies on the basis of their performance to see which ones work best at diagnosing heart disease.

This paper is categorized into several sections. Section 1 offers an introduction to heart diseases and the contribution of machine learning approaches in the health care domain and in the detection of heart disease. Section 2 gives a review of the literature in which various models developed earlier by the authors are studied and their performance is evaluated. After that, the development of models using fuzzy logic and neuro fuzzy model with a brief explanation is given in the methodology section which is section 3. Moreover, all the models investigated in section 2 and models developed in section 3 are compared with each other on the basis of their performance to check which machine learning model works best at monitoring heart disease in section 4. Lastly, the final conclusion is made in section 5.

LITERATURE REVIEW

In the literature, several research works have been reported that assist in the diagnosis of heart diseases by proposing or introducing models using machine learning. No doubt, these models are able to offer the aim of the model's enhanced performance accurately [24]. The work present in the literature displayed that numerous ML approaches like multilayer preceptron, back propagation neural network, logistic regression, random forest and support vector machine are found as effective approaches in the detection of heart diseases by proving any individual data with the highest accuracy. Additionally, some studies revealed that the utilization of hybrid approaches, in which two ML algorithms are combined, is achieving a better performance percentage [25].

In the work of Chang et al. (2022) [26], a random forest classifier has been utilized to develop a methodology which can able to detect heart conditions with high performance. The random forest classifier algorithm is examined on the basis of tests and findings. As a result, this algorithm improves the accuracy of diagnosis, and the development costs of this application are incredibly minimal. This application outperforms training data by about 83 percent accuracy.

A heart disease prediction model is created by Akter et al. (2021) [27] utilizing the gathered data set and implementing various machine learning classifiers. Binomial Logistic Regression, Decision Tree Classifier, Adaptive Boosting, Naive Bayes, K-Nearest Neighbors and Random Forest are some of the classifier models that are employed. The prediction model's findings and the empirical studies correspond fairly well, and the decision tree classifiers' accuracy is about 87%. When compared to other current-generation models, the proposed model performs more accurately at estimating future decisions. Moreover, the decision tree classifier had the highest accuracy among the classifiers for predicting heart disease.

The Temporal Association rules of Naïve Bayes classification model is also a useful element in the detection of heart disorder as per the work of Orphanou et al. (2018) [28]. This research study pre-processed the dataset using temporal abstraction. An 82% accuracy is achieved by taking into account each TAR pattern's potential recurrence in relation to pertinent medical history.

Arooj et al. (2022) [29] diagnose heart disease using a deep learning method based on image classification. The dataset utilized in this work is the heart-disease dataset from public UCI which consisted of fourteen features and one thousand fifty patients. The feature vector is used as an input to the system which system the proposed model to check if the given data of a patient belongs to the heart disease class or healthy class. This classification is compiled by using the collected attainable features from the dataset. A variety of performance criteria has been utilised which includes F1 measure, recall, precision and accuracy to evaluate the effectiveness of the suggested approach. As a result, the developed model had a validated accuracy of 91.7 percent.

In the study of Sarra et al. (2022) [30], an improved model was used to lessen the computational load and improve the accuracy of heart disease diagnosis and prediction. A classification model based on the ML algorithm was utilised to improve heart disease diagnosis named as support vector machine. The model is developed using two datasets and as per the experimental results, the accuracy using the Statlog dataset is 89.7% which is way more than Cleveland dataset. Additionally, the number of features present in the dataset also decreased to six from fourteen which implies the reduction of computational load as well.

DEVELOPMENT OF FUZZY INFERENCE SYSTEM (FIS)

The steps for the development of Fuzzy Inference System are mentioned below

1.2. Fuzzy Logic

This study effort has offered an expert system employing fuzzy logic to pinpoint the precise degree or stage of heart illness and provide the best approach for treating heart ailments. By asking pertinent questions, the newly developed method obtains exact information from the person experiencing pain. Following that, fuzzy rules are created based on information obtained from the patient, which is then contrasted with the knowledge base (KB) [31]. The inference engine, a crucial component of fuzzy logic, then processes the developed rules. The controller's matching component matches the set of rules from the KB, after which the best rule out of all the others is fired. The platform will automatically reject any inputs that do not match any of the rules. Doctors will only be advised to utilise the system to assess the severity of an illness if a correct diagnosis is obtained using the user's data. The doctor administers the appropriate dosage of medication to the patient once this system has completed the diagnostic. The conclusion made by a medical expert system is now available to a doctor, who can then advise a prescription [32-34]. The flow of methodology used in this work is shown in figure 1.

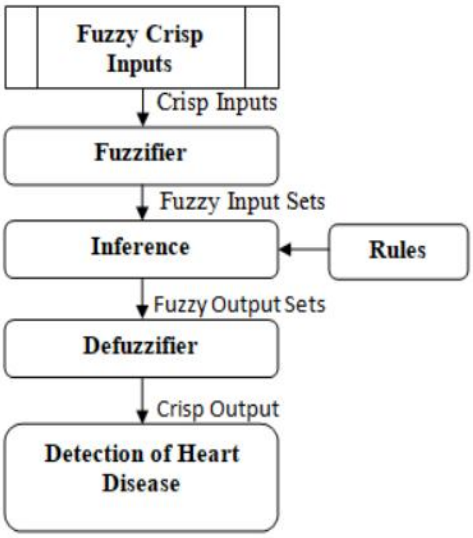

Figure 1: Methodology used for FIS.

1.3. Input Variables

Seven different input parameters are used by the created system. Using the Matlab software and Mamdani inference method, the complete development was carried out. The input variables are:

- Age
- Smoking
- Shortness of breath
- Diabetes
- Blood pressure
- Irregular heartbeat
- Cholesterol

The membership functions used for input variables are triangular and trapezoidal. The pictorial view of all input variables are displayed in figure 2 to 8.

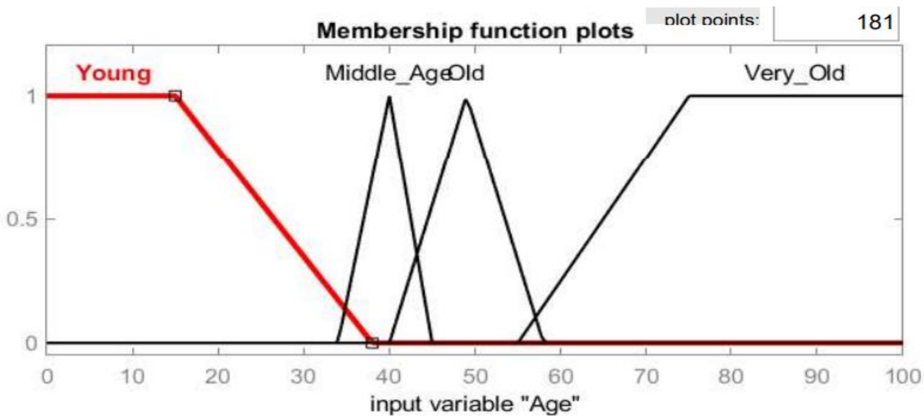

Figure 2: Input Variable “Age”

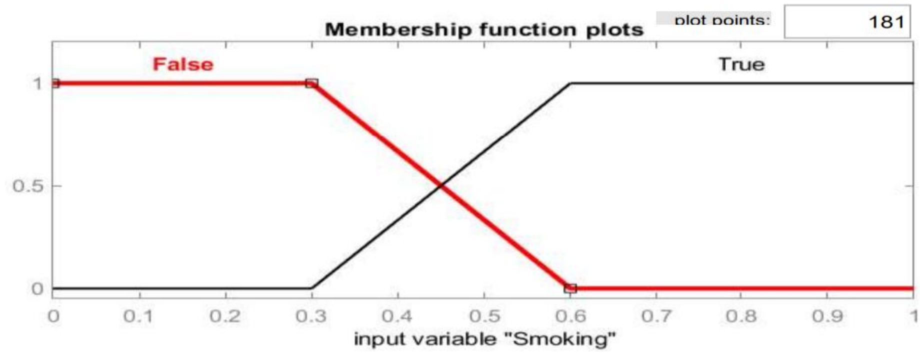

Figure 3: Input variable “Smoking”

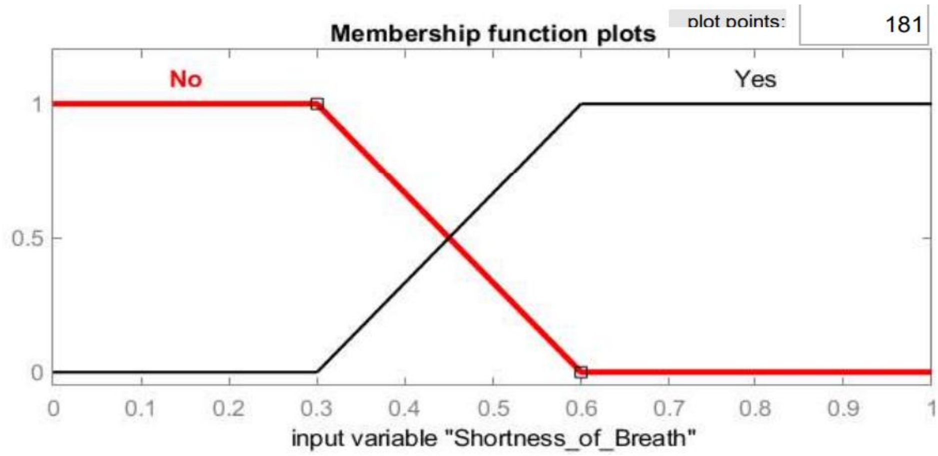

Figure 4: Input Variable “Shortness of Breath”

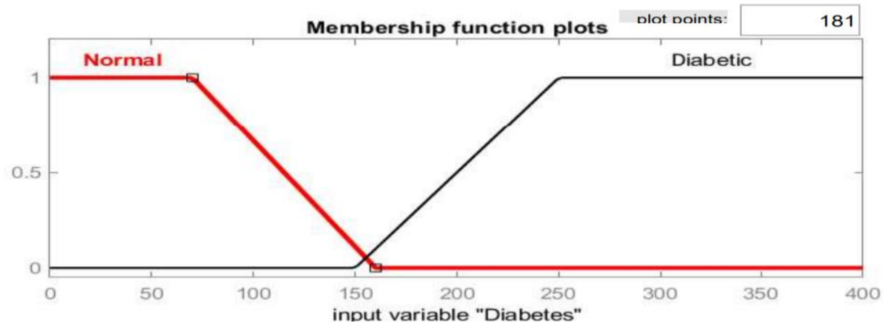

Figure 5: Input Variable “Diabetes”

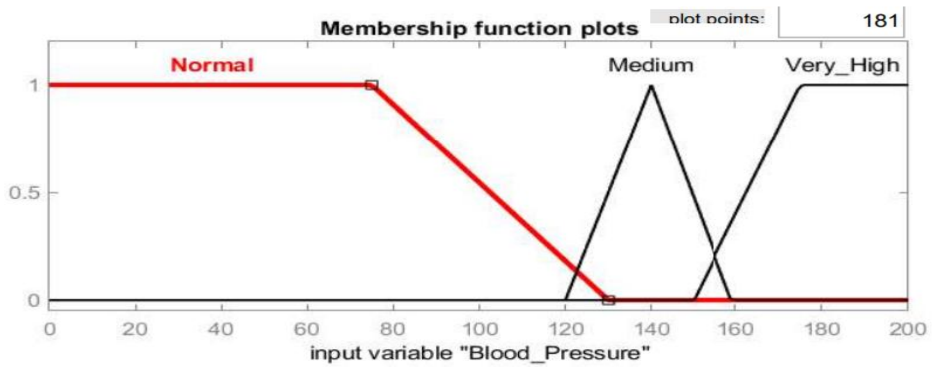

Figure 6: Input Variable “Blood Pressure”

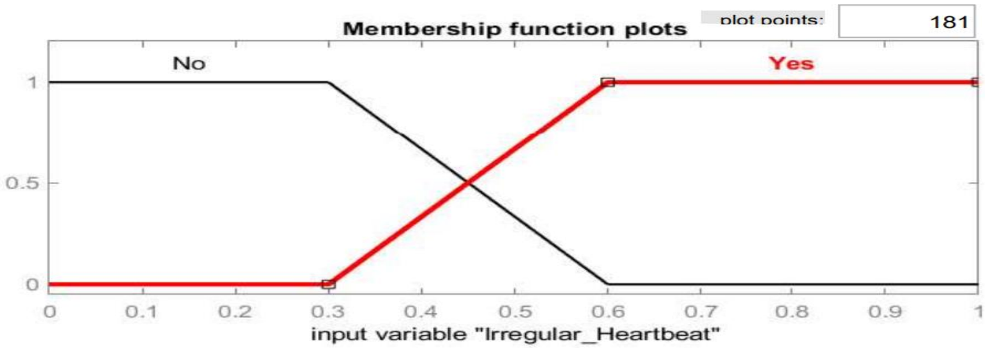

Figure 7: Input Variable “Irregular heartbeat”

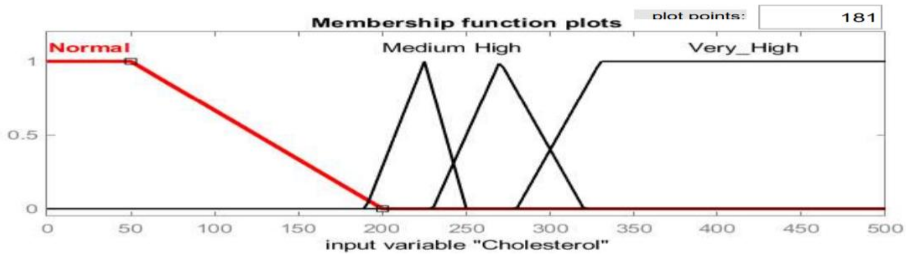

Figure 8: Input Variable “Cholesterol”

1.4. Rules

The rule base is the most crucial and essential part of a fuzzy inference system, and the precision of the outputs produced by the system also has a direct connection with these fuzzy rules. As a result, the system will undoubtedly produce accurate, exact, and right results if the quality of the rules is good as shown in figure 9. The number of rules is always based on multiplying a variety of linguistic input factors. In accordance with this, the KB requires 768 rules. To manage this many rules, though, is quite difficult. Therefore, just fifty rules are used in this work because they are the best and produce accurate findings when compared to other rules.

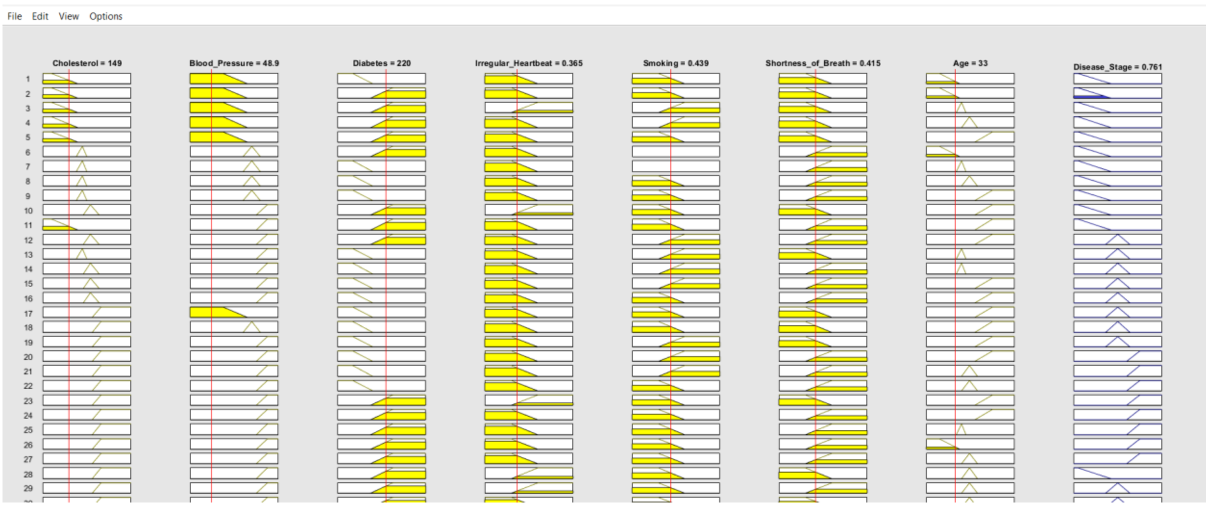

Figure 9: Rule base

1.5. Output Variables

Three parameters are used as output by the developed system. The system's output recognises the presence of cardiac disease and alerts the doctor and patient as necessary. The levels of the disease are the output variables such as:

- Healthy stage
- Early stage
- Advanced stage

The membership functions used for output variables are triangular and trapezoidal. The pictorial view of output variables are displayed in figure 10

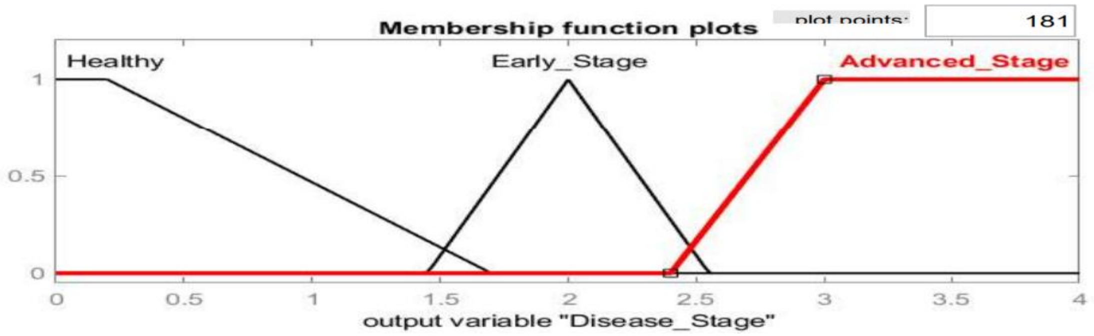

Figure 10: Output variable

DEVELOPMENT OF ADAPTIVE FUZZY INFERENCE SYSTEM (ANFIS)

1.6. Methodology

The two most successful and advantageous machine learning techniques have worked together to create an intelligent hybrid strategy. This approach, known as a "neuro-fuzzy method," produces outcomes by combining the advantages of both neural networks and fuzzy logic. The advantage of combining these two approaches is that the disadvantage of one strategy is outweighed by the strength of the other. Thus, both strategies complement one another to produce results that are extremely precise. This research also introduces an intelligent hybrid system that helps track various heart disease stages. The input and output variables are identical which are used for the development of FIS. The flow of methodology used in this work is shown in figure 11.

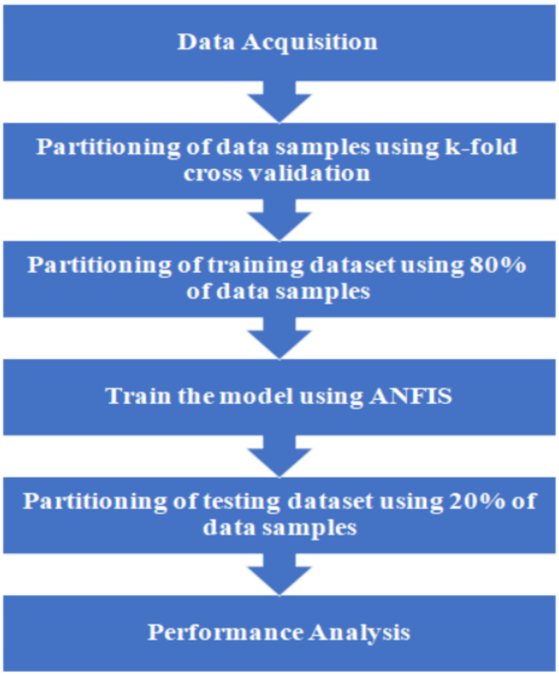

Figure 11: Flow of used methodology

1.7. Membership functions

The membership function plots for all input variables are displayed in figure 12 to 18 along with their type of MFs.

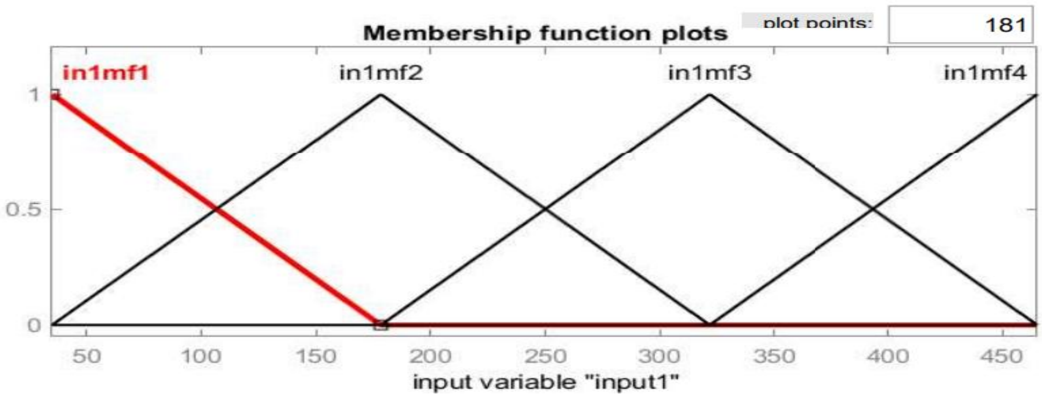

Figure 12: MF plot of input 1

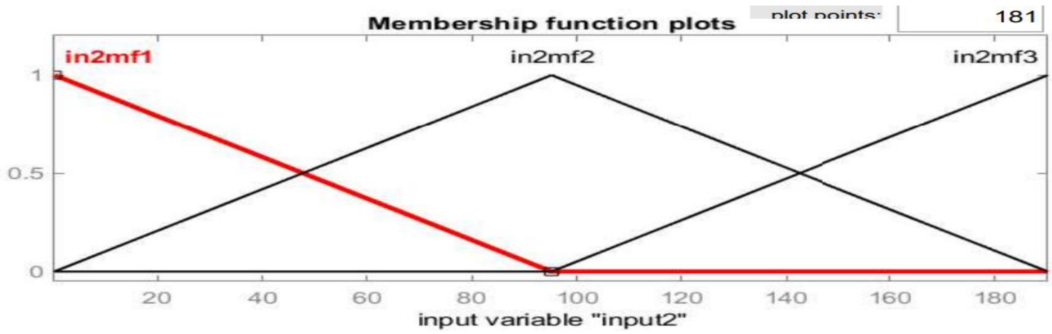

Figure 13: MF plot of input 2

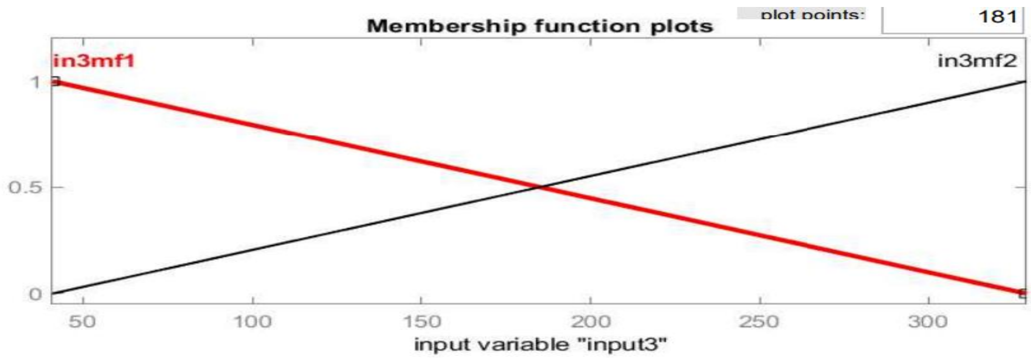

Figure 14: MF plot of input 3

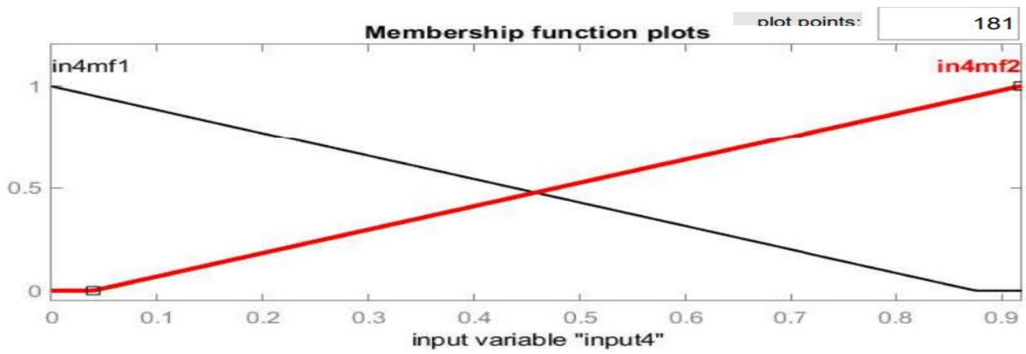

Figure 15: MF plot of input 4

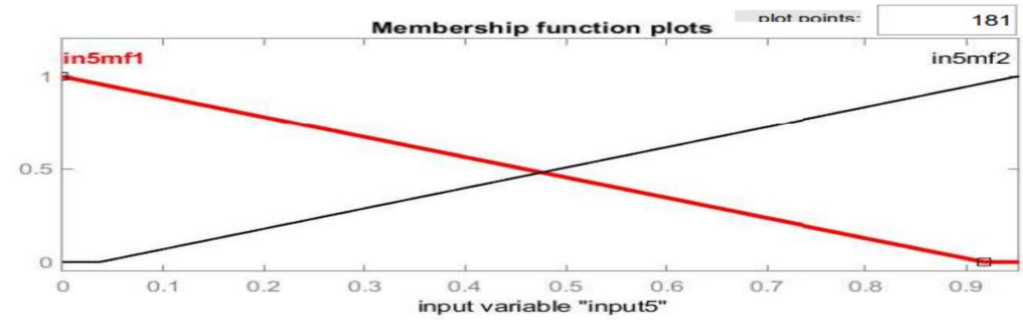

Figure 16: MF plot of input 5

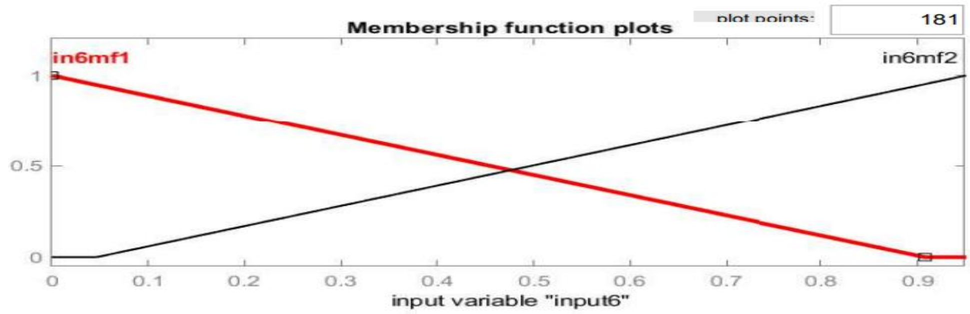

Figure 17: MF plot of input 6

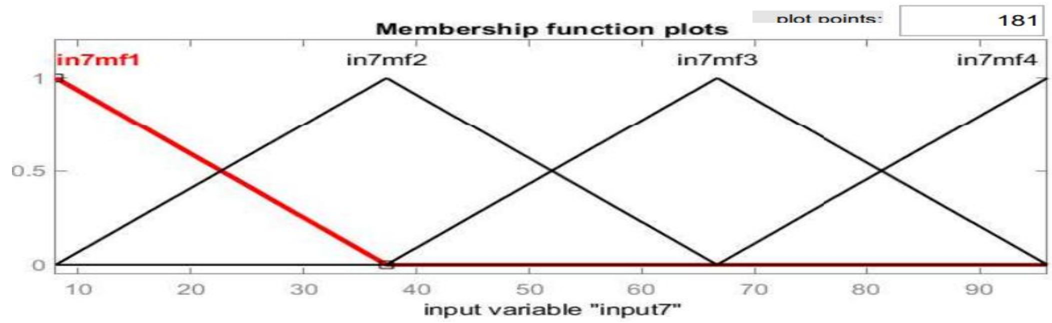

Figure 18: MF plot of input 7

1.8. Rules

During the training phase, the system automatically develops the criteria for this methodology to determine the stage of heart disease using all conceivable combinations of the input data given. The hybrid model created generates the rules using the training set of data displayed in Figure 19. The proposed intelligent hybrid model uses a total of 768 rules. The number of rules can be calculated by multiplying the number of MFs used for each of the system's input variables.

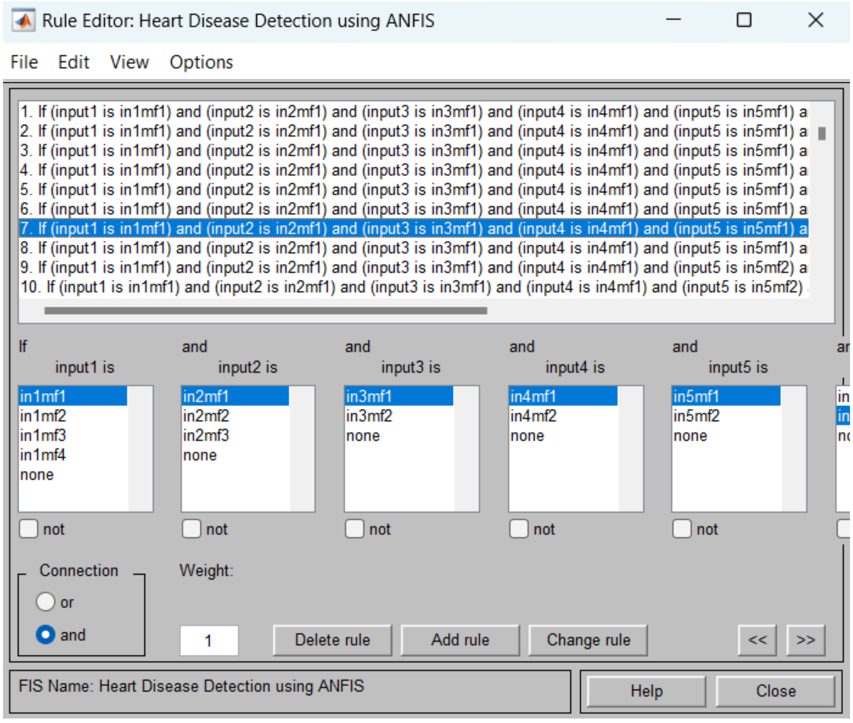

Figure 19: Rules

1.9. *Training & Testing Phase*

The hybrid system's training and testing phases are the most important during installation. The heart specialist is where the data is first obtained. Following data collection, the collected data is divided using k-fold cross validation. The dataset that was used has 800 data samples. This dataset is divided into separate sections according to the value of k using the k-fold cross validation. For instance, the dataset is divided into four pieces in this study since the value of k is assumed to be 4. Additionally, when k = 4, the cross validation procedure is referred to as 4-fold cross validation. Following the training phase, the training error is shown in Figure 20.

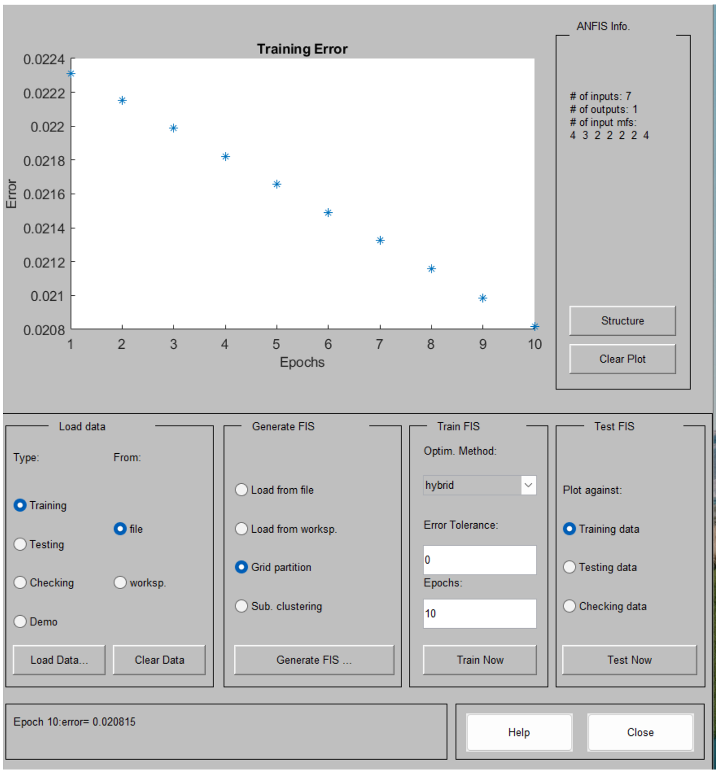

Figure 20: Training error at 10 epochs

RESULT

By comparing the produced models, fuzzy and adaptive neuro-fuzzy techniques have been used. The performance of the two systems is compared to determine whether the system would classify the provided unknown information into the right group and be better able to identify heart disease. In this study, the output produced by the designed systems for a given input is contrasted with the conclusion or outcome offered by the expert physician in chronic kidney disease. The ANFIS provided outputs that were more accurate and correct than a fuzzy inference system and other existing models, according to the comparison study. the comparison of accuracies of developed models and existing systems is shown in table 1 and figure 21.

Table 1: Comparison of existing and proposed models

Models	Classification Accuracy
Naïve Bayes [29]	82%
Random Forest [27]	83%
Decision Tree [28]	87%
SVM [31]	89.7%
Deep Learning [30]	91.7%
FIS	98.75%
ANFIS	98.90%

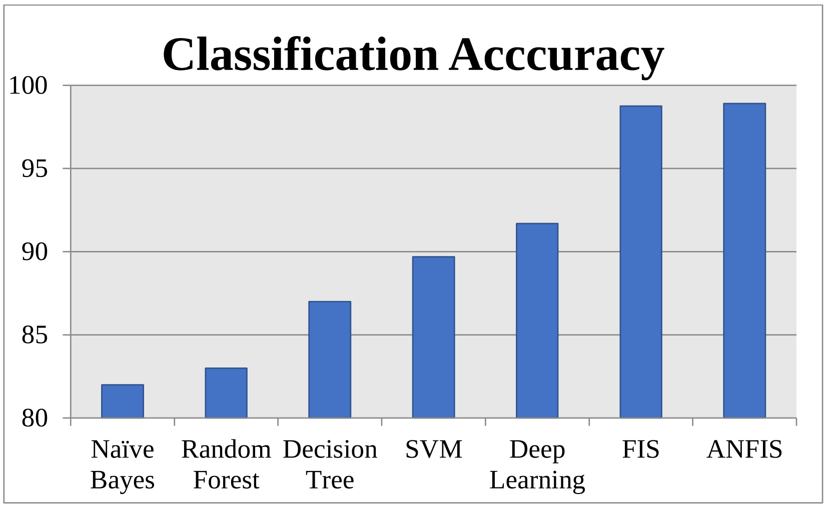

Figure 21: Comparison of existing and proposed models

CONCLUSION

It is a severe problem for individuals and doctors to accurately forecast heart problems and it is necessary to predict this disorder at an early stage as the heart is one of the most important parts of the human body's organs. When evaluating the effectiveness of heart disease prediction systems, method accuracy is one of the parameters considered. This paper provides a comparison between existing and developed machine learning models used to detect heart disorders. In this study, the considered approaches of ML to detect heart disease are ANFIS, FIS, deep learning, SVM, decision tree, Random forest and Naïve Bayes. However, in the results, it is analyzed that the ANFIS methodology has an improved and more accurate performance than other existing methodologies and has 98.90 percent accuracy in classifying the given inputs into correct classes. This study can be extended in the future by adding more features to the dataset and other hybrid methodologies can be developed for this dataset which can outperform ANFIS in the detection of heart diseases.

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