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A Novel Adaptive Neuro Fuzzy Inference System for the Diagnosis of Liver Disease

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Abstract
In recent years, liver diseases have increased to a great extent in a way that it has turned into one of the most fatal diseases in the world. On time diagnosis of this disease can be effective in the prevention of its bad effects, its control and remedy. With technology advancement and changing many issues in software industry, doctors have developed a tendency towards intelligent systems for better diagnosis. Thus, in this paper, we have diagnosed liver sickness using fuzzy logic by obtaining important laboratory parameters. We have used two types of triangular membership function and Gussy membership function per 3 membership function for each input and output and also the design of reference table (search) to construct fuzzy heuristic system and we have managed to compare 243 rules. At the end, we were able to reach to 79/83% of accuracy with the appropriate choice of input parameters, the number and type of membership functions.

Keywords: Liver Sickness, Fuzzy logic, Reference Table, Fuzzy Heuristic System, Membership Function.

1. Introduction

Liver is one of the important body organs that detoxification of drugs, excretion of wasteful things resulting from the destruction and reconstruction of RBCs in the form of bile, production of blood clotting factors, storage of sugar as glycogen, and also the regulation of sugar and fat metabolism are some of the most important functions of this organ in the body; yet, we should not overlook its function in fat absorption and defense before microbus and toxins coming from food stuff [1]. In recent years, death toll resulting from liver disorders has been dramatically increasing. On time diagnosis of this disease can be affective in the prevention of its effects, its control and remedy. Browse considers expert's mentality as one of the most important issues in diagnosing disease because human-being is subject to error and there is error possibility in disease diagnosis [2-3]. One of the significant informatics medical plans is to use expert systems to diagnose disease based on a group of symptoms [3-4]. These systems are based on artificial intelligence and help doctors diagnose the diseases and more effectively treat them by considering laboratory tests. They also reduce cost, time, human expertise and wrong diagnosis to the least level [5]. Therefore, we have tried to diagnose liver disease using fuzzy logic technique in this study. Our aims in selecting fuzzy logic are such advantages as its very simple sense, high flexibility, the ability to tolerate inaccurate data appropriately, the ability to model complicated non- linear functions, to act on the basis of expert experience, the ability to assimilate with common controlling techniques and its being based on natural language.

In this paper, we have used MATLAB software because of its flexibility, plenty of available

functions and its efficiency to simulate fuzzy logic. MATLAB software increases the accuracy of results and the comparison of the efficacy of systems and provides the best operation for system training in the shortest time possible. In the Section 2, we will analyze the previous research conducted about liver disease. In the Section 3, we will define fuzzy logic. In the Section 4, we will introduce the data set. In the Section 5, we will consider the conclusions of the study, and finally in the Section 6, we will elaborate on the conclusions obtained about the proposed approach.

2. Related Works

Experts have reviewed liver cancer using data-mining technique in Adaptive Neuro Fuzzy Inference System (ANFIS) [12]. They have used CT 2-d pictures as their inputs, and at the data analysis phase, they have deleted noise in CT pictures; afterwards, they have attended dividing process, morphological operations and feature-extraction techniques. They also discussed about ANFIS in early diagnosis of liver cancer in humans and they hoped that the proposed method or a hybrid of ANFIS with other data mining techniques will help the medical field in early diagnosis of liver cancer. Hashmi and Saleem Khanb in [7] used the commonest laboratory methods for the evaluation of general health and liver health and analyzed the operation of liver and CBC. They regarded leukocyte, Hematocrit, hemoglobin, and the number of platelets as the inputs of fuzzy logic and infection removal, anemia and thrombocytosis as the outputs. The proposed fuzzy model is divided into four stages; Fuzzification, inference engine and selection of rules and anti-fuzzification.

In [11], using ANFIS, the classification of liver tumors into two categories: benign and malignant has been investigated by analyzing CT pictures. In order to investigate the effect of each type of tumor characteristics on the classification and accurate decision-making process on classification of tumors into benign and malignant, these two sets of features have been taught separately. The results show that the proposed method has the potential to identify the type of tumor. Vafun and colleagues have proposed a hybrid model of case argument and fuzzy decision-making tree (CBFDT) for the diagnosis of liver diseases and have obtained 81.6% accuracy [5]. Cirrhosis which is one of the most common liver diseases, has been diagnosed based on fuzzy expert system [9]. The proposed system has three inputs (rate of AST / ALT, and the number of platelet and INR) and one output (risk of cirrhosis which is marked with the numbers 0 to 6). In the proposed system, Mamdany method is used. Researchers have presented a new approach for diagnose of liver cancer and diabetes using ANFFS and improved KNN [8]. From among the data set, Pima hend diabetes has been regarded as input and classification based on features of the information as output. The results show that the proposed method has better classification accuracy than other methods. The study of [11] from among the data collected from liver biopsy (sampling) of Imam Reza Hospital, Mashhad, Iran, which consists of 300 records with each record having 7 fields is suggested. Strong fuzzy heuristic rules, with the assistance of expert research and experience have been identified. The accuracy of the proposed system in diagnosing the severity of hepatitis, $96 \pm 0.2\%$ is obtained.

In [14] has diagnosed liver disease using artificial neural propagation networks and radial basis function. They used BUPA data set and they reached accuracy of 63% and 70% with 6 inputs and 2 outputs using propagation neural network (with 10 hidden neurons) and radial basis neural network (with 20 hidden neurons). Bahramirad and colleagues in their study used two BUPA and AP data sets to classify liver disease and they reached 73/39 and 67/39 accuracy [6].

3. Fuzzy Logic

Soft Computing is a new computational method which gathers human mind`s outstanding reasoning and acquisition abilities in an uncertain and imprecise environment. Soft Computing consists of such computational components as neural networks, fuzzy sets theory, approximate reasoning and the optimization methods without differentiation such as genetic algorithms and heating and cooling simulation. Unlike the classic series (a series that has defined borders), a fuzzy set, as the name implies, is a set with unclear boundaries. In fact, in this type of collection, transition from inclusion to exclusion is done gradually. This transition is gradual and soft organized by membership function [10].

As noted by Lotfizadeh, traditional techniques are inefficient in analyzing issues related to human-based systems, because the behavior of human-based systems is greatly influenced by the human judgment, perception and emotions. This fact can be restated in the form of the principle of incompatibility which means “with the increasing complexity of a system our capability in expressing its correct

and accurate behavior upon its reaching a certain threshold reduces, and in such a case accuracy and transparency turn into two features in mutual exclusion." That is why Lotfizadeh introduced the concept of linguistic variables as an alternative solution for human thought modeling. This approach summarizes information with approximate behavior and describes them in the form of fuzzy sets (rather than fixed numbers) [13]. In recent years, fuzzy logic applications are rapidly expanding. These applications range from consumer products such as cameras, washing machines and microwaves to control industrial processes, medical apparatus, and decision-making systems and so on. To determine the cause of this growth, we must first be familiar with the concept of fuzzy logic [13].

Fuzzy logic has two different meanings. In the first sense, fuzzy logic which has more limited vision is a logical system derived from a multi-valued logic; however, on a broader sense it is almost synonymous with the theory of fuzzy sets. Fuzzy sets theory is associated with classes of objects with undistinguished boundaries. In these classes membership of objects in each class is described as a concept of membership degree. Another fundamental concept that plays a key role in many fuzzy logic applications is if-then rule or better to say a fuzzy rule. Although rule-based systems have a long historical background in artificial intelligence, they lack a mechanism to deal with assumptions and fuzzy results. In fuzzy logic, this mechanism is provided through fuzzy algebra. Algebra of fuzzy rules plays the role of the foundation and dependency phase (FDCL). Although fuzzy FDCL and instruction language are not used in the toolbox, the important role of fuzzy logic cannot be overlooked.

3.1. Fuzzy Inference

The human brain is made up of inaccurate and incomplete information and thus interprets sensory organs. Fuzzy sets theory provides a systematic method for computing a discussion of linguistic information. This theory acts based on numerical calculations on the values generated by the membership for each of linguistic variables. In addition, choosing if-then fuzzy rule is the main component of ANFIS. Using these rules, we can effectively model the expertise of a human being in a particular field [13].

Fuzzy inference is a process in which the mapping of inputs to outputs is regulated using fuzzy logic. According to the conducted mapping, a decision is made or a pattern is detected. There are two types of ANFISs, i.e., Mamdani and Sugeno, which are different with regards to outcomes. Mamdany method was used in this study. Mamdani fuzzy inference method is the most common fuzzy methodology. Mamdani method is one of the first theories of Fuzzy Control System. This method was invented by Ibrahim Mamdani in 1975 to control steam engine. This invention was introduced by Mamdani based on an article by Lotfizadeh published in 1973 in connection with fuzzy algorithms in complex systems and decision-making processes. In Mamdany inference, output fuzzy set membership functions should be defuzzificated. In most of the cases, it can be more efficient than using output membership function known as an output membership function. This approach increases the efficiency defuzzication process because it reduces the computation required intensely. In Mamdani method, the center of two-dimensional mass function weight is calculated [13].

4. Data Set

The dataset contains information coming from 167 patients with no liver sickness (healthy) and 416 liver disease in North East of a Drop Radesh of India with 441 males and 142 females [17]. Patients over 89 years are assumed to be 90. In all, the above data set has 11 parameters and 583 samples; in this study we consider only 6 of the most important parameters of the dataset as the inputs of Fuzzy System including Billy Robin (TB) set, direct Billy Robin (DB) set, Alkalin Phosphataz or Alkalen Phosphataz (Alkphos), Amino transferaz Alamin (Agpt), Spartat trans Aminaz (Sgot). A summary of these parameters can be seen in Table 1. All parameters are numerical and there is no lost

datum. For gender parameter, 1 is regarded for men and 2 for women.

Table 1. Features of Datasets

Number	Feature	Descriptive
1	Age	patient's age
2	Gender	Patient's Gender
3	TB	Total bilirubin
4	DB	Direct bilirubin
5	Alkphos	Alkaline phosphatase or alkaline phosphatase
6	Agpt	Amin aminotransferase
7	Sgot	Aspartate transaminase
8	TP	Total Proteins
9	ALB	Albumin
10	A/G	The ratio of albumin and globulin ratio
11	1 or 2	Fragmentation of data to two nodes

5. Evaluation and Conclusions

After getting the data of patients from UCI system, we will save them in a 583×6 array. The rows include the data of patients and the columns are the laboratory parameters. We consider the first 5 columns as the network input and the last column as the class of the disease. Totally, the input data must be divided into two sets of training and testing. The suitable choice of the number of training and testing data affects the efficacy of the network, but how to obtain right selection is done with trial and error. In this paper, we have regarded 80% (446 samples) as the training data and 20% (117 samples) as the testing data. The manner of data selection according to this classification was random selection. The architecture of the proposed inference fuzzy system is as Figure 1. As can be seen, this system is composed of 5 inputs and 1 output. The information of the proposed system is stated in Table 1.

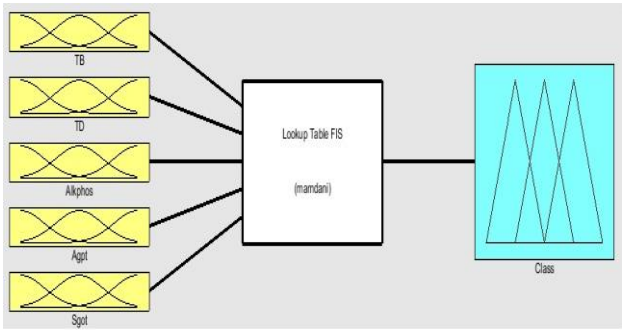

Figure 1. The Proposed ANFIS

As shown in Table (2), the ANFIS includes 243 rules which a summary of rules represented in Figure 2.

Table 2. The Values of the Proposed ANFIS

Name	Lookup Table ANFIS
Type	Mamdani
And Method	Min
Or Method	Max
Defuzzmethod	Centroid
Imp Method	Min
Agg Method	Max
Input	[1x5 Struct]
Output	[1x1 Struct]
Rule	[1x243 Struct]

In Figure 2, the chart of the rules of ANFIS is shown for the diagnosis of liver disease.

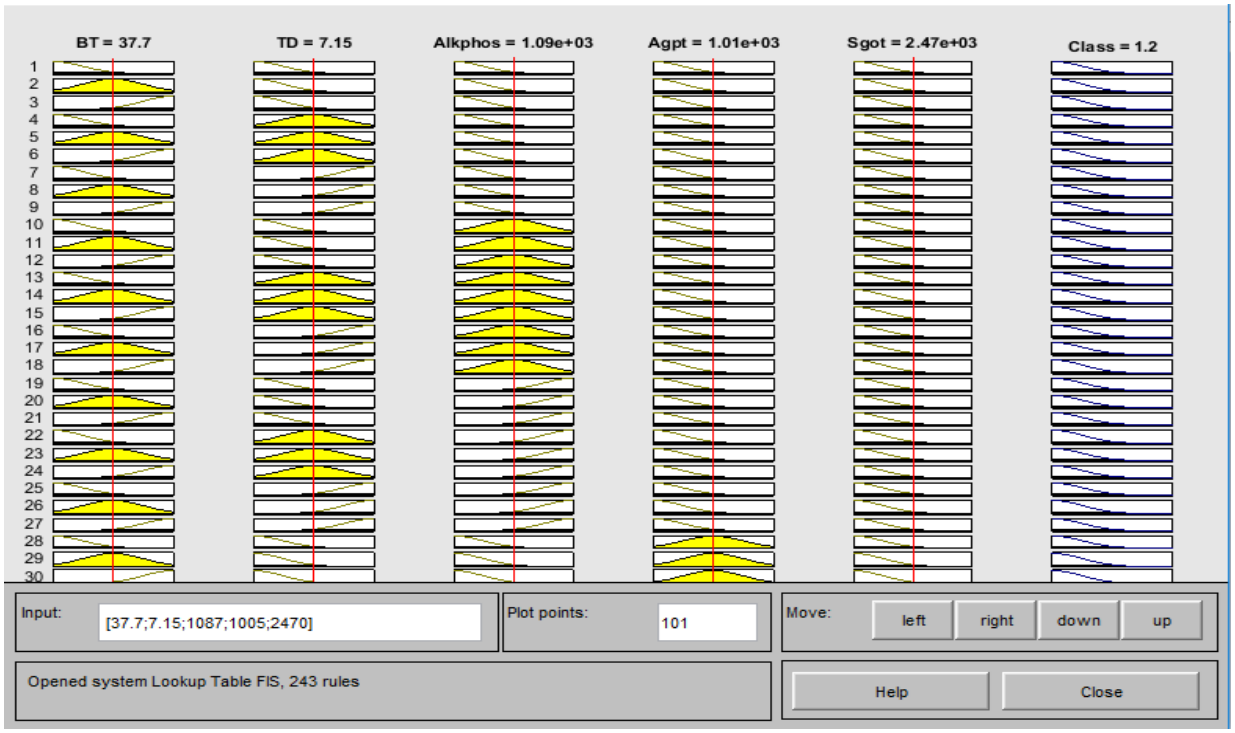

Figure 2. The Chart of the Rules of ANFIS

The average of mean-squared error is calculated as equation (1).

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(Output - Target)^2 \qquad (1)$$

The results of the error of ANFIS is stated based on Gaussian and triangular membership functions in Table (3) and Figure (3) that shows the error of Gaussian membership function is more or less lesser than the error of triangular membership function.

Table 3. Training and Testing Error of the Proposed ANFIS

Train	Gaussian Membership Function	0/2166	MSE
Test		0/2017	
Train	Triangular Membership	0/2232	
Test		0/2065	

In Figure 3, the chart of the error of Gaussian and triangular membership functions is shown.

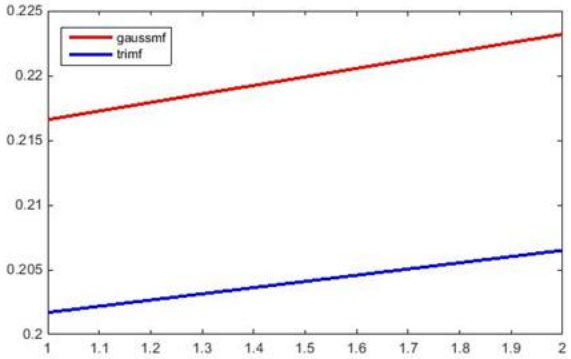

Figure 3. The Chart of the Error of Gaussian and Triangular Membership Functions

Unfortunately, the majority of researchers have used CT pictures instead of datasets for the diagnosis of liver disease. In comparison with the method [6] which used the two BUPA and Ac datasets for the classification of liver disease and their accuracy reached to 73/39 and 67/39, the accuracy of the proposed method is remarkably higher. Also in comparison with [14] which for the diagnosis of liver disease with 6 inputs and 2 outputs used propagation neural network (with 10 hidden neurons) and radial basis neural networks (with 20 hidden neurons) have respectively achieved accuracy of 63% and 70%, the accuracy of the proposed method with 79/83 % is remarkably better.

6. Conclusion and Future Works

In this paper, we used ANFIS to diagnose liver disease because with technology advancing doctors have developed a tendency towards useful applications to reach better and accurate diagnosis. On the other hand, the right selection of the number and the type of membership functions affects the efficacy of the system in better diagnosing the disease. Thus, in this article we used Gaussian and triangular membership functions for three membership function times for each input and output. We chose 80% of the data for the training and 10% for testing and managed to reduce the error to 0/2065 using triangular membership function and to 0/2017 using Gaussian membership function. Therefore, we can say that the proposed method is suitable not only for the diagnosis of liver disease but also for those diseases which require laboratory data-analysis with the least time and money. It can also be effective for other studies based on fuzzy logic and high accuracy.

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