

Intuitionistic Neuro-Fuzzy Optimization in the Management of Medical Diagnosis

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Abstract

Diabetes has become a major concern nowadays and its complications are affecting various organs of a diabetic patient. Therefore, a multi-dimensional technique including all parameters is required to detect the cause, its proper diagnostic procedure and its prevention. In this present work, a technique has been introduced that seeks to build an implementation for the intelligence system based on neural networks. Moreover, it has been described that how the proposed technique can be used to determine the membership together with the non-membership functions in the intuitionistic environment. The dataset has been obtained from Pima Indians Diabetes Database (PIDD). In this work, a complete diagnostic procedure of diabetes has been introduced with seven layered structural frameworks of an Intuitionistic Neuro Sugeno Fuzzy System (INSFS). The first layer is the input, in which six factors have been taken as an input variable. Subsequently, a neural network framework has been developed by constructing IFN for all the six input variables, and then this input has been fuzzified by using triangular intuitionistic fuzzy numbers. In this work, we have introduced a novel optimization technique for the parameters involved in the INSFS. Moreover, an inference system has also been framed for the neural network known as INFS. The results have also been given in the form of tables, which describe each concluding factor.

Keywords

Intuitionistic Fuzzy Set, Neural Network, Neuro-Fuzzy System, Intuitionistic Neuro-Fuzzy System, Optimization, Medical Diagnosis

1. Introduction

Present day's diabetes becomes a major health problem causing many health is-

sues in the human body. Delay in the initial identification of diabetes becomes crucial to control the severity of the disease. Many specific techniques of the prevention and diagnosis for diabetes based on fuzzy logic have already been done so far. Fuzzy logic was first introduced in 1965 by Zadeh [1]. The tremendous utility of fuzzy logic has been used in different fields of science, engineering and medicine. Kabiraj *et al.* gave the utility of fuzzy logic has been used in linear programming [2] [3]. Lee, C.S. and Wang, M.H. gave a fuzzy expert system application for the Ontology-based on intelligent healthcare “Global Neglected Tropical Disease (GNTD)” application to respiratory waveform recognition which gave better results from previous researches [4]. Olej, V. and Hájek, P. designed Inference systems aimed at the forecast of ozone for time series: the situation of Pardubice micro-region showed again in addition to their work, Inference systems with Takagi-Sugeno type in ozone prediction by using comparison of fuzzy operators [5]. Olej and Hájek [6] compared the fuzzy operators Takagi-Sugeno Inference system in ozone prediction. Kalpana, M. and Dr. Kumar, A.V.S. also proposed a system which was the fuzzy expert system with the help of a fuzzy verdict machine for fuzzy rules by fuzzifying the input factors into triangular intuitionistic fuzzy numbers. The whole process is the diagnosis of diabetes. This system gave much accurate results in diagnosing diabetes in comparison to all previous studies [7]. Habib, S. and Akram, M. designed a decision-making system for washing machines by using AIFNN which is very useful nowadays [8]. Jain, V. and Raheja, S. suggested another fuzzy expert system for improving the prediction rate of diabetes their system gave better results from the system which was designed by Kalpana, M. and Dr. Kumar, A.V.S. [9]. Ahmadi, H. proposed a method for diseases diagnosis by using fuzzy logic methods, which is a systematic and meta-analysis review [10]. Bressan, G. M. also suggested a system for diabetes mellitus type-2 classifications which was based on a fuzzy approach [11]. But, due to the consideration of membership grade only, fuzzy logic failed to handle the uncertainty, presents in the diagnosis process. So, we need compelling tools that can deal with that kind of situation. In the last few decades, many efforts have been done to bring out a common framework of neural networks and fuzzy expert systems. First, Detlef Nauck and Rudolf Kruse gave a neuro-fuzzy technique for the classification of data named NEFCLASS which was presented in the symposium proceeding on applied computing [12]. Musilek, P. and Gupta, M. gave the theory of fuzzy systems which provides a mathematical framework for capturing the uncertainties with human cognitive processes [13]. Goncalves, L.B. *et al.* designed such a neuro-fuzzy system for the classification of pattern and rule mining for diabetes which was upturned into a classified neuro-fuzzy BSP system [14]. A seminal review has been provided by Jabbar and Mehrotra [15] in the context of ANN to decision-making in health care. Later on, for nonlinear systems, an ambiguous rule-based fuzzy neural system [16] with a constant knowledge mechanism has been studied [17]. Sentimentality in yearly reports was recognized for economic presentation. The study was given for the

observation of outcomes of the sentiments on upcoming economic crisis [18]. A survey was given by Viharos and Kis on NFS in 2015 [19], this study also shows the utility of both the system, *i.e.*, fuzzy inference system and neural network. [20] gave a prediction fuzzy model for identification and prevention of diabetes, this study expected the five major complications which have arisen due to diabetes. An adaptive neuro-fuzzy inference system [21] has also been studied to determine the economic order quantity and order implementation. Atanassov [22] [23] presented the concept of the intuitionistic fuzzy set that can handle uncertainty very well as compared to traditional fuzzy logic. In the study of intuitionistic fuzzy logic, we consider the values with two types of grades are as the membership and the other is non-membership. So, these methods give us a wide range to cover the uncertainty and vagueness. Neuro-fuzzy system has a vital role in the medical field, especially in the diagnostic process. A large amount of neuro-fuzzy systems has been studied over intuitionistic fuzzy sets. Intuitionistic fuzzy logic has also been used in many medical diagnosis tools. Sang and Zhang gave an approach which was based on Intuitionistic Fuzzy Information [24]. Barrenechea, E. *et al.* generalized the work of Atanassov's intuitionistic fuzzy index construction method [25], Hájek, P. and Olej, V. solved the regression problems by using an adaptive intuitionistic fuzzy inference system of Takagi-Sugeno type approach, afterwards they used again Takagi-Sugeno type intuitionistic Fuzzy Inference System (FIS) by using defuzzification methods to solve the matter of incorporated liquidation forecast, followed by these two works they added Intuitionistic Fuzzy Neural Network, a new approach in their work and got results for the situation of credit scoring using text acquaintance [26] [27] [28]. After Hájek, P. and Olej, V., Zhao, J. *et al.* proposed "a general fuzzy cerebella model neural network multidimensional classifier using Intuitionistic fuzzy sets for medical identification" [29]. Eyoh, I. *et al.* also introduced an intuitionistic fuzzy logic for regression problems that was of interval Type-2 fuzzy sets [30]. An advanced distance measurement technique on intuitionistic fuzzy set-in decision making was also studied [31]. Samuel, A.E. and Rajakumar, S. introduced the intuitionistic fuzzy sets that are useful in the field of medical diagnosis [32]. Chao, L. *et al.* gave such a network which helps in online learning and time series forecast named as an evolving recurrent interval type-2 intuitionistic fuzzy neural network for online learning and time series forecast [33]. Shie-Jue, Lee and Chen-Sen, Ouyang [34] proposed a neuro-fuzzy system model that includes the input-output data found in two phases, in the primarily phase, the input-output datum gives the similarity and then by using the similarity a fuzzy network is constructed in the second step [35]. A genetic algorithm has also been used in the situation of Self-Organized Fuzzy Neural Networks [36], optimized weight technique of artificial neural networks [37], the type-2 fuzzy logic system which is used for the linguistic prognostic models (for economic praxis) [38] and Elman model based neural network algorithm [39]. Later, a multidisciplinary technique has also been applied to artificial swarm intelligence to deal with heterogeneous computing and

cloud scheduling [40]. In order to carry out the applications of fuzzy logic in the medical field, Guzman [41] proposed an optimized fuzzy qualifier for blood pressure disease. Tyagi, K. and Tyagi, K. published a paper *A Comparative Analysis of Optimization Techniques*, in which they used various techniques for the test cases of optimization to choose less vague test cases [42]. Later on, Parouha, R.P. and Verma, P. [43] also discussed various optimization techniques in the paper *State-of-the-Art Reviews of Meta-Heuristic Algorithms with Their Novel Proposal for Unconstrained Optimization and Applications*. This paper is not only about GA and PSO but the comparison amongst different types of algorithms also done such that Meta-heuristic, aroused from the actions of societal creatures or animals, aroused from ecology, aroused by the laws leading a natural phenomenon, aroused from the human being.

The basic objectives of this research paper are pointed out the following points to focus the whole work as follows:

- 1) We will design a novel intuitionistic fuzzy logic based neural network approach for the diagnosis of diabetes.
- 2) We observed six input factors and with the help of the fuzzification process; we constructed the membership function for these inputs and with the help of Sugeno's fuzzy inference system. We applied this over the intuitionistic fuzzy numbers.
- 3) A new approach is developed for optimization to get the optimized weights of the neurons.

The present work is separated into nine sections. In Section 2, we defined some basic definitions related to intuitionistic fuzzy sets. In Section 3, a survey on optimization techniques is discussed. We proposed the intuitionistic neuro-fuzzy system in the form of Sugeno's intuitionistic neuro-fuzzy approach in Section 4 of the paper. In Section 5, the mathematical formulation and description of the system are given. The proposed optimization technique is also been described in Section 6 of the paper. In Section 7, the data collection method is given and Section 8 of the research paper describes the numerical computation part of the present work and comparison with the previous algorithm. In Section 9, the last section describes the discussions and conclusions of the paper.

2. Basic Perceptions

2.1. Intuitionistic Fuzzy Set

Let S be any Intuitionistic fuzzy set on a universe of discourse U is defined as:

$$S = \{(\tau, \mu_S(\tau), \nu_S(\tau)) : \tau \in U\} \quad (1)$$

where $\mu_S(\tau) \in [0, 1]$ is called the "degree of membership" of τ in S and $\nu_S(\tau) \in [0, 1]$ is called the "degree of non-membership" of τ in S . Where, $0 \leq \mu_S(\tau) + \nu_S(\tau) \leq 1$. Here, $\pi_S(\tau) = 1 - [\mu_S(\tau) + \nu_S(\tau)]$ is called hesitational

part of τ . $\pi_s(\tau)$ can also be considered as the degree for the lack of uncertainty related with the membership or non-membership grades in S .

The membership and non-membership functions for the trapezoidal and triangular intuitionistic fuzzy number in real line \mathbb{R} , is defined by:

For Trapezoidal:

$$\mu_s(\tau) = \begin{cases} \frac{\tau - a}{b - a}, & a \leq \tau \leq b \\ 1, & b \leq \tau \leq c \\ \frac{d - \tau}{d - c}, & c \leq \tau \leq d \\ 0, & \text{else} \end{cases}$$

$$\nu_s(\tau) = \begin{cases} \frac{a^* - \tau}{b - a^*}, & a^* \leq \tau \leq b \\ 0, & b \leq \tau \leq c \\ \frac{\tau - d^*}{d^* - c}, & c \leq \tau \leq d^* \\ 1, & \text{else} \end{cases}$$

with $a^* < a < b < c < d < d^*$.

For Triangular:

$$\mu_s(\tau) = \begin{cases} \frac{\tau - a}{b - a}, & a \leq \tau \leq b \\ \frac{c - \tau}{c - b}, & b \leq \tau \leq c \\ 0, & \text{else} \end{cases}$$

$$\nu_s(\tau) = \begin{cases} \frac{a^* - \tau}{b - a^*}, & a^* \leq \tau \leq b \\ \frac{\tau - c^*}{c^* - b}, & b \leq \tau \leq c^* \\ 1, & \text{else} \end{cases}$$

with $a^* < a < b < c < c^*$.

2.2. Neural Network

A neural network is a network of neurons that is combination of nodes and links. An artificial neuron constructs a “Artificial Neural Network (ANN)” or “Artificial Neural Systems” and behave like the intelligence of human beings. Neural Network is a natural biological process used for solving the Artificial Intelligence (AI) models. In this structure, we have used the network neurons with the weights function. They have information about the inputs. In this we have constructed the activation function to get the rule in the form of linear combination of inputs and give the extension for the output.

For example, usually the range of output is between 0 and 1 but it could be -1 and 1.

2.3. Neural Fuzzy System

A neuro-fuzzy system is a learning mechanism which finds the constraints of a fuzzy system by manipulating the estimate systems from neural networks. The Fuzzy Neuro System is a construction of FNN (N, W, P, Q, A) with following conditions:

- 1) N is a non-empty set of fuzzy neurons and supplementary units.
- 2) By the given model and constraints of the fuzzy neuro system are defined as the weight matrix W given by Cartesian product $N \times N \rightarrow DW$ (DW is the domain of weights).
- 3) Fuzzy inputs' vector $P \in DP$ defines the inputs of the fuzzy neuro system (DP is defined as the domain of the input vector).
- 4) Fuzzy outputs' vector $Q \in DQ$ defines the output for the fuzzy neuro system (DQ is defined as the domain of the output vector).
- 5) The learning algorithm A defines the phases of learning and adaptation for the new data (usually by changing the weights matrix W).

2.4. Optimization

An optimization problem comprises of maximizing or minimizing an actual function by methodically selecting input values from inside an allowable set and computation for the values of the function. Main aim of optimization is to maximize or minimize the values for better result. The simplification of optimization concept and methods to other formulations create a huge area of applied mathematics. Specifically, optimization contains searching "best available" values for some objective function specified a well-defined input, with a variety of objective functions and various types of inputs.

The methods presently accessible in works for resolving optimization difficulties may generally be classified as deterministic methods and probabilistic methods. Nature inspired algorithms are most popular population-based algorithms mimicking the evolutionary, self-organizing and collective process of nature. Some nature-inspired algorithms use the concepts of natural evolutions like selection, reproduction, crossover and mutation; some display the socio-cooperative behavior of natural species like birds, ants, termites, bees and humans well These algorithms are termed as metaheuristic algorithms such as Genetic Algorithms, Particle Swarm Optimization, Ant Colony Optimization, Differential Evolution, Self-Organizing Migrating Algorithm and many more.

3. Related Background

A survey has been done over the evolution of various kinds of algorithms for the presented research work. These algorithms are inspired from natural phenomenon and their social behaviors which helps in finding the optimized values for any given problem [43]-[71].

The survey of this study has been listed in the given **Table 1**, which is as follows:

Table 1. Evolution of different algorithms.

Reference No.	Author's Name	Name of Technique	Problem Controlled
[44]	Fonseca, C.M. and Fleming, P.J. [1993]	(MOGA) Multi-Objective Genetic Algorithm	Optimization
[45]	Horn, J. <i>et al.</i> [1994]	(NPGA) Niche Pareto Genetic Algorithm	Multi-Objective Optimization
[46]	Srinivas, N. and Deb, K. [1995]	(NSGA) Non-Dominated Sorting Genetic Algorithms	Multi-Objective Optimization
[47]	Stutzle, T. [1998]	(PAS) Parallelization of Ant System	Combinatorial Optimization
[48]	Bullnheimer, B., Hartl, R.F. and Strauss, C. [1997]	(AS rank) Rank Based Ant System	TSP
[49]	Van den Bergh, F. and Engelbrecht, A. [2002]	(GCP SO) Guaranteed Convergence Particle Swarm Optimization	Convergence to Local Minimum
[50]	Yang, C. and Simon, D. [2005]	(HPSO) Hierarchical Particle Swarm Optimization	Better Solution
[51]	Janson, S. and Middenfort, M. [2006]	(NPSO) New Particle Swarm Optimization	Better Solution
[52]	Kim, D.H. <i>et al.</i> [2007]	(HGA) Hybrid Genetic Algorithm	Global Optimization
[53]	Hu, X.M., Zhong, J. and Li, Y. [2008]	(COAC) Continuous Orthogonal Ant Colony	Continuous Optimizing Problems
[54]	Yu, B., Yang, Z-Z. and Yao, B.Z. [2009]	(IACO) Improved Ant Colony Optimization	Vehicle Routing
[55]	Ruhana, K. and Aljanaby, K.M.A. [2010]	(IMACO) Interacted Multiple Ant Colony Optimization	Different Instances of TSP
[56]	Taspinar, N. [2010]	(ABC-PTS) Partial Transmit Sequences (PTSs) Based on ABC	Peak-to-Average Power Ratio
[57]	El-Abd, M. [2011]	(OABC) ABC with the Concept of Opposition Number-Based Optimization	Black Box Optimization
[58]	Sonmez, M. [2011]	(ABC-AP) Artificial Bee Colony with Adaptive Penalty Function	Weight of Truss Structures
[59]	Gupta, D.K., Arora, Y. <i>et al.</i> [2012]	(RMACO) Recursive Multiple Ant Colony Optimization	Estimation of Parameters of a Function
[60]	Deepak, R. <i>et al.</i> [2014]	(HBMO) Honeybee Mating Optimization Algorithm	Test Case Optimization
[61]	Tsai, P.W. <i>et al.</i> [2014]	(IABC) Interactive Artificial Bee Colony Optimization	Numerical Optimization
[62]	Zheng, Y.J. [2015]	(WWO) Water Wave Optimization	Train Scheduling Problem
[63]	Mirjalili, S. and Lewis, A. [2016]	(WOA) Whale Optimization Algorithm	Multimodal Functions

Continued

[64]	Saremi, S., Mirjalili, S. and Lewis, A. [2017]	(GOA) Grasshopper Optimization Algorithm	Real Life Problems
[65]	Yu, H. et al. [2018]	(SHPSO) Surrogate-Assisted Hierarchical PSO	High-Dimensional Problems
[66]	Pierezan, J. and Dos Santos Coelho, L. [2018]	(COA) Coyote Optimization Algorithm	Global Optimization Problems
[67]	Khajeh, A., Ghasemi, M.R. and Arab, H.G. [2019]	(MPSO) Modified PSO with Novel Population Initialization	Benchmark Function Optimization
[68]	Shabani, A. et al. [2019]	(SAR) Search and Rescue Optimization	Single-Objective Continuous Optimization Problems
[69]	Hosseini, S.A., Hajipour, A. and Tavakoli, H. [2019]	(HAFPSO) Hunter-Attack Fractional-Order PSO	Optimum Design of Power Amplifier
[70]	Marzbali, A.G. [2020]	(BSSA) Bear Smell Search Algorithm	Real World Engineering Problems
[71]	Xiong, H., Qiu, B. and Liu, J. [2020]	(NMSPSO) Novel Multi-Swam PSO	Real-World Applications Problem
[72]	Dash, J., Dam, B. and Swain, R. [2020]	(HDEPSO) Hybrid Differential Evolution Particle Swarm Optimization	Sharp Edge FIR Filter (SEFIRF) Design Problem

4. Intuitionistic Neuro-Fuzzy System

We introduced the structure of Intuitionistic Neuro Sugeno Fuzzy System (INSFS) for multilayered neural network. The detail of this network is as follows:

We consider if-then based rules of Sugeno's approach. Initially, we will construct a structure of six inputs with one output then inputs are further categorized into three or four linguistic terms and divided in Membership and Non-Membership in the context of favorable and unfavorable cases. Our inputs are I_1, I_2, I_3, I_4, I_5 and I_6 and y_i is the functional consequent value for each $i = 1, 2, 3, 4, \dots$, where I denotes the number of rules.

Let i^{th} if-then rule of INSFS expressed as:

IF I_1 is x_1 and I_2 is x_2 and I_3 is x_3 and I_4 is x_4 and I_5 is x_5 and I_6 is x_6 .

Then y_i can be stated as:

$$y_i = \alpha_{i_0} + \alpha_{i_0} I_1 + \alpha_{i_1} I_2 + \dots + \alpha_{i_n} I_n \quad (2)$$

where x denotes the linguistic characterization variables into three categories as; Low, Medium, Normal, High, Overweight & Obesity class I, Obesity class II & III, Less High, More High, Most High, Less Chance, More Chance, Most Chance and High Risk (such that L, M, N, H, OW, OB, LH, MRH, MTH, LC, MRC, MTC and HR respectively). The linguistic characterization variables are further divided into two categories membership and non-membership shown in **Figure 1**.

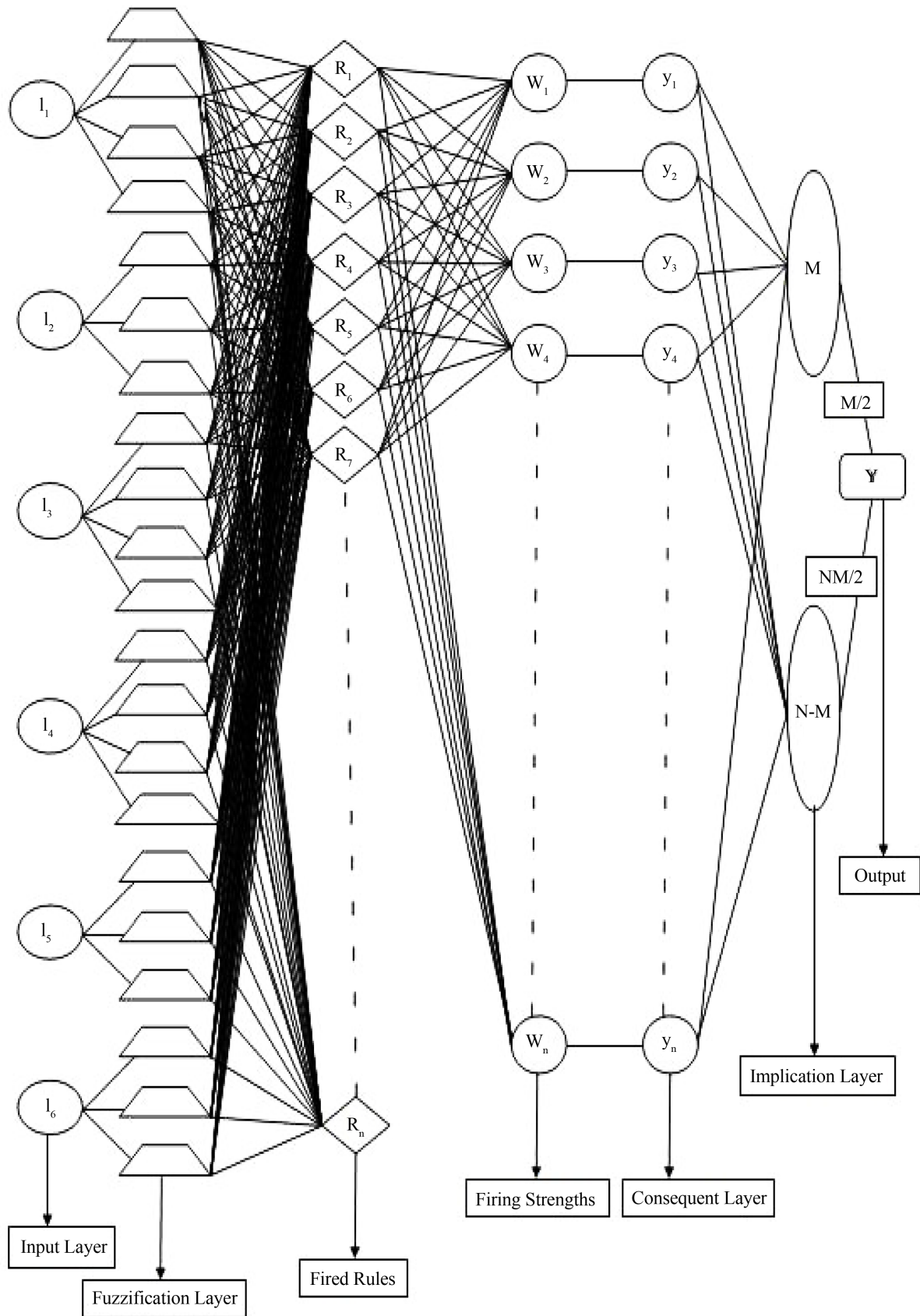


Figure 1. Proposed structure of INSFS.

5. Description of System and Mathematical Formulation

Layer 1 (Input Layer): we define layer 1 as input layer in which we taken six inputs and use the non-linear system which is considered as combination of several linear systems or non-linear systems. The membership functions for this input layer have shown in **Figure 2**.

Layer 2 (Fuzzification): we described this layer as fuzzification layer. In these layers neurons receives an input which will fuzzify this layer with some degree of membership or non-membership. After the fuzzification this layer works as input for layer 3. This is simply the membership and non-membership values for the given inputs.

We have used Trapezoidal and Triangular function in our work, for example, Membership and Non-Membership function for Glucose:

For membership function:

$$\mu_L = \begin{cases} 1, & 0 \leq x \leq 25 \\ \frac{50-x}{25}, & 25 \leq x \leq 50 \end{cases}$$

$$\mu_N = \begin{cases} \frac{x-25}{25}, & 25 \leq x \leq 50 \\ 1, & 50 \leq x \leq 95 \\ \frac{120-x}{25}, & 95 \leq x \leq 120 \end{cases}$$

$$\mu_M = \begin{cases} \frac{x-95}{25}, & 95 \leq x \leq 120 \\ 1, & 120 \leq x \leq 162 \\ \frac{180-x}{18}, & 162 \leq x \leq 180 \end{cases}$$

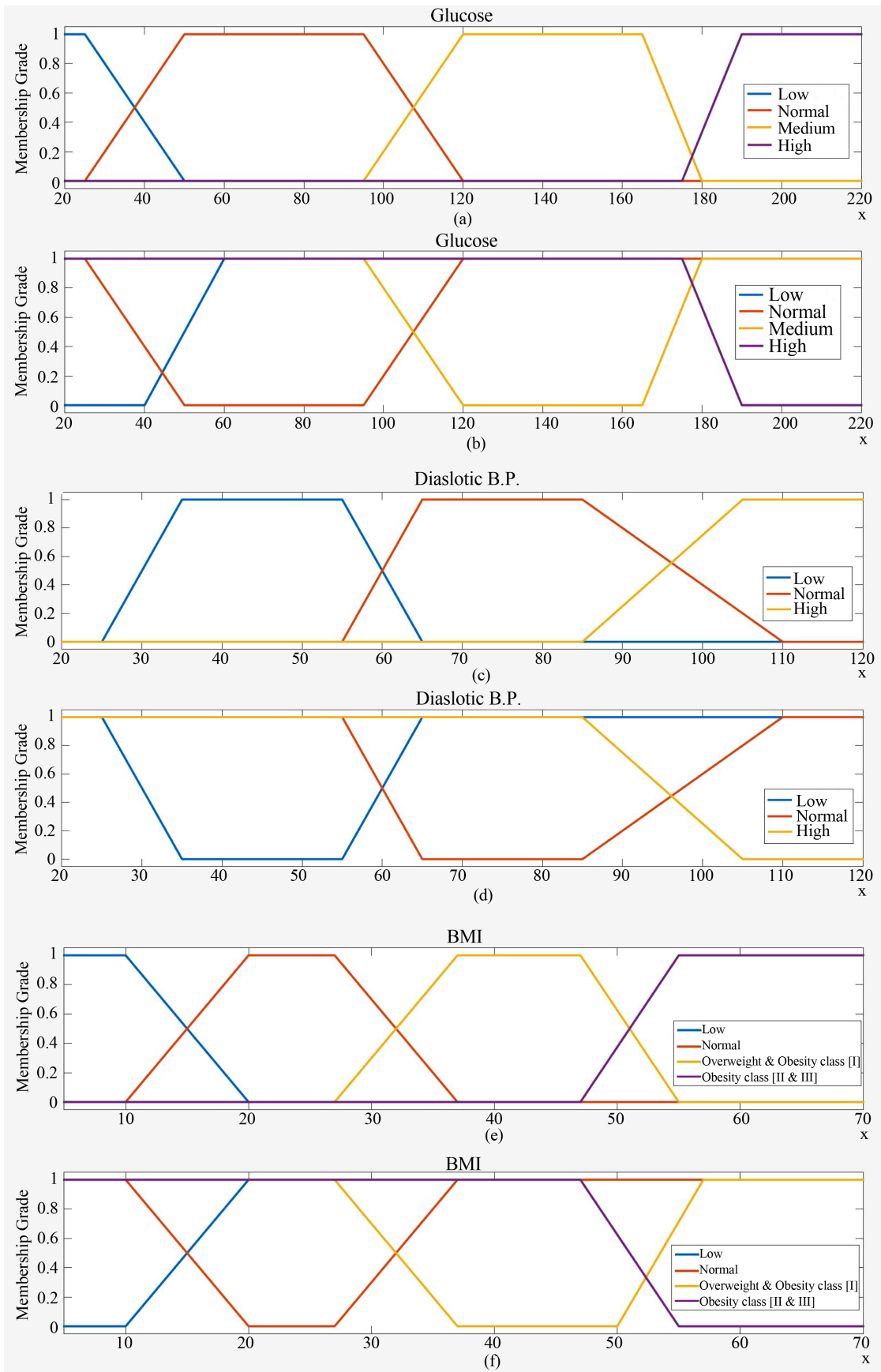
$$\mu_H = \begin{cases} \frac{x-172}{18}, & 172 \leq x \leq 190 \\ 1, & x \geq 190 \end{cases}$$

For non-membership function:

$$\nu_L = \begin{cases} \frac{x-25}{18}, & 25 \leq x \leq 50 \\ 0, & x \leq 25 \end{cases}$$

$$\nu_N = \begin{cases} \frac{50-x}{25}, & 25 \leq \tau \leq 50 \\ 0, & 50 \leq \tau \leq 95 \\ \frac{x-95}{25}, & 95 \leq \tau \leq 120 \end{cases}$$

$$\nu_M = \begin{cases} \frac{120-x}{25}, & 95 \leq \tau \leq 120 \\ 0, & 120 \leq \tau \leq 162 \\ \frac{x-162}{18}, & 162 \leq \tau \leq 180 \end{cases}$$



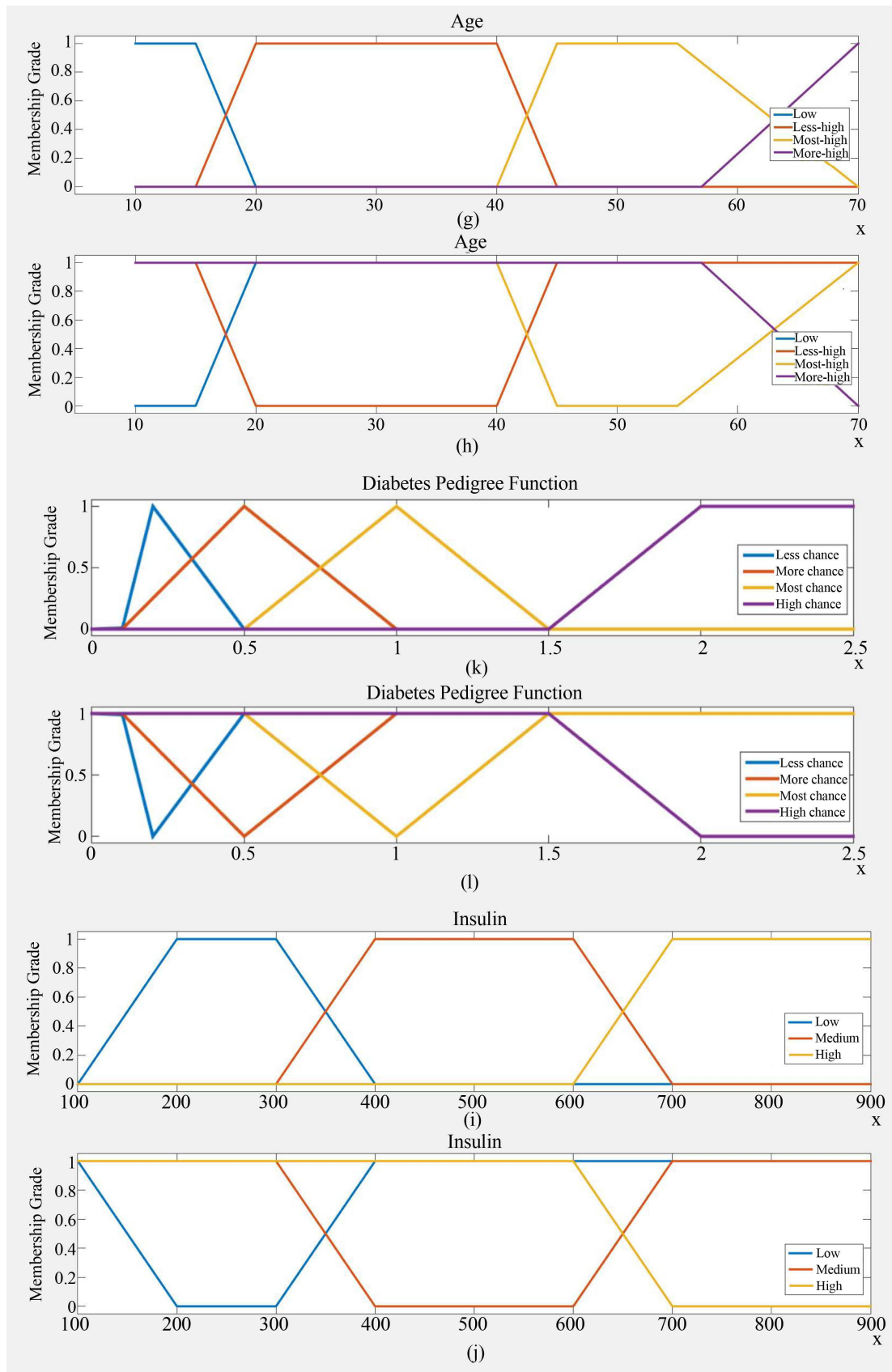


Figure 2. The graphical representation for the membership and non-membership grade of input factors.

$$v_H = \begin{cases} \frac{190-x}{18}, & 172 \leq x \leq 190 \\ 0, & 190 \leq x \leq 200 \end{cases}$$

Layer 3 (Fired set of Inputs): In this layer, we choose those rules which should be fired out of the total number of rules which are constructed by the inputs, which as follows:

e.g.: IF I_1 is x_1 and I_2 is x_2 AND I_3 is x_3 and I_4 is x_4 and I_5 is x_5 and I_6 is x_6 .

Layer 4 (Layer of Firing Strengths or Weights): This layer corresponds to an *if-then* rules with each neuron of sugeno's type and computes the firing strength for every rule by using Max-Min operator.

$$W_i = \min_{i=1,2,3,\dots} [\mu_{x_1}(I_1), \mu_{x_2}(I_2), \dots, \mu_{x_n}(I_n)] \tag{3}$$

and:

$$W_i = \max_{i=1,2,3,\dots} [v_{x_1}(I_1), v_{x_2}(I_2), \dots, v_{x_n}(I_n)] \tag{4}$$

Layer 5 (Functional Consequent Values): In this layer, we find the values of (y_i 's) with the help of fired set of inputs. These values help us in next layer, which are as follows:

$$y_i = \alpha_{i_0} + \alpha_{i_0} I_1 + \alpha_{i_1} I_2 + \dots + \alpha_{i_n} I_n$$

Layer 6 (Implication Layer): Sixth layer of our system is described in the form of implication, which expresses the consequent part of our Sugeno-based approach. The objective of this layer is to find the average of Membership grade (M) and Non-Membership grade (NM) as follows:

$$M = \frac{\sum_{i=1}^k W_i y_i}{\sum_{i=1}^k W_i} \tag{5}$$

W_i is the minimum of membership values, and:

$$NM = \frac{\sum_{i=1}^k W_i y_i}{\sum_{i=1}^k W_i} \tag{6}$$

W_i is the maximum of non-membership values:

Layer 7 (Output or Defuzzification Layer): This is the final layer of our system and output for our proposed system will be calculated as:

$$Y = \frac{M + NM}{2} \tag{7}$$

Moreover, the error for our proposed system is calculated as:

$$e = \frac{(Y - T)^2}{2} \tag{8}$$

where Y is the output value calculated by our system and T is the targeted values value.

Our system might be wrong in calculating and finding the correct output due to uncertainties in data. So, we have to optimize these errors by optimizing the weights which are used by us in the equation of y_i ,

$$y_i = \alpha_{i_0} + \alpha_{i_0} I_1 + \alpha_{i_1} I_2 + \dots + \alpha_{i_n} I_n$$

where $i = 1, 2, 3, \dots$

6. Proposed Optimization Technique

We have the output equation as:

$$y_1 = \alpha_0 + \alpha_M G + \alpha_N BP + \alpha_N BMI + \alpha_{MTH} A + \alpha_L I + \alpha_{LC} DPF \tag{9}$$

in which we got six weights as $\alpha_0, \alpha_M, \alpha_N, \alpha_N, \alpha_{MTH}, \alpha_L, \alpha_{LC}$ that are to be optimized to minimize the error. In this respective work we used the general concept of Hit and Trial method to optimize the weights. The given method is used to minimize the error in this paper which can increase its accuracy.

In this method we have used a technique in which we choose the optimized value for the $\alpha_0, \alpha_M, \alpha_N, \alpha_N, \alpha_{MTH}, \alpha_L, \alpha_{LC}$ by any existing method. In this technique we find the values for these weights once and after that we used these values thoroughly for each example. This proposed technique is better than other techniques due to its low complexity in calculations. In other techniques we must do more complex calculations to optimize weights again and again but, in this technique, we optimize these weights once and use in whole calculation. Flow chart for this proposed technique has shown in **Figure 3**.

7. Data Collection Method

In this paper, we have used the dataset from the website of Pima Indians Diabetes Database (PIDD). PIDD is a huge group which has the large number of datasets for diabetes globally. The National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) [37] have studied the Pima Indians. And the database of PIDD for this work is saved from the Internet (<http://archive.ics.uci.edu/ml/>).

8. Numerical Computations and Comparison with Existing Algorithms

We choose the patients randomly from the given data to check the output of diabetes; first, we developed the INSFS structure considering fuzzy rules based on Sugeno’s Approach.

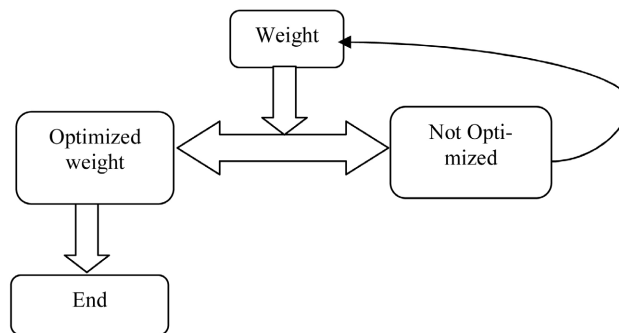


Figure 3. Representation of proposed technique.

We have two outputs for diabetes *i.e.*, 1 and 0, which means Yes and No.

For example: we took one patient with ID 31 which is shown in **Table 2**.

Layer 1: $G = 145$ mg/dL; $BP = 82$ mmHg; $BMI = 22.2$ kg/m²; $A = 57$ yrs; $I = 110$ IU/mL; $DPF = 0.245$ are six inputs for patient 31.

Layer 2: After taken the values of inputs from given data we have to fuzzify them for further calculation.

So, the membership and non-membership values for given inputs given as:

For glucose: $\mu_M = 1$ & $\nu_M = 0$;

For BP: $\mu_N = 1$ & $\nu_N = 0$;

For insulin: $\mu_L = 1$ & $\nu_L = 0$;

For BM: $\mu_N = 1$ & $\nu_N = 0$;

For DPF: $\mu_{LC} = 0.6375$ & $\nu_{LC} = 0.3625$;

For MRC: $\mu_{MRC} = 0.49$ & $\nu_{MRC} = 0.51$;

For age: $\mu_{MTH} = 1$ & $\nu_{MTH} = 0$.

Here we got two values for DPF as 0.245 lies between two ranges *i.e.*, MRC and LC, which has given above.

Layer 3: Corresponding to these six inputs from all possible rules, we have only two rules, which will be fired in this case.

Therefore, we have two fired rules as follows:

R₁: IF Glucose is medium and Diastolic B.P. is normal and BMI is normal and Age is most high and Insulin is low and DPF is less chance THEN output is:

$$y_1 = \alpha_0 + \alpha_M G + \alpha_N BP + \alpha_N BMI + \alpha_{MTH} A + \alpha_L I + \alpha_{LC} DPF$$

R₂: IF Glucose is medium and Diastolic B.P. is normal and BMI is normal and Age is most high and Insulin is low and DPF is more chance THEN output is:

$$y_1 = \alpha_0 + \alpha_M G + \alpha_N BP + \alpha_N BMI + \alpha_{MTH} A + \alpha_L I + \alpha_{LC} DPF$$

Layer 4: Weight or strength of the rules can be determined as follows:

W_1 :

$$\min[\mu_M(145), \mu_n(82), \mu_N(22.2), \mu_{MTH}(57), \mu_L(110), \mu_{LC}(0.245)]$$

and:

$$\max[\nu_M(145), \nu_n(82), \nu_N(22.2), \nu_{MTH}(57), \nu_L(110), \nu_{LC}(0.245)]$$

W_2 :

$$\min[\mu_M(145), \mu_n(82), \mu_N(22.2), \mu_{MTH}(57), \mu_L(110), \mu_{LC}(0.245)]$$

and:

$$\max[\nu_M(145), \nu_n(82), \nu_N(22.2), \nu_{MTH}(57), \nu_L(110), \nu_{LC}(0.245)]$$

i.e., $W_1 = 0.6375$ and 0.3625

$W_2 = 0.49$ and 0.51 .

Layer 5: We have calculated the values of functional consequent by the expression of y_b which is the consequent part of fuzzy rules. After calculating, we have the values of y_1 and y_2 as follows:

Table 2. Computational results for output, error and accuracy.

Patient ID	Patient 5	Patient 21	Patient 29
Layer1 (Input)	G = 137, BP = 40, Insulin = 168, BMI = 43.1, DPF = 2.288, A = 33	G = 126, BP = 88, Insulin = 235, BMI = 39.3, DPF = 0.704, A = 27	G = 145, BP = 82, Insulin = 110, BMI = 22.2, DPF = 0.245, A = 57
Layer2	$\mu_M = 1, \mu_L = 1,$ $\mu_L = 0.68, \mu_{OW} = 1,$ $\mu_{HR} = 1, \mu_{LH} = 1$ and $v_M = 0, v_L = 0,$ $v_L = 0.32, v_{OW} = 0,$ $v_{HR} = 0, v_{LH} = 0$	$\mu_M = 1, \mu_N = 0.85$ & $\mu_H = 0.15, \mu_L = 0.65,$ & $\mu_M = 0.35,$ $\mu_{OW} = 1, \mu_{MTC} = 0.408$ & $\mu_{MRC} = 0.592, \mu_{LH} = 1$ And $v_M = 0, v_N = 0.15$ & $v_H = 0.85, v_L = 0.35$ & $v_M = 0.65,$ $v_{OW} = 0, v_{MTC} = 0.592$ & $v_{MRC} = 0.408, v_{LH} = 0$	$\mu_M = 1, \mu_N = 1, \mu_L = 1,$ $\mu_N = 1, \mu_{LC} = 0.6375$ & $\mu_{MRC} = 0.49, \mu_{MTH} = 1$ And $v_M = 0, v_N = 0, v_L = 0.32,$ $v_N = 0, v_{LC} = 0.3625$ & $\mu_{MRC} = 0.51, v_{MTH} = 0$
Layer3	$R_1 = \alpha_0 + \alpha_M \times G$ $+ \alpha_L \times BP + \alpha_L \times I$ $+ \alpha_{OW} \times BMI$	$R_1 = \alpha_0 + \alpha\alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{LH} \times A$ $R_2 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A$ $R_3 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{LH} \times A$ $R_4 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A$ $R_5 = \alpha_0 + \alpha_M \times G + \alpha_H \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{LH} \times A$ $R_6 = \alpha_0 + \alpha_M \times G + \alpha_H \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A$ $R_7 = \alpha_0 + \alpha_M \times G + \alpha_H \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{LH} \times A$ $R_8 = \alpha_0 + \alpha_M \times G + \alpha_H \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A$	$R_1 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP$ $+ \alpha_L \times I + \alpha_N \times BMI$ $+ \alpha_{LC} \times DPF + \alpha_{MTH} \times A$ $R_2 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP$ $+ \alpha_L \times I + \alpha_N \times BMI$ $+ \alpha_{MRC} \times DPF + \alpha_{MTH} \times A$
Layer4	$W_1 = 0.68$ and 0.32	$W_1 = 0.408$ and $0.592, W_2 = 0.592$ and 0.408 $W_3 = 0.35$ and $0.65, W_4 = 0.35$ and 0.65 $W_5 = 0.15$ and $0.85, W_6 = 0.15$ and 0.85 $W_7 = 0.15$ and $0.85, W_8 = 0.15$ and 0.85	$W_1 = 0.6375$ and $0.3625,$ $W_2 = 0.49$ and 0.51
Layer5	$y_1 = 1.11$	$y_1 = 0.12847, y_2 = 0.12855$ $y_3 = 0.12142, y_4 = 0.12150$ $y_5 = 0.13903, y_6 = 0.13911$ $y_7 = 0.13198, y_8 = 0.13206$	$y_1 = 0.0984964$ $y_2 = 0.0985037$
Layer6	$M = 1.11$ and $NM = 1.11$	$M = 0.12821$ and $NM = 0.131097$	$M = 0.0985$ and $NM = 0.0985$
Layer7 (Output)	$Y = 1.11$	$Y = 0.1297$	$Y = 0.0985$
Error	$e = 0.00605$ Or 11%	$e = 0.008405$ Or 12.97%	$e = 0.00485$ Or 9.85%
Accuracy	89%	87.03%	90.15%

Continued

Patient 44

G = 171, BP = 110, Insulin = 240,
BMI = 45.4, DPF = 0.721, A = 54

$$\mu_M = 0.5, \mu_H = 1, \mu_L = 0.6 \text{ \& } \mu_M = 0.4, \mu_{OW} = 1, \mu_{MTC} = 0.558 \text{ \& } \mu_{MTC} = 0.442, \mu_{MTH} = 1$$

And

$$v_M = 0.5, v_H = 0, v_L = 0.4 \text{ \& } v_M = 0.6, v_{OW} = 0, v_{MRC} = 0.442 \text{ \& } v_{MTC} = 0.558, v_{MTH} = 0$$

Patient 40

G = 111, BP = 72, Insulin = 207,
BMI = 37.1, DPF = 1.39, A = 56

$$\mu_N = 0.36 \text{ \& } \mu_M = 0.64, \mu_N = 1, \mu_L = 0.93 \text{ \& } \mu_M = 0.07, \mu_{OW} = 1, \mu_{MTC} = 0.22, \mu_{MTH} = 1$$

and

$$v_N = 0.64 \text{ \& } v_M = 0.36, v_N = 0, v_L = 0.07 \text{ \& } v_M = 0.93, v_{OW} = 0, v_{MTC} = 0.78, v_{MTH} = 0$$

$$R_1 = \alpha_0 + \alpha_M \times G + \alpha_H \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{MTH} \times A \quad R_1 = \alpha_0 + \alpha_N \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{MTH} \times A$$

$$R_2 = \alpha_0 + \alpha_M \times G + \alpha_H \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{MTH} \times A \quad R_2 = \alpha_0 + \alpha_N \times G + \alpha_N \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{MTH} \times A$$

$$R_3 = \alpha_0 + \alpha_M \times G + \alpha_H \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{MTH} \times A \quad R_3 = \alpha_0 + \alpha_N \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{MTH} \times A$$

$$R_4 = \alpha_0 + \alpha_M \times G + \alpha_H \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{MTH} \times A \quad R_4 = \alpha_0 + \alpha_N \times G + \alpha_N \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{MTH} \times A$$

$$W_1 = 0.5 \text{ and } 0.5, W_2 = 0.442 \text{ and } 0.558$$

$$W_3 = 0.4 \text{ and } 0.6, W_4 = 0.4 \text{ and } 0.6$$

$$y_1 = 1.1552$$

$$y_2 = 1.1543$$

$$y_3 = 1.2032$$

$$y_4 = 1.2023$$

$$M = 1.1768 \text{ and } NM = 1.1803$$

$$Y = 1.17855$$

$$e = 0.01594 \text{ Or } 17.86\%$$

82.15%

$$W_1 = 0.22 \text{ and } 0.78, W_2 = 0.07 \text{ and } 0.93$$

$$W_3 = 0.22 \text{ and } 0.78, W_4 = 0.07 \text{ and } 0.93$$

$$y_1 = 1.1384$$

$$y_2 = 1.0763$$

$$y_3 = 1.2272$$

$$y_4 = 1.1651$$

$$M = 1.1679 \text{ and } NM = 1.1491$$

$$Y = 1.1585$$

$$e = 0.0126 \text{ Or } 15.85\%$$

84.15%

Continued

Patient 72

G = 139, BP = 64, Insulin = 140,
BMI = 28.6, DPF = 0.411, A = 26

$\mu_M = 1, \mu_L = 0.1$ & $\mu_N = 0.9, \mu_L = 1, \mu_N = 0.64$
& $\mu_{OW} = 0.36, \mu_{LC} = 0.2225$ & $\mu_{MRC} = 0.822, \mu_{LH} = 1$
And $v_M = 0, v_L = 0.9$ & $v_N = 0.1, v_L = 0, v_N = 0.36$
& $v_{OW} = 0.64, v_{LC} = 0.7775$ & $v_{MRC} = 0.178, v_{LH} = 0$

$R_1 = \alpha_0 + \alpha_M \times G + \alpha_L \times BP + \alpha_L \times I + \alpha_N \times BMI + \alpha_{LC} \times DPF + \alpha_{LH} \times A$
 $R_2 = \alpha_0 + \alpha_M \times G + \alpha_L \times BP + \alpha_L \times I + \alpha_N \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A$
 $R_3 = \alpha_0 + \alpha_M \times G + \alpha_L \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{LC} \times DPF + \alpha_{LH} \times A$
 $R_4 = \alpha_0 + \alpha_M \times G + \alpha_L \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A$
 $R_5 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_N \times BMI + \alpha_{LC} \times DPF + \alpha_{LH} \times A$
 $R_6 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_N \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A$
 $R_7 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{LC} \times DPF + \alpha_{LH} \times A$
 $R_8 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A$

$W_1 = 0.1$ and $0.9, W_2 = 0.1$ and 0.9
 $W_3 = 0.1$ and $0.9, W_4 = 0.1$ and 0.9
 $W_5 = 0.2225$ and $0.7775, W_6 = 0.64$ and 0.36
 $W_7 = 0.2225$ and $0.7775, W_8 = 0.36$ and 0.64

$y_1 = 0.10106, y_2 = 0.10111,$
 $y_3 = 0.10478, y_4 = 0.10482$
 $y_5 = 0.09408, y_6 = 0.09412$
 $y_7 = 0.09780, y_8 = 0.09782$

M = 0.0972 and NM = 0.10013

Y = 0.0987

e = 0.00487 Or 9.87%

90.13%

Patient 59

G = 146, BP = 82, Insulin = 0,
MI = 40.5, DPF = 1.781, A = 44

$\mu_M = 1, \mu_N = 1, \mu_L = 0, \mu_{OW} = 1,$
 $\mu_{HR} = 0.562, \mu_{LH} = 0.2$ & $\mu_{MTH} = 0.8$
And
 $v_M = 0, v_N = 0, v_L = 1, v_{OW} = 0,$
 $v_{HR} = 0.438, v_{LH} = 0.8$ & $v_{MTH} = 0.2$

$R_1 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{HR} \times DPF + \alpha_{LH} \times A$
 $R_2 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{HR} \times DPF + \alpha_{MTH} \times A$

$W_1 = 0$ and $1, W_2 = 0$ and 1

$y_1 = 0.044951$
 $y_2 = 0.048471$

M = 0 and NM = 0.046711

Y = 0.0234

e = 0.000274 Or 2.34%

97.66%

Continued

Patient 104

G = 81, BP = 72, Insulin = 40, BMI = 26.6, DPF = 0.283, A = 24

$$\mu_N = 1, \mu_L = 1, \mu_H = 0.4, \mu_N = 0.84 \text{ \& } \mu_{OW} = 0.16, \mu_{LC} = 0.5425 \text{ \& } \mu_{MRC} = 0.566, \mu_{LH} = 1$$

And

$$v_N = 0, v_L = 0, v_H = 0.6, v_N = 0.16 \text{ \& } v_{OW} = 0.84, v_{LC} = 0.4575 \text{ \& } v_{MRC} = 0.434, v_{LH} = 0$$

$$R_1 = \alpha_0 + \alpha_N \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_N \times BMI + \alpha_{LC} \times DPF + \alpha_{LH} \times A$$

$$R_2 = \alpha_0 + \alpha_N \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_N \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A$$

$$R_3 = \alpha_0 + \alpha_N \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{LC} \times DPF + \alpha_{LH} \times A$$

$$R_4 = \alpha_0 + \alpha_N \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MR} \times DPF + \alpha_{LH} \times A$$

$$W_1 = 0.4 \text{ and } 0.4575, W_2 = 0.4 \text{ and } 0.434$$

$$W_3 = 0.16 \text{ and } 0.84, W_4 = 0.16 \text{ and } 0.84$$

$$y_1 = 0.045705$$

$$y_2 = 0.045774$$

$$y_3 = 0.049245$$

$$y_4 = 0.049254$$

$$M = 0.04679 \text{ and } NM = 0.04807$$

$$Y = 0.04743$$

$$e = 0.001125 \text{ Or } 4.74\%$$

95.26%

Patient 88

G = 100, BP = 68, Insulin = 71, BMI = 38.5, DPF = 0.324, A = 26

$$\mu_N = 0.8 \text{ \& } \mu_M = 0.2, \mu_N = 1, \mu_L = 0.71, \mu_{OW} = 1, \mu_{LC} = 0.44 \text{ \& } \mu_{MRC}, \mu_{LH} = 1$$

And

$$v_N = 0.2 \text{ \& } v_M = 0.8, v_N = 0, v_L = 0.29, v_{OW} = 0, v_{LC} = 0.224 \text{ \& } v_{MRC} = 0.352, v_{LH} = 0$$

$$R_1 = \alpha_0 + \alpha_N \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{LC} \times DPF + \alpha_{LH} \times A$$

$$R_2 = \alpha_0 + \alpha_N \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A$$

$$R_3 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{LC} \times DPF + \alpha_{LH} \times A$$

$$R_4 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A$$

$$W_1 = 0.44 \text{ and } 0.29, W_2 = 0.648 \text{ and } 0.352$$

$$W_3 = 0.2 \text{ and } 0.8, W_4 = 0.2 \text{ and } 0.8$$

$$y_1 = 0.064426$$

$$y_2 = 0.064384$$

$$y_3 = 0.072375$$

$$y_4 = 0.072384$$

$$M = 0.06655 \text{ and } NM = 0.070094$$

$$Y = 0.066832$$

$$e = 0.00234 \text{ Or } 6.83\%$$

93.17%

Continued

Patient 112

G = 155, BP = 62, Insulin = 495, BMI = 34, DPF = 0.543, A = 46

$$\begin{aligned} \mu_M &= 1, \mu_L = 0.3 \text{ \& } \mu_N = 0.7, \mu_M = 1, \mu_N = 0.1 \\ \text{\& } \mu_{OW} &= 0.9, \mu_{MRC} = 0.914 \text{ \& } \mu_{MTC} = 0.086, \mu_{MTH} = 1 \\ \text{And} \\ \nu_M &= 0, \nu_L = 0.7 \text{ \& } \nu_N = 0.3, \nu_M = 0, \nu_N = 0.9 \\ \text{\& } \nu_{OW} &= 0.1, \nu_{MRC} = 0.086 \text{ \& } \nu_{MTC} = 0.914, \nu_{MTH} = 0 \end{aligned}$$

$$\begin{aligned} R_1 &= \alpha_0 + \alpha_M \times G + \alpha_L \times BP + \alpha_M \times I + \alpha_N \times BMI + \alpha_{MRC} \times DPF + \alpha_{MTH} \times A \\ R_2 &= \alpha_0 + \alpha_M \times G + \alpha_L \times BP + \alpha_M \times I + \alpha_N \times BMI + \alpha_{MTC} \times DPF + \alpha_{MTH} \times A \\ R_3 &= \alpha_0 + \alpha_M \times G + \alpha_L \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{MTH} \times A \\ R_4 &= \alpha_0 + \alpha_M \times G + \alpha_L \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{MTH} \times A \\ R_5 &= \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_M \times I + \alpha_N \times BMI + \alpha_{MRC} \times DPF + \alpha_{MTH} \times A \\ R_6 &= \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_M \times I + \alpha_N \times BMI + \alpha_{MTC} \times DPF + \alpha_{MTH} \times A \\ R_7 &= \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{MTH} \times A \\ R_8 &= \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_M \times I + \alpha_{OW} \times BMI + \alpha_{MTC} \times DPF + \alpha_{MTH} \times A \end{aligned}$$

$$\begin{aligned} W_1 &= 0.1 \text{ and } 0.9, W_2 = 0.086 \text{ and } 0.914 \\ W_3 &= 0.3 \text{ and } 0.7, W_4 = 0.086 \text{ and } 0.914 \\ W_5 &= 0.1 \text{ and } 0.9, W_6 = 0.086 \text{ and } 0.914 \\ W_7 &= 0.7 \text{ and } 0.3, W_8 = 0.086 \text{ and } 0.914 \end{aligned}$$

$$\begin{aligned} y_1 &= 1.2676, y_2 = 1.2670, \\ y_3 &= 1.3118, y_4 = 1.3112 \\ y_5 &= 1.1994, y_6 = 1.1988 \\ y_7 &= 1.2436, y_8 = 1.2430 \end{aligned}$$

$$M = 1.25808 \text{ and } NM = 1.2546$$

$$Y = 1.25636$$

$$e = 0.03286 \text{ Or } 25.64\%$$

$$74.36\%$$

Patient 111

G = 171, BP = 72, Insulin = 135, BMI = 33.3, DPF = 0.199, A = 24

$$\begin{aligned} \mu_M &= 0.5, \mu_N = 1, \mu_L = 1, \mu_N = 0.17 \text{ \& } \mu_{OW} = 83, \\ \mu_{LC} &= 0.7525 \text{ \& } \mu_{MRC} = 0.398, \mu_{LH} = 1 \\ \text{And} \\ \nu_M &= 0.5, \nu_N = 0, \nu_L = 0, \nu_N = 0.83 \text{ \& } \nu_{OW} = 0.17, \\ \nu_{LC} &= 0.2475 \text{ \& } \nu_{MRC} = 0.6902, \nu_{LH} = 0 \end{aligned}$$

$$\begin{aligned} R_1 &= \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_N \times BMI + \alpha_{LC} \times DPF + \alpha_{LH} \times A \\ R_2 &= \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_N \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A \\ R_3 &= \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{LC} \times DPF + \alpha_{LH} \times A \\ R_4 &= \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_L \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPF + \alpha_{LH} \times A \end{aligned}$$

$$\begin{aligned} W_1 &= 0.17 \text{ and } 0.83, W_2 = 0.17 \text{ and } 0.83 \\ W_3 &= 0.5 \text{ and } 0.5, W_4 = 0.398 \text{ and } 0.602 \end{aligned}$$

$$\begin{aligned} y_1 &= 1.0234 \\ y_2 &= 1.0234 \\ y_3 &= 1.0667 \\ y_4 &= 1.0667 \end{aligned}$$

$$M = 1.0548 \text{ and } NM = 1.0407$$

$$Y = 1.04774$$

$$e = 0.00114$$

$$\text{Or } 4.77\%$$

$$95.23\%$$

Continued

Patient 140

G = 105, BP = 72, Insulin = 325, BMI = 36.9, DPPF = 0.159, A = 28

$$\mu_N = 0.6 \text{ \& } \mu_M = 0.4, \mu_N = 1, \mu_M = 0.68,$$

$$\mu_{OW} = 1, \mu_{LC} = 0.825 \text{ \& } \mu_{MRC} = 0.318, \mu_{LH} = 1$$

And

$$v_N = 0.4 \text{ \& } v_M = 0.6, v_N = 0, v_M = 0, v_{OW} = 0,$$

$$v_{LC} = 0.1475 \text{ \& } v_{MRC} = 0.682, v_{LH} = 0$$

$$R_1 = \alpha_0 + \alpha_N \times G + \alpha_M \times BP + \alpha_{OW} \times I + \alpha_{OW} \times BMI + \alpha_{LC} \times DPPF + \alpha_{LH} \times A$$

$$R_2 = \alpha_0 + \alpha_N \times G + \alpha_M \times BP + \alpha_{OW} \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPPF + \alpha_{LH} \times A$$

$$R_3 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_{OW} \times I + \alpha_{OW} \times BMI + \alpha_{LC} \times DPPF + \alpha_{LH} \times A$$

$$R_4 = \alpha_0 + \alpha_M \times G + \alpha_N \times BP + \alpha_{OW} \times I + \alpha_{OW} \times BMI + \alpha_{MRC} \times DPPF + \alpha_{LH} \times A$$

$$W_1 = 0.6 \text{ and } 0.4, W_2 = 0.318 \text{ and } 0.682$$

$$W_3 = 0.4 \text{ and } 0.6, W_4 = 0.318 \text{ and } 0.682$$

$$y_1 = 0.12714$$

$$y_2 = 0.12714$$

$$y_3 = 0.13549$$

$$y_4 = 0.13549$$

$$M = 0.130805 \text{ and } NM = 0.131668$$

$$Y = 0.1312366$$

$$e = 0.0086115 \text{ Or } 13.12\%$$

86.88%

$$y_1 = 0.0984964 \text{ and } y_2 = 0.985037.$$

Layer 6: This is the Implication layer; here we have calculated the value of overall Membership and Non-Membership, as following:

$$M = \frac{W_1 y_1 + W_2 y_2}{W_1 + W_2} = 0.0985,$$

M is membership value:

$$NM = \frac{W_1 y_1 + W_2 y_2}{W_1 + W_2} = 0.0985,$$

NM is non-membership value.

Layer 7: This is the final layer of our structure, which is Output Layer and the output have calculated as:

$$Y = \frac{M + NM}{2} = 0.0985$$

The error of our structure is shown as:

We have, $Y = 0.0985$ and $T = 0$ (as given o/p from the given data).

So,

$$e = \frac{(Y - T)^2}{2} = 0.00485$$

Table 3. Comparison of proposed technique's accuracy with the existing [7] [9].

Method	Accuracy (%)	Author(s)
Proposed Approach (INFS Structure)	88.76	Our Approach
FLDDS for Very Young	87.2	Vaishali Jain, Supriya Raheja
FVM for Diabetes Decision Very Young	85.03	Kalpana, M. Kumar, A.V.S.
FES	81.7	Lee and Wang
HNFB-1	78.26	Goncalves <i>et al.</i>
Logdisc	77.7	Statlog
IncNet	77.6	Norbert Jankowski
DIPOL 92	77.6	Statlog

9. Conclusions and Discussions

The entire work done in this article illustrates the following points:

1) Proposed intuitionistic fuzzy logic-based neuro system shows the diagnostic process of diabetes with the help of membership and non-membership function with some hesitation margins. We have adopted the framework of intuitionistic fuzzy logic-based inference system in the neural network, in which the neural network works as hardware and intuitionistic fuzzy-based inference system works as software.

2) The experimental data of the diabetic patient is collected from PIDD, to check the accuracy of our proposed system and to minimize the complexity of treating diabetes.

3) In this work, a survey has been done on various optimization techniques. We have considered many optimization tools used in existing literature for optimization, the proposed work contains 21 previous studies on optimization in different fields.

4) A comparative study is also given in this work (as revealed in **Table 3**), the accuracy value of our system has also been calculated as shown in **Table 2**. The obtained value is 88.76% which is more optimal than the values obtained in the previously existing techniques. Therefore, the proposed system can help doctors in hospitals to evaluate the risk of diabetes.

5) For the future perspective, the proposed method describes that its performance is increased with the use of any population-based optimization technique and it will provide better results.

6) To decrease the complexity of the system, we have used the MATLAB software to the representation of membership and non-membership values of the input variable. And the further process is handled by using Sugeno's fuzzy inference system based on the intuitionistic fuzzy logic approach.

7) The proposed model has considered the six major input factors (due to the

effects of these factors on diabetes diseases) for Sugeno's fuzzy inference system in the intuitionistic environment.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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