MEDIATIVE FUZZY LOGIC OF SUGENO-TSK MODEL FOR THE DIAGNOSIS OF DIABETES

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Abstract. Fuzzy Logic (FL) is very beneficial in medical field. But due to the consideration of membership function only; it cannot give an appropriate result in present era of contradiction. So, we need to consider favourable as well as unfavourable cases together as the Intuitionistic Fuzzy Logic (IFL) does. But what happens if we have imperfect information that cannot be dealt with the IFL. When there exist a contradiction in the expert knowledge, then we have to propose a Mediative Fuzzy Logic (MFL) based Sugeno’s inference system for the diagnosis of diabetes. In the present research paper, we have proposed a new approach to the diagnosis of diabetes, we have collected certain information from Pima Indians Diabetes Database (PIDD) as input variables and we used MFL based inference system for the diagnosis of diabetes.

1. Introduction
Diabetes mellitus or simply diabetes is a major health issue that causes high level blood sugar. Its prevalence has been rapidly increasing in low- and middle-income countries; diabetes causes kidney failure, stroke, blindness, heart attacks and many more. When a doctor fails to correct diagnosis of diabetic patient then it may harmful to the patient. Diabetes mellitus or simply diabetes is a major health issue that causes high level blood sugar. Its prevalence has been rapidly increasing in low- and middle-income countries; diabetes causes kidney failure, stroke, blindness, heart attacks and many more. When a doctor fails to correct diagnosis of diabetic patient then it may harmful to the patient. Firstly, fuzzy set were introduced by professor L.A. Zadeh [1] in 1965 by using membership functions only. For a given universal set \( X \) and \( A \subseteq X \), describe a set by using membership function \( \mu_A(x) : X \to [0, 1] \), which takes value from closed interval of unit length. The possibility of an object \( x \) belongs to the fuzzy set \( A \) varying between \([0, 1]\) we may say that FL was used to handle partial truth value, which is not completely true or completely false. On the behalf of this theory, Zadeh described that fuzzy set theory is nothing but an extension of classical set theory. Fuzzy set have many real life and practical applications, it has been used to many areas from controlling system to Artificial Intelligence (AI). Later on, both concepts, classical logic as well as FL extended to IFL. IFL deals with two functions, membership and non-membership function and their values lies between closed unit interval \([0, 1]\) and sum of these two values also lies in the same unit interval. IFL is generalization of FL; IFL helps to represent impartial knowledge and used to present many real-world problems in more appropriate manner. In 1986, K. Atanassov [2, 3] provide concept of IFL and used
membership function, non-membership function and hesitation grade to handle the uncertainty to deal with impartial knowledge. There was some situation arises in which contradictory and incomplete information presents. FL and IFL fail to handle these types of situations to deal with that kind of situations a fuzzy inference system used based on Mediative Fuzzy Logic (MFL). It is an extension of IFL. It can handle contradictory and incomplete situation easily. In 2008, and Montiel [4] gave a contradictory knowledge management algorithm based on information for controlling population size, which may be inconsistent, incomplete and contradiction. In 2018, Iancu [5] provided MFL for heart disease diagnosis based on Mandani’s fuzzy inference system with single input and single output. Later In 2019, Nitesh and Mukesh [6] presented mediative Sugeno’s-TSK fuzzy logic-based screening analysis to diagnosis of heart disease; this research paper shows that mediative fuzzy inference based on Sugeno’s-TSK can handle the heart disease diagnosis in appropriate way. The concept of MFL have also been used in multi-criteria decision making [7] based on various alternatives. In 2011, Kalpana and Senthil [8] provided fuzzy expert system for diabetes using fuzzy verdict mechanism, later, in 2015 Vaishali and Supriya [9] provides a research article on improving the prediction rate of diabetes using fuzzy this work shows that the approach which have used shows better accuracy as compared to other prediction approaches. After that in 2018 Asadi and Nekoukar [10] proposed a new adaptive fuzzy integral sliding mode control scheme for blood glucose level regulation in type 1 diabetic patients using FL system. Later on, in 2019 Siva and Manikandan [11] described diagnosis of diabetes diseases using optimized fuzzy rule set by grey wolf optimization this work presented the concept of artificial intelligence to learns the fuzzy rule and then optimized according to the GWO algorithm. In this paper, we have proposed a Sugeno’s-TSK model based on MFL for diagnosis of diabetes by using two inputs and one output rule base system.

This research paper has been divided into six sections; in the second section of the research paper, we have defined some basic concepts and the definitions on fuzzy set, Intuitionistic Fuzzy Set (IFS) and MFL. In the third section of the paper, we have proposed an algorithm for the Sugeno’s fuzzy - TSK model based on MFL. The algorithm contains some steps which we have proposed for our method. In this section we have also presented the architecture form of the proposed algorithm. In fourth section of the research paper, we have constructed membership and non-membership function for input and output variables, which have been constructed on the data collected from Pima Indians Diabetes Dataset (PIDD) and used as input variables. In this section, we have also categorized the output and made the membership and non-membership for the stages of the risk about the sickness. In fifth section we have formed the fuzzy rules and the fuzzy propositions used in the inference system. We have computed the values of the output by using the defuzzification method and the firing level observed for corresponding output. In the sixth section, we have made some computations for getting the output values as shown in table-2 by giving some input values. We also have got the firing level and given some conclusive evidence as shown in chart-1 for our numerical computations.

2. Some Basic Concepts and Definitions

2.1. Fuzzy Set

If X is a universal set then a fuzzy set A on X is defined as

\[ A = (x, \mu_A(x)) : x \in X \]  

(1)

Where \( \mu_A(x) : X \rightarrow [0, 1] \) is called the membership function of A in X.
2.2. Intuitionistic Fuzzy Set (IFS)

Let X is a universal set then IFS B in X is defined as

\[ B = (x, \mu_B(x), \nu_B(x)) : x \in X \]  \hspace{1cm} (2)

where, \( \mu_B(x), \nu_B(x) : X \rightarrow [0, 1] \) with \( 0 \leq \mu_B(x) + \nu_B(x) \leq 1 \) are called the membership and non-membership functions respectively, and \( \pi_B(x) = 1 - (\mu_B(x) + \nu_B(x)) \) with \( 0 \leq \pi_B(x) \leq 1 \) IF. \( FS_\mu \) and \( FS_\nu \) are denotes the traditional outputs of fuzzy system using membership and non-membership function respectively, then for Intuitionistic Fuzzy System the total output calculated by a linear relation [12] between \( FS_\mu \) and \( FS_\nu \)

\[ IFS = (1 - \pi)FS_\mu + \pi FS_\nu \]  \hspace{1cm} (3)

Noted that if \( \pi = 0 \) then it will reduce as the output of a traditional fuzzy system, but if \( \pi \neq 0 \)

2.3. Contradiction Fuzzy Set

A contradiction fuzzy set C in X is defined by

\[ \zeta_C(x) = \text{min}(\mu_C(x), \nu_C(x)) \]  \hspace{1cm} (4)

where \( \mu_C \) called agreement memberships function and \( \nu_C \) called non-agreement membership function. To the analysis of our work, in place of membership and non-membership functions, we will use the agreement and non-agreement membership functions, because these names are more appropriate by using intuitionistic fuzzy set for handling the uncertainty. On the behalf of these contradiction fuzzy set, Montiel et. al [13], proposed the following three expressions as:

\[ MFS = (1 - \pi - \zeta/2)FS_\mu + (\pi + \zeta/2)FS_\nu \]  \hspace{1cm} (5)

\[ MFS = \text{min}((1 - \pi)FS_\mu + \pi FS_\nu, 1 - \zeta/2) \]  \hspace{1cm} (6)

\[ MFS = ((1 - \pi)FS_\mu + \pi FS_\nu)(1 - \zeta/2) \]  \hspace{1cm} (7)

2.4. Intuitionistic Fuzzy Number

Let an IFS B in X defines as \( B = (x, \mu_B(x), \nu_B(x)) : x \in X \), Then B is called intuitionistic fuzzy number if:

1. B is normal, i.e. there exist [14] at least one element \( x_0 \in X \)
2. B is convex, i.e \( \forall x_1, x_2 \in X \) and \( \lambda \in [0, 1] \)
\[ \mu_B(\lambda x_1 + (1 - \lambda)x_2) \geq \text{min}(\mu_B(x_1), \mu_B(x_2)) \] and
\[ \nu_B(\lambda x_1 + (1 - \lambda)x_2) \leq \text{max}(\nu_B(x_1), \nu_B(x_2)) \]
3. Membership and non-membership functions are piece-wise continuous.

Triangular intuitionistic fuzzy number in \( R_i \) is defined with their membership and non-membership grade as

\[ \mu_B(x) = \begin{cases} \frac{x - a}{b - a} & \text{if } a \leq x \leq b \\ \frac{c - x}{c - b} & \text{if } b \leq x \leq c \\ 0 & \text{if } \text{else} \end{cases} \]
and

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

2.5. **Diabetes and Their Types**

Diabetes is a kind of disease, which occurs when blood sugar/blood glucose is too high. Blood sugar is the main source of energy, which comes from food we eat. Insulin is hormone made by pancreas, helps glucose to get into cells. Their Types: There are three most common types of diabetes: Type 1 diabetes: when body does not make insulin. Type 2 diabetes: when body does not make insulin and does not use insulin well. Gestational diabetes: developed in some pregnant women.

2.6. **PIDD**

Pima Indians is a group which has the highest rate of diabetes across the world. The National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) [15] have examined the Pima Indians. It includes more than 700 data of diabetic female patients.

3. **Proposed Algorithm Based on Mediative Fuzzy Logic for Diabetes Diagnosis**

Suppose we have a conditional and unqualified proposition as P: IF “X is A” and “Y is B” THEN “Z is C” with two input and one output The proposed algorithm follows various steps as shown in figure 1

Step 1. Set the triangular intuitionistic fuzzy number for including variables, Glucose, Insulin, Body Mass Index (BMI), Diabetes Pedigree Function (DPF), Age and Diabetes Mellitus (DM) as shown in Table 1

Step 2. Input the crisp value for Glucose, Insulin, BMI, DPF and Age and set firing levels $\alpha_1$ and $\alpha_2$ for membership functions and $\beta_1$ and $\beta_2$ for non-membership functions as we are working with two input variables

Step 3. Calculate the aggregation of the firing levels for antecedent (membership and non-membership functions) for a given fuzzy rule by taking $\alpha$ as a minimum of $(\alpha_1, \alpha_2)$ and $\beta$ as a minimum of $(\beta_1, \beta_2)$

Step 4. After the step 3 calculate the contradiction factor $\gamma = \min(\alpha, \beta)$

Step 5. Calculate the defuzzified values of consequences of the rule at $\alpha$ and $\beta$ say $z_1$ and $z_2$ corresponds to membership and non-membership functions of output variable

Step 6. Finally get the output by monteil [3] expression as

$$z = (1 - \pi - \frac{\gamma}{2})z_1 + (\pi + \frac{\gamma}{2})z_2$$
Table 1. Including variables and their corresponding range for triangular Intuitionistic fuzzy numbers

| Including Factors | Linguistic Variables | Ranges               |
|-------------------|----------------------|----------------------|
| Glucose           | low, medium, high    | [56 − 125], [68.2 − 145], [109.9 − 198] |
| Insulin           | low, medium, high    | [0 − 87.67], [63.63 − 191.6], [95.34 − 586] |
| BMI               | low, medium, high    | [18 − 30.8], [31.01 − 45.01], [36.43 − 67] |
| DPF               | low, medium, high    | [0.085 − 1.132], [0.547 − 1.717], [1.09 − 2.4] |
| Age               | young, middle, old   | [24 − 26], [25 − 27], [26 − 30] |
| DM                | low, medium, high    | [0 − 0.4], [0.3 − 0.7], [0.6 − 1] |

4. Including Factors

NIDDK studied on 768 adult females Pima Indians which lives near Phoenix, there are many factors were recorded, out of these; we are taken some factors as shown in table 1 on the behalf of PIDD with their membership and non-membership functions are as follows:

![Architecture of proposed algorithm](image)

Figure 1. Architecture of proposed algorithm

4.1. Glucose

Plasma glucose concentration 2 hours in an oral glucose tolerance test (56-198mg/dl), and normal blood sugar level is 72-99 mg/dl (up to 140mg/dl after eating). We divide this into three categories; as low, medium and high and their triangular membership and non-membership functions are given as:
\[ \mu_{\text{Low}}(x) = \begin{cases} 
\frac{x - 56}{44}, & \text{if } 56 \leq x \leq 100 \\
\frac{125 - x}{25}, & \text{if } 100 \leq x \leq 125 \\
0, & \text{if else} 
\end{cases} \]

\[ \mu_{\text{Medium}}(x) = \begin{cases} 
\frac{x - 48.8}{145 - x}, & \text{if } 68.2 \leq x \leq 117 \\
0, & \text{if else} 
\end{cases} \]

\[ \mu_{\text{High}}(x) = \begin{cases} 
\frac{x - 109.9}{36.2}, & \text{if } 109.9 \leq x \leq 146 \\
0, & \text{if else} 
\end{cases} \]

\[ \nu_{\text{Low}}(x) = \begin{cases} 
\frac{100 - x}{48}, & \text{if } 52 \leq x \leq 100 \\
\frac{x - 100}{35}, & \text{if } 100 \leq x \leq 135 \\
1, & \text{if else} 
\end{cases} \]

\[ \nu_{\text{Medium}}(x) = \begin{cases} 
\frac{117 - x}{42.6}, & \text{if } 64.4 \leq x \leq 117 \\
\frac{x - 117}{35}, & \text{if } 117 \leq x \leq 152 \\
1, & \text{if else} 
\end{cases} \]

\[ \nu_{\text{High}}(x) = \begin{cases} 
\frac{146 - x}{44}, & \text{if } 102 \leq x \leq 117 \\
\frac{x - 146}{59}, & \text{if } 146 \leq x \leq 205 \\
1, & \text{if else} 
\end{cases} \]

4.2. Insulin

2-Hour serum insulin (mu U/ml) is recorded and divided it into three categories; low, medium and high. Their membership and non-membership functions are shown below

\[ \mu_{\text{Low}}(x) = \begin{cases} 
\frac{x}{55.11}, & \text{if } 0 \leq x \leq 55.11 \\
\frac{87.67 - x}{32.56}, & \text{if } 55.11 \leq x \leq 87.67 \\
0, & \text{if else} 
\end{cases} \]

\[ \mu_{\text{Medium}}(x) = \begin{cases} 
\frac{x - 63.63}{34.79}, & \text{if } 63.63 \leq x \leq 98.42 \\
\frac{191.61 - x}{93.19}, & \text{if } 98.42 \leq x \leq 93.19 \\
0, & \text{if else} 
\end{cases} \]
\[
\mu_{High}(x) = \begin{cases} 
\frac{x - 95.34}{92.96}, & \text{if } 95.34 \leq x \leq 188.3 \\
\frac{586 - x}{397.7}, & \text{if } 188.3 \leq x \leq 586 \\
0, & \text{else}
\end{cases}
\]

and

\[
\nu_{Low}(x) = \begin{cases} 
\frac{55.11 - x}{55.11}, & \text{if } 0 \leq x \leq 55.11 \\
\frac{x - 100}{37.46}, & \text{if } 55.11 \leq x \leq 92.57 \\
1, & \text{else}
\end{cases}
\]

\[
\nu_{Medium}(x) = \begin{cases} 
\frac{98.42 - x}{39.52}, & \text{if } 58.9 \leq x \leq 98.42 \\
\frac{x - 98.42}{98.98}, & \text{if } 98.42 \leq x \leq 197.4 \\
1, & \text{else}
\end{cases}
\]

\[
\nu_{High}(x) = \begin{cases} 
\frac{188.3 - x}{98.28}, & \text{if } 90.02 \leq x \leq 188.3 \\
\frac{x - 188.3}{407.7}, & \text{if } 188.3 \leq x \leq 596 \\
1, & \text{else}
\end{cases}
\]

4.3. BMI

BMI weight in kg/(m)^2 is also divided into three categories: low, medium and high with membership and non-membership are given below

\[
\mu_{Low}(x) = \begin{cases} 
\frac{x - 18}{4}, & \text{if } 18 \leq x \leq 22 \\
\frac{30.8 - x}{8.8}, & \text{if } 22 \leq x \leq 30.8 \\
0, & \text{else}
\end{cases}
\]

\[
\mu_{Medium}(x) = \begin{cases} 
\frac{x - 31.01}{6}, & \text{if } 31.01 \leq x \leq 37.01 \\
\frac{45.01 - x}{8}, & \text{if } 37.01 \leq x \leq 45.01 \\
0, & \text{else}
\end{cases}
\]

\[
\mu_{High}(x) = \begin{cases} 
\frac{x - 36.43}{8}, & \text{if } 36.43 \leq x \leq 44.33 \\
\frac{67 - x}{22.57}, & \text{if } 44.33 \leq x \leq 67 \\
0, & \text{else}
\end{cases}
\]

and

\[
\nu_{Low}(x) = \begin{cases} 
\frac{22 - x}{6}, & \text{if } 16 \leq x \leq 22 \\
\frac{x - 22}{12}, & \text{if } 22 \leq x \leq 34 \\
1, & \text{else}
\end{cases}
\]
\[ \nu_{\text{Medium}}(x) = \begin{cases} 
\frac{37.01 - x}{8}, & \text{if } 29.01 \leq x \leq 37.01 \\
\frac{x - 67}{22.57}, & \text{if } 37.01 \leq x \leq 47.01 \\
1, & \text{if else} 
\end{cases} \]

\[ \nu_{\text{High}}(x) = \begin{cases} 
\frac{44.43 - x}{9}, & \text{if } 35.43 \leq x \leq 44.43 \\
\frac{x - 44.43}{24.57}, & \text{if } 44.43 \leq x \leq 69 \\
1, & \text{if else} 
\end{cases} \]

### 4.4. DPF

According to PIMA this factor is also characterized into three factors and their membership and non-membership functions are given below as

\[ \mu_{\text{Low}}(x) = \begin{cases} 
\frac{x - .085}{44.57}, & \text{if } 18 \leq x \leq 22 \\
\frac{1.132 - x}{.5998}, & \text{if } 22 \leq x \leq 30.8 \\
0, & \text{if else} 
\end{cases} \]

\[ \mu_{\text{Medium}}(x) = \begin{cases} 
\frac{x - .547}{.483}, & \text{if } .547 \leq x \leq 1.03 \\
\frac{1.717 - x}{.678}, & \text{if } 1.03 \leq x \leq .678 \\
0, & \text{if else} 
\end{cases} \]

\[ \mu_{\text{High}}(x) = \begin{cases} 
\frac{x - 1.09}{.386}, & \text{if } 1.09 \leq x \leq 1.476 \\
\frac{2.4 - x}{.924}, & \text{if } 1.476 \leq x \leq 2.4 \\
0, & \text{if else} 
\end{cases} \]

and

\[ \nu_{\text{Low}}(x) = \begin{cases} 
\frac{22 - x}{6}, & \text{if } 16 \leq x \leq 22 \\
\frac{x - 22}{12}, & \text{if } 22 \leq x \leq 34 \\
1, & \text{if else} 
\end{cases} \]

\[ \nu_{\text{Medium}}(x) = \begin{cases} 
\frac{.5322 - x}{.4572}, & \text{if } .075 \leq x \leq .5322 \\
\frac{x - .5322}{1.4498}, & \text{if } .5322 \leq x \leq 1.982 \\
1, & \text{if else} 
\end{cases} \]

\[ \nu_{\text{High}}(x) = \begin{cases} 
\frac{1.03 - x}{.583}, & \text{if } .447 \leq x \leq 1.03 \\
\frac{x - 1.03}{.788}, & \text{if } 1.03 \leq x \leq 1.818 \\
1, & \text{if else} 
\end{cases} \]
4.5. Age

Age (in years) have characterized into three categories; young, middle and old. Their membership and non-membership functions are given below as

\[
\mu_{\text{Young}}(x) = \begin{cases} 
\frac{x-24}{1}, & \text{if } 24 \leq x \leq 25 \\
\frac{26-x}{1}, & \text{if } 25 \leq x \leq 26 \\
0, & \text{if else}
\end{cases}
\]

\[
\mu_{\text{Middle}}(x) = \begin{cases} 
\frac{x-25}{1}, & \text{if } 25 \leq x \leq 26 \\
\frac{27-x}{1}, & \text{if } 26 \leq x \leq 27 \\
0, & \text{if else}
\end{cases}
\]

\[
\mu_{\text{Old}}(x) = \begin{cases} 
\frac{x-26}{1}, & \text{if } 26 \leq x \leq 27 \\
\frac{30-x}{3}, & \text{if } 27 \leq x \leq 30 \\
0, & \text{if else}
\end{cases}
\]

\[
\nu_{\text{Young}}(x) = \begin{cases} 
\frac{25-x}{4}, & \text{if } 0 \leq x \leq 25 \\
\frac{x-25}{2}, & \text{if } 25 \leq x \leq 27 \\
1, & \text{if else}
\end{cases}
\]

\[
\nu_{\text{Middle}}(x) = \begin{cases} 
\frac{26-x}{2}, & \text{if } 0 \leq x \leq 26 \\
\frac{x-26}{2}, & \text{if } 26 \leq x \leq 28 \\
1, & \text{if else}
\end{cases}
\]

\[
\nu_{\text{Old}}(x) = \begin{cases} 
\frac{27-x}{2}, & \text{if } 0 \leq x \leq 27 \\
\frac{x-27}{5}, & \text{if } 27 \leq x \leq 32 \\
1, & \text{if else}
\end{cases}
\]

4.6. Output Factor (DM)

The possibility of status level of DM for output Intuitionistic fuzzy number, DM has characterized into three categories; low, medium and high and converted them into Intuitionistic fuzzy numbers with their membership and non-membership functions as shown below

\[
\mu_{\text{Low}}(x) = \begin{cases} 
\frac{x}{2}, & \text{if } 0 \leq x \leq .2 \\
\frac{.4-x}{2}, & \text{if } .2 \leq x \leq .4 \\
0, & \text{if else}
\end{cases}
\]
\[
\begin{align*}
\mu_{Medium}(x) &= \begin{cases} 
\frac{x - .3}{.2}, & \text{if } .3 \leq x \leq .5 \\
\frac{.5 - x}{.2}, & \text{if } .5 \leq x \leq .7 \\
0, & \text{if else}
\end{cases} \\
\mu_{High}(x) &= \begin{cases} 
\frac{x - .6}{.2}, & \text{if } .6 \leq x \leq .8 \\
1 - \frac{x}{.2}, & \text{if } .8 \leq x \leq 1 \\
0, & \text{if else}
\end{cases}
\end{align*}
\]

and

\[
\begin{align*}
\nu_{Low}(x) &= \begin{cases} 
\frac{2 - x}{.2}, & \text{if } 0 \leq x \leq .2 \\
\frac{x - .2}{.3}, & \text{if } .2 \leq x \leq .5 \\
1, & \text{if else}
\end{cases} \\
\nu_{Medium}(x) &= \begin{cases} 
\frac{.5 - x}{.3}, & \text{if } .2 \leq x \leq .5 \\
\frac{x - .5}{.4}, & \text{if } .5 \leq x \leq .9 \\
1, & \text{if else}
\end{cases} \\
\nu_{High}(x) &= \begin{cases} 
\frac{.8 - x}{.3}, & \text{if } .5 \leq x \leq .8 \\
\frac{x - .8}{.2}, & \text{if } .8 \leq x \leq 1 \\
1, & \text{if else}
\end{cases}
\end{align*}
\]

5. Fuzzy Rules
There are around 150 rules constructed behalf of the algorithm which have used in the present paper, but we are considering only 28 rules where we found some drastic change in our output which are as follows;

- \( R_1 \) IF Glucose is low and Insulin is high THEN DM is high
- \( R_2 \) IF Glucose is medium and BMI is medium THEN DM is medium
- \( R_3 \) IF Insulin is low and DPF is low THEN DM is low
- \( R_4 \) IF BMI is high and DPF is high THEN DM is high
- \( R_5 \) IF Age is old and Insulin is high THEN DM is high
- \( R_6 \) IF Age is young and BMI is medium THEN DM is medium
- \( R_7 \) IF DPF is medium and BMI is low THEN DM is low
- \( R_8 \) IF Insulin is medium and Age is middle THEN DM is medium
- \( R_9 \) IF BMI is low and Age is young THEN DM is low
- \( R_{10} \) IF DPF is high and Glucose is high THEN DM is high
- \( R_{11} \) IF Age is Middle and Glucose is high THEN DM is high
- \( R_{12} \) IF Glucose is medium and DPF is medium THEN DM is medium
- \( R_{13} \) IF BMI is medium and Insulin is low THEN DM is low
- \( R_{14} \) IF Insulin is high and Glucose is high THEN DM is high
Table 2. Firing levels and their crisp output

| Rules | Firing Levels | Crisp Outputs | Diabetes |
|-------|---------------|---------------|----------|
| $R_1$ | 0.156         | 0.758         | High     |
| $R_2$ | 0.23          | 0.457         | Medium   |
| $R_3$ | 0.55          | 0.174         | Low      |
| $R_4$ | 0.36          | 0.791         | High     |
| $R_5$ | 1             | 0.8           | High     |
| $R_6$ | 0.4489        | 0.5           | Medium   |
| $R_7$ | 0.1007        | 0.199         | Low      |
| $R_8$ | 0.324         | 0.561         | Medium   |
| $R_9$ | 0.25          | 0.1           | Low      |
| $R_{10}$ | 0.08         | 0.764         | High     |

$R_{15}$ IF Age is old and BMI is low THEN DM is high  
$R_{16}$ IF DPF is high and Insulin is high THEN DM is high  
$R_{17}$ IF BMI is low and DPF is low THEN DM is low  
$R_{18}$ IF Age is young and Insulin is high THEN DM is high  
$R_{19}$ IF Insulin is low and Glucose is low THEN DM is low  
$R_{20}$ IF BMI is high and Age is old THEN DM is high  
$R_{21}$ IF Glucose is medium and Age is young THEN DM is medium  
$R_{22}$ IF DPF is high and Age is old THEN DM is high  
$R_{23}$ IF DPF is low and Age is young THEN DM is low  
$R_{24}$ IF Glucose is low and Insulin is medium THEN DM is low  
$R_{25}$ IF Glucose is high and Insulin is high THEN DM is high  
$R_{26}$ IF DPF is low and Age is old THEN DM is low  
$R_{27}$ IF DPF is medium and BMI is medium THEN DM is medium  
$R_{28}$ IF Insulin is high and Age is old THEN DM is high

6. Output Results and Conclusion

![Figure 2](image)

**Figure 2.** Relation between firing levels and crisp output values

When the criteria is not up to the mark in the decisions taken by the human beings due to
some unexplained reasons. So human ability to take such type of decisions is not capable and it contains some unclear boundaries or haziness. FL provides a better foundation to handle such type of uncertainty. But FL does not provide the perfection due to those parts, which considering the favourable cases i.e., its membership value. To overcome such type of uncertainty IFS plays a vital role because of considering the membership and non-membership values. But in present era MFL plays an important role in medical field because it has contradictory factor, which is the important consideration of this method. In this present research paper, it is observed that for the first fired rule, when the firing value is low then we observed that the patient goes under higher diabetic condition and in the second fired rule when the firing value slightly increases then patient recovers her/his condition, but in the third fired rule when the firing level is about 0.55 then diabetic level of patient is low and so on. On the behalf of the above observation we can say it has sudden changes at different firing levels as shown in table 2 and figure 2. So, the patient should be observed carefully because diabetic risk may be high at some firing levels.

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References
[1] Zadeh L A 1965 Fuzzy Sets Inf. Control. 8 338-56
[2] Atanassov K 1986 Intuitionistic fuzzy sets Fuzzy Sets Syst. 20 87-96
[3] Atanassov K T 1999 Intuitionistic fuzzy sets Springer. 1
[4] Montiel O, Castillo O, Melin P and Sepulveda R 2008 Mediative fuzzy logic: A New Approach for contradictory knowledge management Soft Comput. 12 251-56
[5] Iancu I 2018 Heart diseases diagnosis based on mediative fuzzy logic Artif Intell Med. 89 51-60
[6] Dhiman N and Sharma M K 2019 Mediative sugeno’s-TSK fuzzy logic based screening analysis to diagnosis of heart disease Appl. Math. 10 448-67
[7] Dhiman N and Sharma M K 2019 Mediative Multi-Criteria decision support system for various alternatives based on fuzzy logic (IJRTE 8 7940-46
[8] Kalpana M and Kumar S A V 2011 Fuzzy expert system for diabetes using fuzzy verdict mechanism IJANA 3 1128-34
[9] Jain V and Raheja S 2015 Improving the prediction rate of diabetes using fuzzy expert system, IJITCS 10 84-91
[10] Asadia S H and Nekoukar V 2018 Adaptive fuzzy integral sliding mode control of blood glucose level in patients with type 1 diabetes; in silico studies Math. Biosci.
[11] Siva S G and Manikandan K 2019 Diagnosis of diabetes diseases using optimized fuzzy rule set by Grey Wolf optimization, Pattern Recognit. Lett. 125 432–38.
[12] Castillo O and Melin P 2003 A new method for fuzzy inference in intuitionistic fuzzy systems 22nd International Conference of NAFIPS.
[13] Montiel O, Castillo O, Melin P and Sepulveda M 2009 Mediative fuzzy logic for controlling population size in evolutionary algorithms Intell. Inf. Manag. 1 108-19
[14] Mahapatra G S and Roy T K 2013 Intuitionistic fuzzy number and its arithmetic operation with application on system failure J. Uncertain Syst. 7 92-107.
[15] Demouy J, Chamberlain J, Harris M and Marchand L H 1995 The Pima Indians: pathfinders of health. bethesda, MD: NIDDK.