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Mediative Sugeno's-TSK Fuzzy Logic Based Screening Analysis to Diagnosis of Heart Disease

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Abstract

Fuzzy logic is an approach which deals with the incomplete information to handle the imperfect knowledge. In the present research paper we have proposed a new approach that can handle the imperfect knowledge, in a broader way that we will consider the unfavourable case also as the intuitionistic fuzzy logic does. The mediative fuzzy logic is an extensive approach of intuitionistic fuzzy logic, which provides a solution, when there is a contradiction in the expert knowledge for favourable as well as unfavourable cases. The purpose of the present paper is to design a mediative fuzzy inference system based Sugeno-TSK model for the diagnosis of heart disease. Our proposed method is the extension of Sugeno-TSK fuzzy logic controller in the form of Sugeno-TSK mediative fuzzy logic controller.

Keywords

Fuzzy Logic, Intuitionistic Fuzzy Logic, Mediative Fuzzy Logic, Sugeno's Fuzzy Controller, Fuzzy Rule, Firing Level, Heart Disease

1. Introduction

Uncertainty affects all the decision of experts and appears in different forms. Uncertainty is an objective fact or just a subjective impression which is closely related to individual person. The choice of an appropriate uncertainty calculus may depend on the cause of uncertainty, quantity and quality of information available, type of information processing required by the respective uncertainty calculus and the language required by the final observer. The concept of information is fully connected with concept of uncertainty. The most fundamental aspect of this connection is that uncertainty involved in any problem-solving

situation is a result of some information deficiency, which may be incomplete, imprecise, fragmentary, vague, contradictory and not reliable information. Fuzzy approximate reasoning [1] [2] allows handling such type of uncertainty. Fuzzy logic proposed by L. A. Zadeh in 1965 [3] [4] covers the uncertainty with the help of membership function only. Fuzzy logic provides a mathematical theory to handle the uncertainty associated with the human decision with the help of its membership function. In 1986 the concept of intuitionistic fuzzy sets was proposed by K. Atanassov [5] [6], which deals with membership function, non-membership function and hesitation part which has the property to incorporate the uncertainty of the information. Intuitionistic fuzzy sets are the generalization of fuzzy sets. IFSs proffer a new criterion to represent impartial knowledge and therefore, to present in a more adequate manner for may real world problems. In 2014 Hajek [7] gave the methods for the defuzzification in the inference system for the Takagi-Sugeno type so that we can observe the crisp values for the outputs.

Many real life applications have given the evidence that intuitionistic fuzzy sets are better than the traditional fuzzy logic. In this list we may also mention some more aspects [8] [9] that may give better results than traditional fuzzy logic *i.e.* type-I, type-II, interval valued fuzzy sets and vague sets, interval valued vague sets etc. but the intuitionistic fuzzy sets cover the uncertainty caused by membership, non-membership and the hesitation part. Castillo etc. [10] in 2003 gave a new method for the inference for the fuzzy inference based on intuitionistic fuzzy logic that is in this work he explained the importance of favorable and unfavorable cases. Again in 2007 [11] used this concept for plant monitoring system and gave a scheme for the diagnosis of the defects. In 2007 Melin [12] used the mediative fuzzy logic for the contradictory knowledge management and explained how the logic is better than previous ones. Montiel etc. [13] in 2008 gave the concept of mediative fuzzy logic that is a new approach for handling the contradiction in the decision. So we can construct an intuitionistic fuzzy logic controller similar to the fuzzy logic controller given by Jang etc. [14] in neuro-fuzzy and soft computing. 1979 Sanchez [15] used the fuzzy logic and fuzzy relation for medical diagnosis in 2001 Supriya [16] used the extension of fuzzy sets in the form of intuitionistic fuzzy sets in medical diagnosis but What happens if the knowledge base rule changes with the perception of experts give a contradictory, non-contradictory and the incomplete information or the combination of these situations? Intuitionistic fuzzy sets are inadequate to explain these situations. To deal such situations, which inference system be used. Montiel [17] etc. in 2009 gave an algorithm which is able to deal with kind of information for controlling population size, which may be inconsistent, incomplete and contradiction exists. This is a mediate solution. Mediative fuzzy logic can bring down to the intuitionistic and fuzzy logic based on the affirmations and denials are established. In 2018 Iancu [18] used the mediative fuzzy logic in the heart disease using the Mamdani fuzzy inference rule for single input and single output. In our work we have extended this by using Sugeno's-TSK fuzzy infe-

rence system with two inputs and one output. By using this inference system we have developed an algorithm and on the basis of this algorithm we have constructed eight hundred and eighty five rules, from these rules here we have given the fifty rules and their crisp outputs and the firing level.

In this present research paper we have designed a meditative fuzzy inference system in Figure 1 for Sugeno's-TSK fuzzy controller for the diagnosis of heart disease. The present research paper is divided into six sections. In the second section we have taken some basic definitions on mediative fuzzy logic, contradiction fuzzy sets and intuitionstic fuzzy numbers. In section third of the research paper we have developed an algorithm which is based on Sugeno's-TSK controller using mediative fuzzy logic. The algorithm contains all the steps which we have proposed for our method including the block diagram. In section four of the research paper we have categorized the outputs and make the membership and non-membership for the stages of the risk about the sickness. In section five we have computed the values of the outputs using the defuzzification methods and the firing level of the observed during that output. In the last section conclusion of the research paper is given.

2. Basic Definitions

2.1. Meditative Fuzzy Logic

Intuitionistic Fuzzy Sets: let X be an universal set then IFSs (instuitionistic fuzzy sets) A^I in X is defined as

$$A^I = \left\langle \left(x, \mu_{A^I}(x), \upsilon_{A^I}(x) : x \in X \right) \right\rangle \tag{1}$$

where

$$\mu_{A^I}(x) : X \rightarrow [0,1] \text{ and } \upsilon_{A^I}(x) : X \rightarrow [0,1], \text{ with, } 0 \le \mu_{A^I}(x) + \upsilon_{A^I}(x) \le 1 \tag{2}$$

are called membership and non membership functions respectively. And for all IFSs A^I in X,

$$\pi_{A^I}(x) = 1 - \mu_{A^I}(x) - \upsilon_{A^I}(x) \tag{3}$$

where,

$$0 \le \pi_{A^I}(x) \le 1 \tag{4}$$

hesitation part of x in A^I is called intuitionistic fuzzy index or we can say the hesitation part.

Total IFS output of an intuitionistic fuzzy system, calculated by the linear relation between FS_μ and FS_υ, which are traditional output of system with using membership and non membership values respectively, as

$$IFS = (1 - \pi) FS_\mu + \pi FS_\upsilon \tag{5}$$

We may observe if $\pi = 0$ then it will reduce as the output of a traditional fuzzy system, but for other values of π different from zero we will get the different outputs for the intuitionistic fuzzy systems. The advantage of this method for finding the IFS output of an intuitionistic system, is that we can use methodolo-

gy based on membership functions representing the fuzzy systems for computing FS_μ and FS_υ.
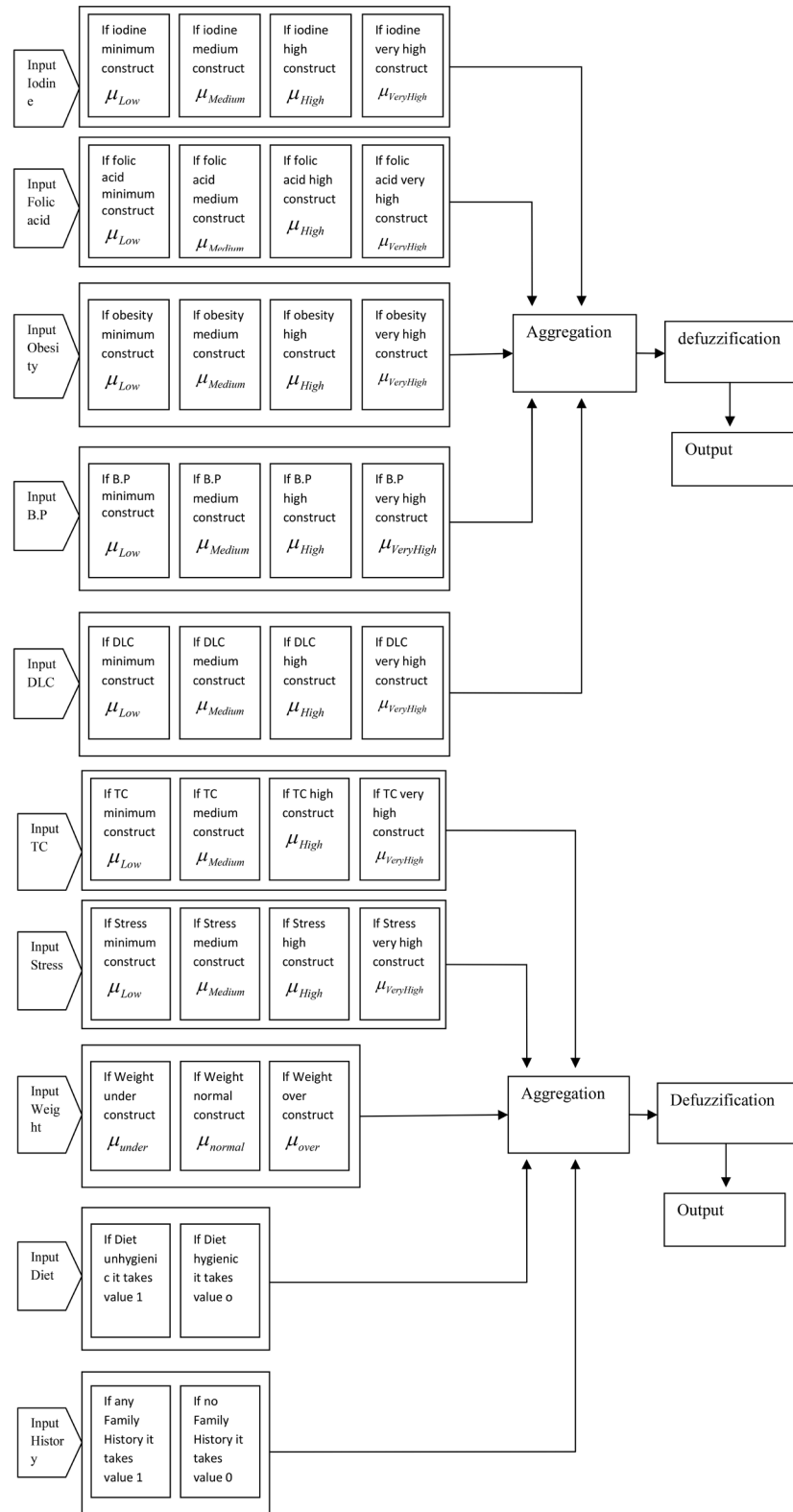

Figure 1. Computing framework of fuzzy inference system.

2.2. Contradiction Fuzzy Set

A contradiction fuzzy set C in X is given by

$$\zeta_c(x) = \min(\mu_c(x), \upsilon_c(x)), \tag{6}$$

where $\mu_c(x)$ represents the agreement membership function, and $\upsilon_c(x)$ non-agreement membership function. We will use the agreement and non-agreement membership functions in place of membership and non-membership functions in the analysis of our study, because we think these names are more appropriate for handling the uncertainty with the help of intuitionistic fuzzy sets. On the basis of these contradiction fuzzy sets, Montiel *et al.* [8], proposed the following three expressions

$$MFS = \left(1 - \pi - \frac{\zeta}{2}\right) FS_\mu + \left(\pi + \frac{\zeta}{2}\right) FS_\upsilon \tag{7}$$

$$MFS = \min\left((1-\pi) FS_\mu + \pi FS_\upsilon, 1 - \frac{\zeta}{2}\right) \tag{8}$$

$$MFS = \left((1-\pi) FS_\mu + \pi FS_\upsilon\right)\left(1 - \frac{\zeta}{2}\right) \tag{9}$$

2.3. Intuitionistic Fuzzy Number

Let an intuitionistic fuzzy set A^I in X defines as
$A^I = \left\langle\left(x, \mu_{A^I}(x), \upsilon_{A^I}(x) : x \in X\right)\right\rangle$ Then A^I is called intuitionistic fuzzy number if:

1) A^I is normal.

2) A^I is convex

3) Membership and non membership functions are path wise continuous.

a) Triangular instuitionistic fuzzy number in R, is defined with their membership and non membership grade as

$$\mu_{A^I}(x) = \begin{cases} \dfrac{x-a}{b-a} & \text{if } a \leq x < b \\ \dfrac{c-x}{c-b} & \text{if } b \leq x \leq c \\ 0 & \text{if } x > c \text{ and } x < a \end{cases} \quad \text{and} \quad \upsilon_{A^I}(x) = \begin{cases} \dfrac{b-x}{b-a^*} & \text{if } a^* \leq x < b \\ \dfrac{c^*-x}{c^*-b} & \text{if } b \leq x \leq c^* \\ 1 & \text{if } x < a^* \text{ and } x > c^* \end{cases}$$

where $a^* < a < b < c < c^*$ on real line.

b) Trapezoidal intuitionistic fuzzy number in R, is defined with their membership and non membership grade as

$$\mu_{A^I}(x) = \begin{cases} \dfrac{x-a}{b-a} & \text{if } a \leq x < b \\ 1 & \text{if } b \leq x \leq c \\ \dfrac{d-x}{d-c} & \text{if } c < x \leq d \\ 0 & \text{if } x > d \text{ and } x < a \end{cases} \quad \text{and} \quad \upsilon_{A^I}(x) = \begin{cases} \dfrac{b-x}{b-a^*} & \text{if } a^* \leq x < b \\ 1 & \text{if } b \leq x \leq c \\ \dfrac{d^*-x}{d^*-c} & \text{if } c < x \leq d^* \\ 0 & \text{if } x > d^* \text{ and } x < a \end{cases}$$

where $a^* < a < b < c < d < d^*$ on real line.

2.4. Fuzzy Implication

Czogala and Leski [19] analyzing a set of eight implications (Kleene-Dienes, Reichenbach, Lukasiewicz, Godel, Rescher-Gaines, Goguen, Zadeh, Fodor) concluded that the Lukasiewicz implication,

$$I_L(x, y) = \min(1, 1 - x + y) \tag{10}$$

2.5. Firing Level

Processing of the fuzzification means that we have to assign a membership as well as non-membership grade to each input value to make it intuitionistic fuzzy set. Let $x_\circ \in U$ is fuzzified into $\overline{x_\circ}$ according to the relations:

$$\mu_{\overline{x_\circ}}(x) = \begin{cases} 1 & \text{if } x = x_\circ \\ 0 & \text{else} \end{cases}, \quad \upsilon_{\overline{x_\circ}}(x) = \begin{cases} 0 & \text{if } x = x_\circ \\ 1 & \text{else} \end{cases}$$

The μ-firing level and ν-firing level of an intuitionistic fuzzy set A^I with $x_\circ$ as crisp input are $\mu_{A^I}(x_\circ)$ and $\upsilon_{A^I}(x_\circ)$ respectively.

3. Proposed Algorithm for Planned Sugeno's—TSK Meditative System

In disease diagnosis, we often find illogical information that comes from different inference system that does not concede. In case when the classical logic, fuzzy logic or intuitionistic fuzzy logic do not work, then we need to apply meditative fuzzy logic. That will give the better results considering the favorable, unfavorable and the situation where neither the membership nor non-membership help for getting the better results but also the agreement and non-agreement membership function. In this present research paper we will develop a methodology using Sugeno's fuzzy inference system based on meditative fuzzy logic. We will develop Sugeno's-TSK meditative fuzzy logic controller and make fuzzy rule base with using two parameters as input variables which variations may cause heart disease in the form of one output value for the diagnosis of heart disease. We have proposed the algorithm as follows:

Step 1: Suppose we have a fuzzy inference rule for conditional and unqualified proposition as hypothetical syllogism which is the generalization of inference for hypothetical syllogism for classical logic. In the present research paper we will use the inference rule for fuzzy logic for conditional fuzzy proposition in the extended form of intuitionistic fuzzy logic. That is for conditional and unqualified proposition the inference rule R is: if X_1 is A_1 and X_2 is A_2 then Y is B. Because we are working with a rule with two inputs, so for the intuitionistic fuzzy set, in case of A_1 using μ—firing level I_{μ_1} for the membership will be denoted by α_1 and ν—firing level l_{υ_1} for the non-membership for A_2 will be denoted by β_1 and μ—firing level for I_{μ_2} and ν—firing level I_{ν_2} corresponds to rule R will be denoted by α_2 and β_2 respectively. Firing level for membership and non-membership will be given by setting Here we have two input values, we give some input to both the input variable, and we get the value of firing level corresponds to membership and non membership function.

Namely α_1 and β_1 for first input and α_2 and β_2 for second input respectively. This rule is represented by lukasiewicz implication and conclusion is inferred using Sugeno's TSK Fuzzy Model.

Step 2: Using Sugeno's fuzzy inference model with two input variables and one output variable *i.e.* an inference for conditional and qualified proposition we will get the firing level for the two antecedents that will result in one consequence for the membership and non-membership. Find $I_\mu = \min\left(I_{\mu_1}, I_{\mu_2}\right)$ for membership for the functions and the non-membership $l_\upsilon = \min\left(l_{\upsilon_1}, l_{\upsilon_2}\right)$ for the factors causing the stages of the disease, by setting $\alpha = \min(\alpha_1, \alpha_2)$ and $\beta = \min(\beta_1, \beta_2)$.

Step 3: After the step second we need to calculate the values for the intuitionistic fuzzy index in the form of hesitation part and contradiction that is in the form of agreement and disagreement by taking ζ = minimum of α and β, and $\pi = 1 - (\alpha + \beta)$. The values of α and β will be taken from step 2.

Step 4: For the final Membership Fuzzy System output, the values obtained in step 3 in the form of the conclusions B^μ and B^ν as follows:

$$\mu_{B^\mu}(y) = I_L\left(\alpha, \mu_B(y)\right), \quad \forall y \in Y$$
$$= \min\left(1 - \alpha + \mu_B(y), 1\right)$$
$$y^\mu = defuzz\left(B^\mu\right)$$

(11)

$$\mu_{B^\nu}(y) = I_L\left(\beta, \mu_B(y)\right), \quad \forall y \in Y$$
$$= \min\left(1 - \beta + \mu_B(y), 1\right)$$
$$y^\mu = defuzz\left(B^\nu\right)$$

(12)

Will be defuzzified into the values for membership fuzzy output and non-membership fuzzy output as y^μ and y^υ, respectively by using the defuzzification method of Middle of Maxima and Middle of Minima techniques.

Step 5: Finally for getting the output after the final step from Sugeno's-TSK fuzzy inference system, we will get membership fuzzy system output by the formula

$$Z = \left[1 - (1 - (\alpha + \beta)) + \frac{1}{2}\min(\alpha, \beta)\right]y^\mu + \left[(1 - (\alpha + \beta)) + \frac{1}{2}\min(\alpha, \beta)\right]y^\nu \quad (13)$$

3.1. Factors Effects Heart Disease: (Input Variables)

There are so many factors which affect heart disease but here we have considered the following ten most affecting factors in our study (Table 1).

3.2. Fuzzification of the Factors

First we will fuzzify the above factors according to the given range of the data in the form of membership and non-membership functions as follows:

3.2.1. Iodine
The recommended daily allowance for iodine [150 mcg/day] for adult, this input

is divided into four category low, medium, high and very high. Defined by intuitionistic fuzzy sets, by their μ membership values and υ non membership values, as given below:

$$\mu_{low}(x) = \begin{cases} 1 & \text{if } x \le 110 \\ \dfrac{135-x}{25} & \text{if } 110 < x \le 135 \end{cases},$$

$$\mu_{medium}(x) = \begin{cases} \dfrac{x-125}{10} & \text{if } 125 \le x \le 135 \\ 1 & \text{if } x = 135 \\ \dfrac{170-x}{35} & \text{if } 135 \le x \le 170 \end{cases}$$

$$\mu_{high}(x) = \begin{cases} \dfrac{x-165}{30} & \text{if } 165 \le x \le 195 \\ 1 & \text{if } x = 195 \\ \dfrac{220-x}{25} & \text{if } 195 \le x \le 220 \end{cases},$$

$$\mu_{very\ high}(x) = \begin{cases} \dfrac{x-210}{30} & \text{if } 210 \le x \le 240 \\ 1 & \text{if } x > 240 \end{cases}$$

Non membership values

$$\upsilon_{low}(x) = \begin{cases} \dfrac{x-125}{20} & \text{if } 125 \le x \le 145 \\ 1 & \text{if } x > 145 \end{cases},$$

$$\upsilon_{medium}(x) = \begin{cases} 1 & \text{if } x < 116 \\ \dfrac{135-x}{19} & \text{if } 116 \le x \le 135 \\ 0 & \text{if } x = 135 \\ \dfrac{x-139}{45} & \text{if } 135 \le x \le 180 \\ 1 & \text{if } x > 180 \end{cases}$$

Table 1. Input factors which effects heart disease.

	1) Iodine
	2) Folic acid
	3) Obesity
	4) B.P (Blood Pressure)
Input	5) DLC (Density Lipoprotein Cholesterol)
Factors	6) TC (Total cholesterol)
	7) Stress
	8) Weight
	9) Diet
	10) Family history
Rules	Two input-one output

$$\upsilon_{\text{high}}(x) = \begin{cases} 1 & \text{if } x \leq 145 \\ \dfrac{195-x}{50} & \text{if } 145 \leq x \leq 195 \\ 0 & \text{if } x = 195 \\ \dfrac{x-195}{25} & \text{if } 195 \leq x \leq 220 \\ 1 & \text{if } x > 220 \end{cases},$$

$$\upsilon_{\text{very high}}(x) = \begin{cases} 1 & \text{if } x < 195 \\ \dfrac{225-x}{30} & \text{if } 195 \leq x \leq 225 \end{cases}$$

3.2.2. Folic Acid

Folic acid normal blood reference is around [2 - 20 mg/ml], this input is also divided into four category low, medium, high and very high. Defined by intuitionistic fuzzy sets, by their μ membership values and υ non membership values, are given below:

$$\mu_{\text{low}}(x) = \begin{cases} 1 & \text{if } x \leq 6 \\ \dfrac{10-x}{4} & \text{if } 6 \leq x \leq 10 \end{cases}, \quad \mu_{\text{medium}}(x) = \begin{cases} \dfrac{x-8}{4} & \text{if } 8 \leq x \leq 12 \\ 1 & \text{if } x = 12 \\ \dfrac{15-x}{3} & \text{if } 12 \leq x \leq 15 \end{cases}$$

$$\mu_{\text{high}}(x) = \begin{cases} \dfrac{x-14}{6} & \text{if } 14 \leq x \leq 20 \\ 1 & \text{if } x = 20 \\ \dfrac{25-x}{5} & \text{if } 20 \leq x \leq 25 \end{cases}, \quad \mu_{\text{very high}}(x) = \begin{cases} \dfrac{x-18}{12} & \text{if } 18 \leq x \leq 30 \\ 1 & \text{if } x > 30 \end{cases}$$

Non membership values

$$\upsilon_{\text{low}}(x) = \begin{cases} \dfrac{x-8}{4} & \text{if } 8 \leq x \leq 12 \\ 1 & \text{if } x > 12 \end{cases}, \quad \upsilon_{\text{medium}}(x) = \begin{cases} 1 & \text{if } x < 7 \\ \dfrac{12-x}{5} & \text{if } 7 \leq x \leq 12 \\ 0 & \text{if } x = 12 \\ \dfrac{x-12}{6} & \text{if } 12 < x \leq 18 \\ 1 & \text{if } x > 18 \end{cases}$$

$$\upsilon_{\text{high}}(x) = \begin{cases} 1 & \text{if } x < 12 \\ \dfrac{20-x}{8} & \text{if } 12 \leq x \leq 20 \\ 0 & \text{if } x = 20 \\ \dfrac{x-20}{8} & \text{if } 20 \leq x \leq 28 \\ 1 & \text{if } x > 28 \end{cases}, \quad \upsilon_{\text{very high}}(x) = \begin{cases} 1 & \text{if } x < 26 \\ \dfrac{32-x}{6} & \text{if } 26 \leq x \leq 32 \end{cases}$$

3.2.3. Obesity

Normal range of obesity for heart disease is around [18.5 - 24.9 kg/m^2], obesity

input variable has 4 values low, medium, high and very high as intitutionistic fuzzy set by their membership and non membership values, are given below as:

$$\mu_{\text{low}}(x) = \begin{cases} 1 & \text{if } x < 11 \\ \dfrac{16-x}{5} & \text{if } 11 \le x \le 16 \end{cases},$$

$$\mu_{\text{medium}}(x) = \begin{cases} \dfrac{x-14.5}{5} & \text{if } 14.5 \le x \le 19.5 \\ 1 & \text{if } x = 19.5 \\ \dfrac{22.5-x}{3} & \text{if } 19.5 \le x \le 22.5 \end{cases}$$

$$\mu_{\text{high}}(x) = \begin{cases} \dfrac{x-21}{2.5} & \text{if } 21 \le x \le 23.5 \\ 1 & \text{if } x = 23.5 \\ \dfrac{26.5-x}{3} & \text{if } 23.5 \le x \le 26.5 \end{cases},$$

$$\mu_{\text{very high}}(x) = \begin{cases} \dfrac{x-24.5}{4.1} & \text{if } 24.5 \le x \le 28.6 \\ 1 & \text{if } x > 28.6 \end{cases}$$

Non membership values

$$\upsilon_{\text{low}}(x) = \begin{cases} \dfrac{x-12.5}{6.3} & \text{if } 12.5 \le x \le 18.8 \\ 1 & \text{if } x > 18.8 \end{cases},$$

$$\upsilon_{\text{medium}}(x) = \begin{cases} 1 & \text{if } x < 13.5 \\ \dfrac{19.5-x}{6} & \text{if } 13.5 \le x \le 19.5 \\ 0 & \text{if } x = 19.5 \\ \dfrac{x-19.5}{5.12} & \text{if } 19.5 \le x \le 24.6 \\ 1 & \text{if } x > 24.6 \end{cases}$$

$$\upsilon_{\text{high}}(x) = \begin{cases} 1 & \text{if } x < 19 \\ \dfrac{23.5-x}{4.5} & \text{if } 19 < x < 23.5 \\ 0 & \text{if } x = 23.5 \\ \dfrac{x-23.5}{4.2} & \text{if } 23.5 < x \le 27.6 \\ 1 & \text{if } x > 27.6 \end{cases},$$

$$\upsilon_{\text{very high}}(x) = \begin{cases} 1 & \text{if } x < 26.5 \\ \dfrac{30.2-x}{3.7} & \text{if } 26.5 \le x \le 30.2 \end{cases}$$

3.2.4. Blood Pressure

The range of blood pressure for heart disease for adult is [80 - 120]; this input has four linguistic values and their membership and non membership values are given below:

$$\mu_{\text{low}}(x) = \begin{cases} 1 & \text{if } x < 110 \\ \dfrac{130 - x}{20} & \text{if } 110 \le x \le 130 \end{cases},$$

$$\mu_{\text{medium}}(x) = \begin{cases} \dfrac{x - 122}{13} & \text{if } 122 \le x \le 135 \\ 1 & \text{if } x = 135 \\ \dfrac{151 - x}{16} & \text{if } 135 \le x \le 151 \end{cases}$$

$$\mu_{\text{high}}(x) = \begin{cases} \dfrac{x - 138}{8} & \text{if } 138 \le x \le 145 \\ 1 & \text{if } x = 148 \\ \dfrac{176 - x}{30} & \text{if } 146 \le x \le 176 \end{cases},$$

$$\mu_{\text{very high}}(x) = \begin{cases} \dfrac{x - 144}{30} & \text{if } 144 \le x \le 174 \\ 1 & \text{if } x > 174 \end{cases}$$

Non membership values

$$\upsilon_{\text{low}}(x) = \begin{cases} \dfrac{x - 122}{20} & \text{if } 112 \le x \le 132 \\ 1 & \text{if } x > 132 \end{cases},$$

$$\upsilon_{\text{medium}}(x) = \begin{cases} 1 & \text{if } x < 195 \\ \dfrac{135 - x}{15.5} & \text{if } 195 \le x \le 135 \\ 0 & \text{if } x = 135 \\ \dfrac{x - 135}{21} & \text{if } 135 \le x \le 156 \\ 1 & \text{if } x > 156 \end{cases}$$

$$\upsilon_{\text{high}}(x) = \begin{cases} 1 & \text{if } x < 132 \\ \dfrac{148 - x}{16} & \text{if } 132 \le x \le 148 \\ 0 & \text{if } x = 148 \\ \dfrac{x - 148}{30} & \text{if } 148 \le x \le 178 \\ 1 & \text{if } x > 178 \end{cases},$$

$$\upsilon_{\text{very high}}(x) = \begin{cases} 1 & \text{if } x < 164.5 \\ \dfrac{182.6 - x}{16.1} & \text{if } 164.5 \le x \le 182.6 \end{cases}$$

3.2.5. 1) Cholesterol (Density Lipoprotein Cholesterol)

The quantity of density lipoprotein cholesterol for adult for good heart is around [180 - 250 mg/deciliter]. The DLC input factor also categories into four parts

$$\mu_{\text{low}}(x) = \begin{cases} 1 & \text{if } x < 149 \\ \dfrac{192 - x}{43} & \text{if } 149 \le x \le 192 \end{cases},$$

$$\mu_{\text{medium}}(x) = \begin{cases} \dfrac{x-180}{30} & \text{if } 180 \le x \le 210 \\ 1 & \text{if } x = 210 \\ \dfrac{245-x}{35} & \text{if } 210 \le x \le 245 \end{cases}$$

$$\mu_{\text{high}}(x) = \begin{cases} \dfrac{x-222}{38} & \text{if } 222 \le x \le 260 \\ 1 & \text{if } x = 260 \\ \dfrac{302-x}{42} & \text{if } 260 \le x \le 302 \end{cases},$$

$$\mu_{\text{very high}}(x) = \begin{cases} \dfrac{x-275}{65} & \text{if } 275 \le x \le 340 \\ 1 & \text{if } x > 340 \end{cases}$$

Non membership values

$$\upsilon_{\text{low}}(x) = \begin{cases} \dfrac{x-170}{35} & \text{if } 170 \le x \le 205 \\ 1 & \text{if } x < 205 \end{cases},$$

$$\upsilon_{\text{medium}}(x) = \begin{cases} 1 & \text{if } x < 168 \\ \dfrac{210-x}{42} & \text{if } 168 \le x \le 210 \\ 0 & \text{if } x = 210 \\ \dfrac{x-210}{64} & \text{if } 210 < x \le 274 \\ 1 & \text{if } x > 274 \end{cases}$$

$$\upsilon_{\text{high}}(x) = \begin{cases} 1 & \text{if } x < 196 \\ \dfrac{260-x}{64} & \text{if } 196 \le x \le 260 \\ 0 & \text{if } x = 260 \\ \dfrac{x-260}{55} & \text{if } 260 < x \le 315 \\ 1 & \text{if } x > 315 \end{cases},$$

$$\upsilon_{\text{very high}}(x) = \begin{cases} 1 & \text{if } x < 268 \\ \dfrac{317-x}{49} & \text{if } 268 \le x \le 317 \end{cases}$$

3.2.5. 2) Cholesterol (Total)

It has normal range for adult is [200 - 239 mg/deciliter]. The Total cholesterol also divided into four linguistic values with membership and non membership functions are shown below:

$$\mu_{\text{low}}(x) = \begin{cases} 1 & \text{if } x < 160 \\ \dfrac{180-x}{20} & \text{if } 160 \le x \le 180 \end{cases}, \quad \mu_{\text{medium}}(x) = \begin{cases} \dfrac{x-170}{25} & \text{if } 170 \le x \le 195 \\ 1 & \text{if } x = 195 \\ \dfrac{220-x}{25} & \text{if } 195 \le x \le 220 \end{cases}$$

$$\mu_{\text{very high}}(x) = \begin{cases} \dfrac{x-245}{20} & \text{if } 245 \le x \le 265 \\ 1 & \text{if } x > 265 \end{cases},$$

$$\mu_{\text{high}}(x) = \begin{cases} \dfrac{x-215}{21} & \text{if } 215 \le x \le 236 \\ 1 & \text{if } x = 236 \\ \dfrac{250-x}{14} & \text{if } 236 \le x \le 250 \end{cases}$$

Non membership values

$$\upsilon_{\text{low}}(x) = \begin{cases} \dfrac{x-172}{20} & \text{if } 172 \le x \le 192 \\ 1 & \text{if } x > 192 \end{cases},$$

$$\upsilon_{\text{medium}}(x) = \begin{cases} 1 & \text{if } x < 168 \\ \dfrac{195-x}{27} & \text{if } 168 \le x \le 195 \\ 0 & \text{if } x = 195 \\ \dfrac{x-195}{35} & \text{if } 195 \le x \le 230 \\ 1 & \text{if } x > 230 \end{cases}$$

$$\upsilon_{\text{high}}(x) = \begin{cases} 1 & \text{if } x < 206 \\ \dfrac{236-x}{30} & \text{if } 206 \le x \le 236 \\ 0 & \text{if } x = 236 \\ \dfrac{x-236}{25} & \text{if } 236 \le x \le 261 \\ 1 & \text{if } x > 261 \end{cases},$$

$$\upsilon_{\text{very high}}(x) = \begin{cases} 1 & \text{if } x < 240 \\ \dfrac{260-x}{20} & \text{if } 240 \le x \le 260 \end{cases}$$

3.2.6. Stress

This parameter may be categorized into four categories. The four categories will be divided into low, medium, high and very high respectively with their membership and non membership values denoted as:

$$\mu_{\text{low}}(x) = \begin{cases} 1 & \text{if } x < 10 \\ \dfrac{14-x}{4} & \text{if } 10 \le x \le 14 \end{cases}, \quad \mu_{\text{medium}}(x) = \begin{cases} \dfrac{x-12}{2} & \text{if } 12 \le x \le 14 \\ \dfrac{18-x}{4} & \text{if } 14 \le x \le 18 \end{cases}$$

$$\mu_{\text{high}}(x) = \begin{cases} \dfrac{x-16}{2} & \text{if } 16 \le x \le 18 \\ \dfrac{22-x}{4} & \text{if } 18 \le x \le 22 \end{cases}, \quad \mu_{\text{very high}}(x) = \begin{cases} \dfrac{24-x}{4} & \text{if } 20 \le x \le 24 \\ 1 & \text{if } x > 24 \end{cases}$$

Non membership values

$$\upsilon_{\text{low}}(x) = \begin{cases} \dfrac{11-x}{5} & \text{if } 11 \le x \le 16 \\ 1 & \text{if } x > 16 \end{cases},$$

$$\upsilon_{\text{medium}}(x) = \begin{cases} 1 & \text{if } x < 11 \\ \dfrac{14-x}{3} & \text{if } 11 \le x \le 14 \\ \dfrac{x-14}{5} & \text{if } 14 \le x \le 19 \\ 1 \end{cases}$$

$$\upsilon_{\text{high}}(x) = \begin{cases} 1 & \text{if } x < 14 \\ \dfrac{18-x}{4} & \text{if } 14 \le x \le 18 \\ \dfrac{x-18}{6} & \text{if } 18 \le x \le 24 \\ 1 & \text{if } x > 24 \end{cases},$$

$$\upsilon_{\text{very high}}(x) = \begin{cases} 1 & \text{if } x < 18 \\ \dfrac{22-x}{4} & \text{if } 18 \le x \le 22 \end{cases}$$

3.2.7. Weight

This parameter may be categorized into three categories. The three categories are under weight, normal weight and overweight with membership and non membership values shown below as:

$$\mu_{\text{under}}(x) = \begin{cases} 1 & \text{if } x < 40 \\ \dfrac{60-x}{20} & \text{if } 40 \le x \le 60 \end{cases},$$

$$\mu_{\text{normal}}(x) = \begin{cases} \dfrac{x-55}{10} & \text{if } 55 \le x \le 65 \\ \dfrac{80-x}{15} & \text{if } 65 \le x \le 80 \end{cases}, \quad \mu_{\text{over}}(x) = \begin{cases} \dfrac{x-75}{15} & \text{if } 75 \le x \le 90 \\ 1 & \text{if } x > 90 \end{cases}$$

Non membership

$$\upsilon_{\text{under}}(x) = \begin{cases} \dfrac{x-50}{15} & \text{if } 50 \le x \le 65 \\ 1 & \text{if } x > 65 \end{cases},$$

$$\upsilon_{\text{normal}}(x) = \begin{cases} 1 & \text{if } x < 40 \\ \dfrac{60-x}{25} & \text{if } 40 \le x \le 60 \\ \dfrac{x-60}{25} & \text{if } 60 \le x \le 85 \end{cases},$$

$$\upsilon_{\text{over}}(x) = \begin{cases} 1 & \text{if } x < 70 \\ \dfrac{95-x}{25} & \text{if } 70 \le x \le 95 \\ 0 & \text{if } x > 95 \end{cases}$$

3.2.8. Diet

This parameter may be categorized into two 2 linguistic values hygienic and un-hygienic.

3.2.9. Family History

This parameter may be classified into two categories *i.e.* yes and No. If the patient this input also categories into two linguistic values yes (if patient have heart disease or stroke in his/her family) and no (if patient have no family history for heart disease).

3.2.10. Smoking

This parameter will be classified into two linguistic variable value smoker and non smoker.

3.3. Fuzzy Rule Base

From the inference developed by us for sugeno's-TSK fuzzy controller by using the factors which we have used in our research paper, the total eight hundred eighty five rules will be formed. From the following eight hundred eighty five rules, we have taken fifty rules. The criterion for choosing fuzzy rules for our work is that the critical changes in the heart disease have been taken and the others not affecting more have been omitted.

R_1: IF Iodine is low and folic acid is medium THEN result is stage 2

R_2: IF iodine is medium and obesity is low THEN result is stage 2

R_3: IF iodine is medium and obesity is medium THEN result is stage 1

R_4: IF iodine is high and B.P is medium THEN result is stage 3

R_5: IF iodine is medium and cholesterol (total) is very high THEN result is stage 4

R_6: IF folic acid is low and obesity is high THEN result is stage 3

R_7: IF folic acid is medium and obesity is low THEN result is stage 2

R_8: IF folic acid is medium and B.P is medium THEN result is stage 1

R_9: IF folic acid is high and obesity is high THEN result is stage 3

R_{10}: IF folic acid is very high and obesity is low THEN result is stage 4

R_{11}: IF obesity is low and B.P is low THEN result is stage 2

R_{12}: IF obesity is medium and cholesterol (total) is medium THEN result is stage 1

R_{13}: IF obesity is high and diet is unhygienic THEN result is stage 3

R_{14}: IF obesity is very high and family history is yes/1 THEN result is stage 4

R_{15}: IF obesity is very high and cholesterol (dlc) is very high THEN result is stage 4

R_{16}: IF B.P is low and weight is under THEN result is stage 2

R_{17}: IF B.P is medium and diet is hygienic THEN result is stage 1

R_{18}: IF B.P is high and cholesterol (total) is high THEN result is stage 3

R_{19}: IF B.P is very high and folic acid is very high THEN result is stage 4

R_{20}: IF B.P is very high and iodine is high THEN result is stage 4

R_{21}: IF cholesterol (dlc) is low and stress is low THEN result is stage 2

R_{22}: IF cholesterol (dlc) is medium and iodine is medium THEN result is stage 1

R_{23}: IF cholesterol (dlc) is high and diet is unhygienic THEN result is stage 3

R_{24}: IF cholesterol (dlc) is high and weight is over THEN result is stage 3

R_{25}: IF cholesterol (dlc) is very high and family history is yes/1 THEN result is stage 4

R_{26}: IF cholesterol (total) is low and iodine is medium THEN result is stage 2

R_{27}: IF cholesterol (total) is medium and folic acid is medium THEN result is stage 1

R_{28}: IF cholesterol (total) is high and stress is high THEN result is stage 3

R_{29}: IF cholesterol (total) is very high and B.P is high THEN result is stage 4

R_{30}: IF cholesterol (total) is very high and diet is unhygienic THEN result is stage 4

R_{31}: IF stress is low and iodine is low THEN result is stage 2

R_{32}: IF stress is medium and folic acid is medium THEN result is stage 1

R_{33}: IF stress is high and iodine is low THEN result is stage 3

R_{34}: IF stress is high and weight is over THEN result is stage 3

R_{35}: IF stress is very high and diet is unhygienic THEN result is stage 4

R_{36}: IF diet is hygienic and B.P is medium THEN result is stage 1

R_{37}: IF diet is hygienic and weight is under THEN result is stage 2

R_{38}: IF diet is unhygienic and folic acid is high THEN result is stage 3

R_{39}: IF diet is unhygienic and cholesterol (dlc) is high THEN result is stage 3

R_{40}: IF diet is unhygienic and cholesterol (dlc) is very high THEN result is stage 4

R_{41}: IF weight is under and iodine is low THEN result is stage 2

R_{42}: IF weight is under and cholesterol (total) is normal THEN result is stage 2

R_{43}: IF weight is normal and B.P is medium THEN result is stage 1

R_{44}: IF weight is over and stress is high THEN result is stage 3

R_{45}: IF weight is over and folic acid is very high THEN result is stage 4

R_{46}: IF family history is yes/1 and cholesterol (dlc) is low THEN result is stage 2

R_{47}: IF family history is yes/1 and weight is under THEN result is stage 2

R_{48}: IF family history is yes/1 and folic acid is high THEN result is stage 3

R_{49}: IF family history is yes/1 and B.P is very high THEN result is stage 4

R_{50}: IF family history is yes/1 and obesity is very high THEN result is stage 4

3.4. Fuzzy Inference System

The fuzzy inference system [10] is a popular computing framework based on the concept of fuzzy logic, fuzzy rule base system and fuzzy reasoning. The basic structure of the inference system consists of three conceptual components; a database which defines the membership functions used in fuzzy rules, a rule base and a reasoning procedure. In the research paper we have constructed an Suge-

no's-TSK inference system based on the meditative fuzzy logic.

4. Fuzzy Output Variables

The last step of our proposed algorithm is to get the output in the fuzzy form. First we will obtain the aggregation of the factors and after getting aggregation of we will obtain the fuzzy form of our output. Then the output values obtained from the inference of the input in the form of fuzzy propositions can be classified into four categories. The four categories may be in the combination of qualified, unqualified, conditional and unconditional fuzzy propositions. In the four categories inference from input variables will be divided into four stages. The classification of the stages will be based on the stages to obtain the stages of risk to the patient which are namely classified as stage 1, stage 2, stage 3 and stage 4 and these will take values on the scaling from 1 to 5. Stage 1 patient considered as low risk for heart disease, Stage 2 denotes medium risk, stage 3 denote high risk and stage 4 denotes very high risk for heart disease to the patient. The functions for the output values are shown by using intuitionistic fuzzy numbers.

For membership values

$$\mu_{\text{stage1}}(x) = \begin{cases} 1 & \text{if } x < 1.35 \\ \dfrac{2-x}{0.65} & \text{if } 1.35 \le x \le 2 \end{cases}, \quad \mu_{\text{stage2}}(x) = \begin{cases} \dfrac{1.8-x}{0.8} & \text{if } 1.8 \le x \le 2.6 \\ 1 & \text{if } x = 2.6 \\ \dfrac{3.4-x}{0.8} & \text{if } 2.6 \le x \le 3.4 \end{cases}$$

$$\mu_{\text{stage3}}(x) = \begin{cases} \dfrac{3.2-x}{0.7} & \text{if } 3.2 \le x \le 3.9 \\ 1 & \text{if } x = 3.9 \\ \dfrac{4.6-x}{0.7} & \text{if } 3.9 \le x \le 4.6 \end{cases}, \quad \mu_{\text{stage4}}(x) = \begin{cases} \dfrac{x-4.3}{0.4} & \text{if } 4.3 \le x \le 4.7 \\ 1 & \text{if } x > 4.7 \end{cases}$$

Non membership functions

$$\upsilon_{\text{stage1}}(x) = \begin{cases} \dfrac{x-1.6}{0.8} & \text{if } 1.6 \le x \le 2.8 \\ 1 & \text{if } x > 2.8 \end{cases}, \quad \upsilon_{\text{stage2}}(x) = \begin{cases} 1 & \text{if } x < 1.6 \\ \dfrac{x-1.6}{1} & \text{if } 1.6 \le x \le 2.6 \\ 0 & \text{if } x = 2.6 \\ \dfrac{x-2.6}{0.8} & \text{if } 2.6 \le x \le 3.4 \\ 1 & \text{if } x > 3.4 \end{cases}$$

$$\upsilon_{\text{stage3}}(x) = \begin{cases} 1 & \text{if } x < 2.9 \\ \dfrac{3.9-x}{1.5} & \text{if } 2.9 \le x \le 3.9 \\ 0 & \text{if } x = 3.9 \\ \dfrac{x-3.9}{1} & \text{if } 3.9 \le x \le 4.9 \\ 1 & \text{if } x > 4.9 \end{cases}, \quad \upsilon_{\text{stage4}}(x) = \begin{cases} 1 & \text{if } x < 4.1 \\ \dfrac{4.8-x}{0.7} & \text{if } 4.1 \le x \le 4.8 \end{cases}$$

5. Numerical Results and Interpretations

Table 2. Results and interpretations.

Rules	Firing level	Output	Rules	Firing level	Output
R_1	1	2.6	R_{26}	0.443831	2.589
R_2	0.25	2.55	R_{27}	0.41	1.038
R_3	0.195	3.064	R_{28}	0.3284	3.89416
R_4	0.194	3.7073	R_{29}	0.4274	3.08616
R_5	0.2324	4.59	R_{30}	0.16	3.2324
R_6	1	3.9	R_{31}	1	2.6
R_7	0.3204	1.44524	R_{32}	0.4744	1.8
R_8	0.4159	1.8599575	R_{33}	0.25	3.9
R_9	0.2869	3.5255	R_{34}	0.3031	3.9
R_{10}	0.027884	0.7822	R_{35}	0.0625	2.7125
R_{11}	1	2.6	R_{36}	0.1659	2.838
R_{12}	0.41	1.689	R_{37}	0.2244	2.6
R_{13}	0.028	3.316	R_{38}	0.1256	3.9
R_{14}	0.1369	3.03938	R_{39}	0.0625	3.9
R_{15}	0.1476	4.235	R_{40}	0.005776	2.251
R_{16}	1	2.6	R_{41}	1	2.6
R_{17}	0.1659	2.118	R_{42}	0.16	2.6
R_{18}	0.2351	3.9	R_{43}	0.25	2.6
R_{19}	0.215389	2.54	R_{44}	0.3301	3.9
R_{20}	0.2782	2.97	R_{45}	0.128089	3.97
R_{21}	0.28	1.020625	R_{46}	0.0784	2.528
R_{22}	0.3094	0.615	R_{47}	1	2.6
R_{23}	0.676	3.9	R_{48}	0.1156	3.9
R_{24}	0.5284	3.9	R_{49}	0.2913	3.29568
R_{25}	0.5776	4.14152	R_{50}	0.1369	3.73162

6. Conclusion

Fuzzy logic provides a platform to handle the uncertainty associated with human cognizance. The cognizance may be due to reasoning or thinking of the human being. But when the information may be incomplete, vague, fragmentarily reliable that is not fully reliable, there exists contradictory remark about the information then we are not in the position to deal it with fuzzy logic. In the present research paper we will use the inference rule for fuzzy logic for conditional fuzzy proposition in the extended form of intuitionistic fuzzy logic for the input factors which have been shown in Table 1 (effects the heart diseases). That is for conditional and unqualified proposition the inference rule R is: if X_1 is A_1

and X_2 is A_2 then Y is B. In this present paper we have evaluated the firing level and output which have been shown in Table 2 with a rule which included two inputs, so for the meditative fuzzy logic. In the present research paper we have also shown the superiority of meditative fuzzy logic on the previous traditional and intuitional logics. In the present paper we have extended and improved the system by using Sugeno's-TSK model with the help of meditative fuzzy logic. On the basis of output we can categorize the risk stages. The output of the reasoning system corresponds to the category of sickness.

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Conflicts of Interest

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

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