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Research paper



A Fuzzy Rule based Expert System for T2DM Diagnosis

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Abstract

Expert system is an intelligent system to captures the knowledge of a human expert in a specific area. It is capable to make decisions and dealing with ambiguous data. It is used to take an expert view in the absence of a human expertise. Moreover, it is not possible that everyone is expert in every field; to overcome this kind of situation, the expert system is called to handle the complex cases [7]. Due to non availability of the doctor, sometimes patient's life is in risk and lead to death due to not diagnose the disease properly as there are several diseases whose symptoms are quite similar in initial stage. Hence, the objective of this paper is to design the expert system for diagnosing the diabetes to go for early treatment.

Keywords: *Linguistic term, Fuzzy number, Fuzzy Expert System, Diabetes.*

1. Introduction

One of the most significant applications of fuzzy logic is Fuzzy Expert System. Expert System is a branch of applied artificial intelligence, it is used to take an expert view in the absence of a human expertise. Due to the absence of expert in a particular field, FES will solve the real world complex problem. It was first introduced by Kandel [5]. It is an intelligent tool and capable of making decisions and dealing with ambiguous data [10]. FES are applied in many field, medical field is the most important among them. Recently, many researchers designed fuzzy expert system for diagnosing heart disease [1], prostate cancer disease [3]. Web-based fuzzy expert systems are constructed, to deal with human disease diagnosis to overcome various difficulties [2], to predict the risk of diabetic nephropathy [9].

Moreover, soft computing fraternities constructed fuzzy assessment methodology with MATLAB fuzzy logic tool box to diagnose and improve the accuracy of diabetes [4], expert system for all types of diabetes diagnosis based on rule-based [11], case-based and rule-based expert system for type 2 diabetes mellitus management [8]. [7] studied the conception of an efficient fuzzy expert system to minimize the uncertainty effects in different surveillance such as industrial diagnosis, medical diagnosis, video surveillance, economic domain, civil domain, software domain using MATLAB software. Fuzzy expert system and neuro-fuzzy system was derived for gestational diabetes mellitus diagnosis [6]. It is observed that each application has its own inputs and outputs. Thus, the developments of fuzzy expert system is specific for each treated problem. Hence, this paper constructs a new Fuzzy Expert System using Linguistic variable to diagnosis diabetes.

2. Preliminaries

Definition 2.1

A fuzzy set $\tilde{A}$ is a subset of a universe of discourse *X*, which is characterized by a membership function $\mu_{\tilde{A}}(x)$ representing a mapping $\mu_{\tilde{A}} : X \to [0,1]$. The function value of $\mu_{\tilde{A}}(x)$ is called the membership value, which represents the degree of truth that *x* is an element of fuzzy set $\tilde{A}$.

Definition 2.2

A fuzzy set $\tilde{A}$ defined on the set of real numbers R is said to be a fuzzy number and its membership function $\tilde{A}: R \to [0,1]$ has the following characteristics,

(i) $\tilde{A}$ is convex.
$\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq \min(\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)),\ \forall x \in [x_1, x_2], \lambda \in [0,1].$

(ii) $\tilde{A}$ is normal if $\max \mu_{\tilde{A}}(x) = 1$.

(iii) $\tilde{A}$ is piecewise continuous.

Definition 2.3

The α-cut of the fuzzy set $\tilde{A}$ of the universe of discourse *X* is defined as $\tilde{A}_\alpha = \{x \in X / \mu_{\tilde{A}}(x) \geq \alpha\}$, where $\alpha \in [0,1]$.

Definition 2.4

A triangular fuzzy number $\tilde{N}$ can be defined as a triplet (l, m, r) and the membership function $\mu_{\tilde{N}}(x)$ is defined as:

$$\mu_{\tilde{N}}(x) = \begin{cases} 0 & x < l \\ \left(\frac{x-l}{m-l}\right) & l \leq x \leq m \\ \left(\frac{r-x}{r-m}\right) & m \leq x \leq r \\ 0 & x > r \end{cases}$$

Where *l*, *m*, *r* are real numbers and $l \leq m \leq r$.

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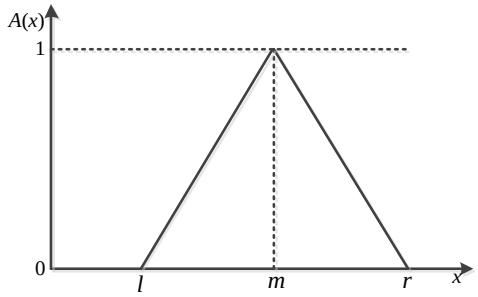


Fig.1: Triangular Fuzzy Number

Definition 2.5

A trapezoidal fuzzy number $\tilde{A}$ can be defined as (a_1, a_2, a_3, a_4) and the membership function is defined as

$$\mu_{\tilde{A}}(x) = \begin{cases} \left(\dfrac{x-a_1}{a_2-a_1}\right) & a_1 \le x \le a_2 \\ 1 & a_2 \le x \le a_3 \\ \left(\dfrac{a_4-x}{a_4-a_3}\right) & a_3 \le x \le a_4 \\ 0 & a_1 \le 0 \,\&\, a_4 \ge 0 \end{cases}$$

Where a_1, a_2, a_3, a_4 are real numbers $a_1 \le a_2 \le a_3 \le a_4$.

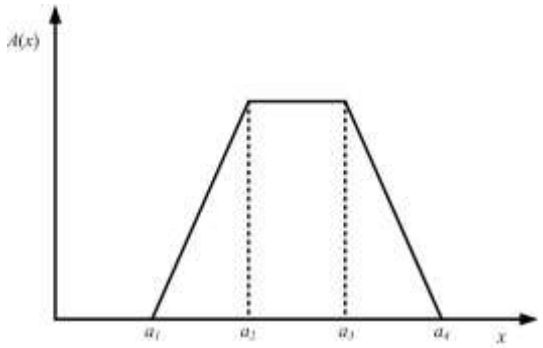


Fig. 2: Trapezoidal Fuzzy Number

Definition 2.6

Linguistic Variables and Hedges: [12,13] Linguistic variables are the root of fuzzy set theory. A linguistic variable is called fuzzy variable. The statement "Low Density Lipoprotein" is very high implies that the linguistic variable "Low Density Lipoprotein" takes the linguistic value "very high". In fuzzy expert systems, linguistic variables are used in fuzzy rules.

3. Methodology

This Fuzzy Expert System was designed in MATLAB tool with the help of Dr.Sebastina (MBBS) from Sri Manakula Vinayagar Medical College (SMVNC), Pondicherry Kalitheerthalkuppam, Madagadipet, Pondicherry. This system has 1200 rule base, the linguistic term of five input variables and one output variable are represented by trapezoidal and triangular fuzzy number respectively.

3.1. Input Variables

In this system, we have five input variables such as AGE, HDL, LDL, BW, PA, are given by Trapezoidal Fuzzy Number using classified linguistic variables.

IV_1-Age:

It is classified into five linguistic variables are described as follows. Consider

$$\mu_{Adol}(x) = \begin{cases} 1 & x \le 15 \\ \dfrac{20-x}{5} & 15 \le x \le 20 \\ 0 & x \ge 20 \end{cases}, \quad \mu_{Young}(x) = \begin{cases} \dfrac{x-15}{5} & 15 \le x \le 20 \\ 1 & 20 \le x \le 30 \\ \dfrac{35-x}{5} & 30 \le x \le 35 \\ 0 & x \le 15, x \ge 35 \end{cases}$$

$$\mu_{Middle}(x) = \begin{cases} \dfrac{x-30}{5} & 30 \le x \le 35 \\ 1 & 35 \le x \le 45 \\ \dfrac{50-x}{5} & 45 \le x \le 50 \\ 0 & x \le 35, x \ge 50 \end{cases}, \quad \mu_{Old}(x) = \begin{cases} \dfrac{x-45}{5} & 45 \le x \le 50 \\ 1 & 50 \le x \le 60 \\ \dfrac{65-x}{5} & 60 \le x \le 65 \\ 0 & x \le 45, x \ge 65 \end{cases}$$

$$\mu_{Vold}(x) = \begin{cases} 0 & x \le 60 \\ \dfrac{x-60}{5} & 60 \le x \le 65 \\ 1 & x \ge 65 \end{cases}$$

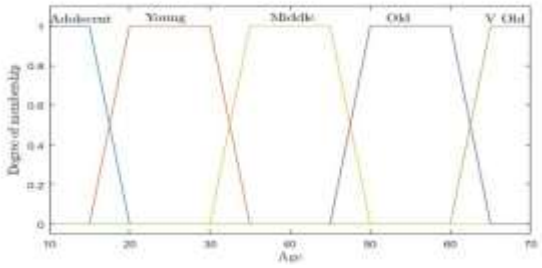


Fig. 3: Classification of Age

Lipoproteins:

The two types of lipoproteins are HDL (Good Cholesterol) and LDL (Bad Cholesterol).

IV_2-High Density Lipoprotein:

HDL protects against heart disease by taking bad cholesterol out of our blood and keeping it from our building up in our arteries.

$$\mu_{Low}(x) = \begin{cases} 1 & x \le 35 \\ \dfrac{40-x}{5} & 35 \le x \le 40 \\ 0 & x \ge 40 \end{cases}, \quad \mu_{Medium}(x) = \begin{cases} \dfrac{x-35}{5} & 35 \le x \le 40 \\ 1 & 40 \le x \le 50 \\ \dfrac{55-x}{5} & 50 \le x \le 55 \\ 0 & x \le 35, x \ge 55 \end{cases}$$

$$\mu_{High}(x) = \begin{cases} 0 & x \le 50 \\ \dfrac{x-50}{5} & 50 \le x \le 55 \\ 1 & x \ge 55 \end{cases}$$

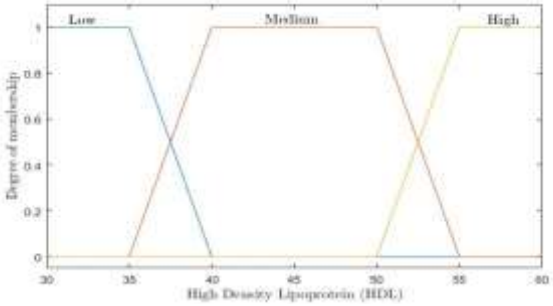


Fig. 4: Classification of HDL

IV_3-Low Density Lipoprotein:
It can build up on the walls of our arteries and increase our chances of getting heart disease. If our LDL is 175 or more, it is considered very high.

$$\mu_{Optimal}(x)=\begin{cases}1 & x\le 95\\ \dfrac{100-x}{5} & 95\le x\le 100\\ 0 & x\ge 100\end{cases},\quad \mu_{Blind}(x)=\begin{cases}\dfrac{x-95}{5} & 95\le x\le 100\\ 1 & 100\le x\le 120\\ \dfrac{125-x}{5} & 120\le x\le 125\\ 0 & x\le 95, x\ge 125\end{cases}$$

$$\mu_{BlindHigh}(x)=\begin{cases}\dfrac{x-120}{10} & 120\le x\le 130\\ 1 & 130\le x\le 140\\ \dfrac{150-x}{10} & 140\le x\le 150\\ 0 & x\le 120, x\ge 150\end{cases},\quad \mu_{High}(x)=\begin{cases}\dfrac{x-145}{10} & 145\le x\le 155\\ 1 & 155\le x\le 165\\ \dfrac{175-x}{10} & 165\le x\le 175\\ 0 & x\le 145, x\ge 175\end{cases}$$

$$\mu_{VHigh}(x)=\begin{cases}0 & x\le 170\\ \dfrac{x-170}{5} & 170\le x\le 175\\ 1 & x\ge 175\end{cases}$$

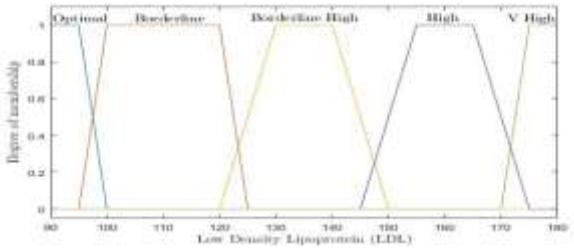


Fig. 5: Classification of LDL

IV_4-Body Weight:
It refers to a person body weight; it can be modified by factors such as gender, age, degree of muscular development.

$$\mu_{Uwt}(x)=\begin{cases}1 & x\le 17\\ \dfrac{18.5-x}{1.5} & 17\le x\le 18.5\\ 0 & x\ge 18.5\end{cases},\quad \mu_{Nwt}(x)=\begin{cases}\dfrac{x-17}{3} & 17\le x\le 20\\ 1 & 20\le x\le 22\\ \dfrac{24.9-x}{2.9} & 22\le x\le 24.9\\ 0 & x\le 17, x\ge 24.9\end{cases}$$

$$\mu_{Oweight}(x)=\begin{cases}\dfrac{x-23.4}{1.6} & 23.4\le x\le 25\\ 1 & 25\le x\le 28\\ \dfrac{29.9-x}{1.9} & 28\le x\le 29.9\\ 0 & x\le 23.4, x\ge 29.9\end{cases},\quad \mu_{Obesity}(x)=\begin{cases}0 & x\le 28\\ \dfrac{x-28}{2} & 28\le x\le 30\\ 1 & x\ge 30\end{cases}$$

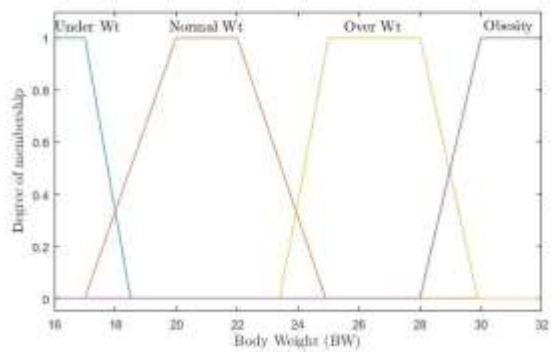


Fig. 6: Classification of Body Weight (BW)

IV_5-Physical Activity:
It is defined as any bodily movement produced by skeletal a muscle that requires energy expenditure. Energy Expenditure balances the energy and weight control. It enhances the physical fitness and overall health and wellness.

$$\mu_{LEffect}(x)=\begin{cases}\dfrac{x-10}{5} & 10\le x\le 15\\ 1 & 15\le x\le 20\\ \dfrac{25-x}{5} & 20\le x\le 25\\ 0 & x\le 10, x\ge 25\end{cases},\quad \mu_{SEffect}(x)=\begin{cases}\dfrac{x-20}{5} & 20\le x\le 25\\ 1 & 25\le x\le 30\\ \dfrac{35-x}{5} & 30\le x\le 35\\ 0 & x\le 20, x\ge 35\end{cases}$$

$$\mu_{VEffect}(x)=\begin{cases}\dfrac{x-30}{5} & 30\le x\le 35\\ 1 & 35\le x\le 40\\ \dfrac{45-x}{5} & 40\le x\le 45\\ 0 & x\le 30, x\ge 45\end{cases},\quad \mu_{EEffect}(x)=\begin{cases}0 & x\le 40\\ \dfrac{x-40}{5} & 40\le x\le 45\\ 1 & x\ge 45\end{cases}$$

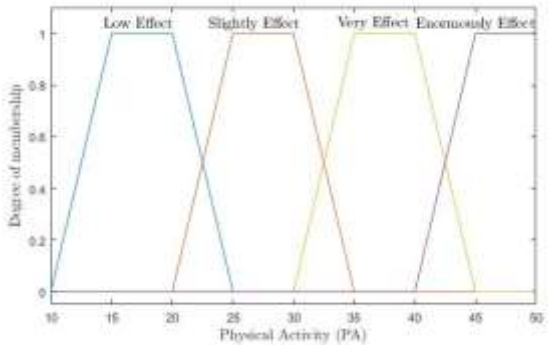


Fig. 7: Classification of Physical Activity (PA)

3.2. Output Variables

In this system, the given output variable Health Condition are defined and classified into linguistic variables with interval and their membership function is given by Triangular fuzzy number.
Health Condition: HC is classified into seven linguistic variables with interval and triangular fuzzy number are described as follows. Consider

$$\mu_{VLow}(x)=\begin{cases}\dfrac{x-0.1}{0.1} & 0.1\le x\le 0.2\\ \dfrac{0.3-x}{0.1} & 0.2\le x\le 0.3\\ 0 & x\le 0.1, x\ge 0.3\end{cases},\quad \mu_{Low}(x)=\begin{cases}\dfrac{x-0.2}{0.1} & 0.2\le x\le 0.3\\ \dfrac{0.4-x}{0.1} & 0.3\le x\le 0.4\\ 0 & x\le 0.2, x\ge 0.4\end{cases}$$

$$\mu_{MedLow}(x)=\begin{cases}\dfrac{x-0.3}{0.1} & 0.3\le x\le 0.4\\ \dfrac{0.5-x}{0.1} & 0.4\le x\le 0.5\\ 0 & x\le 0.3, x\ge 0.5\end{cases},\quad \mu_{Medium}(x)=\begin{cases}\dfrac{x-0.4}{0.1} & 0.4\le x\le 0.5\\ \dfrac{0.6-x}{0.1} & 0.5\le x\le 0.6\\ 0 & x\le 0.4, x\ge 0.6\end{cases}$$

$$\mu_{MedSevere}(x)=\begin{cases}\dfrac{x-0.5}{0.1} & 0.5\le x\le 0.6\\ \dfrac{0.7-x}{0.1} & 0.6\le x\le 0.7\\ 0 & x\le 0.5, x\ge 0.7\end{cases},\quad \mu_{Severe}(x)=\begin{cases}\dfrac{x-0.6}{0.1} & 0.6\le x\le 0.7\\ \dfrac{0.8-x}{0.1} & 0.7\le x\le 0.8\\ 0 & x\le 0.6, x\ge 0.8\end{cases}$$

$$\mu_{VerySevere}(x)=\begin{cases}\dfrac{x-0.7}{0.15} & 0.7\le x\le 0.85\\ \dfrac{1-x}{0.15} & 0.85\le x\le 1\\ 0 & x\le 0.7, x\ge 1\end{cases}$$

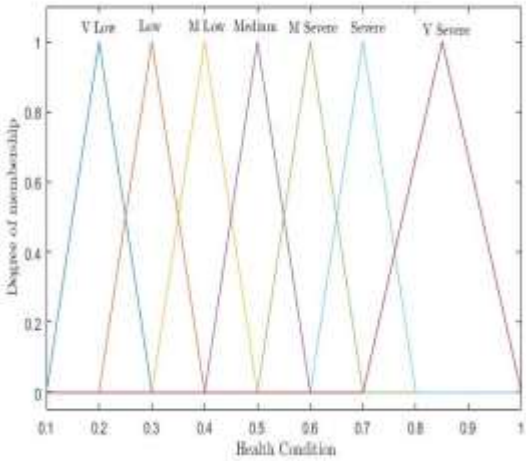


Fig. 8: Classification of Health Condition

4. Algorithm for the Fuzzy Expert System

Step-1
Here, n input factor D_i , i = 1, 2, ..., n and m outputs R_j , j = 1, 2,...,m.

Step-2
Divide the input factors D_i , i = 1, 2,..., n and m outputs factors R_j , j = 1, 2,...,m
into linguistic terms from the set $\tilde{S} = \{s_i, s_{i+1}, ..., s_u\}$ where

s_l and s_u are the lower and upper limits, $l, u = (0,1,...,g)$

Step-3
Construct the suitable fuzzy membership function for each linguistic terms D_i,
R_j using the available information.

Step-4
Develop p If-then rules with aid of expert's (E_i), i = 1, 2, ... , k
Input- Fuzzy strings from R_p and the value of the parameter D_i.
Calculating the sting strength $w_p = A_1 \wedge A_2 \wedge \cdots \wedge A_p$
Op= p^{th} rule's consequent fuzzy rules.
Output of the system = $\sum_{p=1}^{r} \frac{O_p w_p}{w_p}$

Step-5 Final output would be the required impact.

5. Results and Discussion

In type 2 diabetes, when insulin isn't available, blood glucose levels rise higher in the blood stream. Most of the people are living in India without knowing that they are affected with T2DM. Due to imprecise and vague, the diabetic factors cannot be predicted earlier. Hence, this paper deals with five factors to find the actual health condition of diabetic individual's.
Case 1: The input variables of first patient P_1 are {(40, Age), (45, HDL), (135, LDL), (30.5, BW), (60, PA)}.
The linguistic string of concerned patient P_1 is (Middle, Medium, Borderline High, Obesity, Enormously Effective) occurs at R608.
The Rule R608 states that *if Age* $_{Middle}$ *and* HDL_{Medium} *and* $LDL_{Borderline\ High}$ *and BW* $_{Obesity}$ *and PA* $_{Enormously\ Effective}$ *then T2DM is Severe*. Hence, the patient P_1 is affected T2DM in severe level with 0.7 membership grade.



Fig. 9: Fuzzy Rule Base

6. Conclusion

This present study designs Fuzzy Expert System for T2DM with Linguistic term and membership functions for input variables, output variables and 1200 rule base. This system has been constructed and tested with aid of medical practitioners. The proposed Expert system would assist the medical experts for early diagnosis of the disease and proceed the treatment to save one's life.

References

[1] Ali Adeli., & Mehdi Neshat. (2010), A Fuzzy Expert System for Heart Disease Diagnosis, *Proceedings for the International Multi-Conference of Engineers and Computer Scientists*, Vol-I, 136-139.
[2] Hasan Mir Anamul. Khaja. Sher-E-Alam., & Ahsan Raja Chowdhury. (2010), Human disease diagnosis using a fuzzy expert system, *Journal of Computing*, 2(6), 66-70.
[3] Ismail Saritas., Novruz Allahverdi., & Ibrahim Unal Sert. (2003), A Fuzzy Expert System Design for Diagnosis of Prostate Cancer, *International Conference on Computer Systems and Technologies - Compsystech.*
[4] Kalpana. M., Senthil Kumar. A.V. (2012), Design And Implementation of Fuzzy Expert System Using Fuzzy Assessment Methodology, *International Journal of Science And Applied Information Technology*, 1(1), 39-45.
[5] Kandel, A. (1992), Fuzzy Expert Systems. *CRC Press, Inc., Boca Raton*.
[6] Maryam Mirsharif., Mahmoud Alborzi., & Amir Ashkan Nasir Pour. (2014), IA Fuzzy Expert System & Neuro-Fuzzy System Using Soft Computing For Gestational Diabetes Mellitus Diagnosis, *Inte. J. Of Information, Security snf System Magm*t., 3(1), 249-252.
[7] Najar Yousra., Ketata Raouf., & Ksouri Mekki. (2013), A Study On The Conception Of Generic Fuzzy Expert System For Surveillance, *Int. J. Of Advanced Comp. Sci. Appli*., 4(8), 218-227.
[8] Nonso Nnamoko et.al. (2013), Fuzzy Expert System For Type 2 Diabetes Mellitus (T2DM) Management Using Dual Inference Mechanism, Data Driven Wellness: Association For The Advancement Of Artificial Intelligence, 67-70.
[9] Rama Devi. E., Nagaveni. N. (2010), Design Methodology of a Fuzzy Knowledgebase System to Predict the Risk Of Diabetic Nephropathy. *International Journal Of Comp. Sci. Issues*, 7(5), 239-247.
[10] Siler W., Buckley J. (2005), Fuzzy Expert Systems and Fuzzy Reasoning, *John Wiley & Sons, Inc., New Jersey*.
[11] Tawfik Saeed Zeki., et.al, (2012), An Expert System For Diabetes Diagnosis, *American Academic & Scholarly Research Journal*, 4(5), 1-13.
[12] Zadeh, L.A. (1994), Soft Computing and Fuzzy Logic, *IEEE software*,11(6), 48-56.
[13] Zadeh, L.A., (1965), Fuzzy sets, *Information and Control*, 8 (1965), 338-353.