Soft Computing Diagnostic System for Diabetes

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ABSTRACT
In the present paper, we propose a soft computing diagnostic system for detecting different phases of diabetes. The proposed system is user friendly and will guide patients to evolve proper strategies so that they could maintain their blood sugar level by adopting suitable life style. The proposed system not only acts as a referral system in between patient and medical expert but also sharpen the diagnostic process of medical experts. A number of cases on the basis of available clinical datas have been investigated to check the validity of system.

Keywords
Diabetes, Soft Computing, Diagnostic System, Fuzzy Tools.

1. INTRODUCTION
Diabetes is a medical disorder characterized by varying or persistent high blood sugar level, caused by either lack of or resistance to insulin. Many people have diabetes for years without knowing it, since our body is a complex machine, so there are numerous variables which affect our body and it is not easy to determine precisely about any disease. Increased pressure and poor tolerance among youngsters as well as aged people is making them vulnerable to diabetes, it contributes to higher rates of morbidity people with diabetes are at higher risk for heart disease, blindness, kidney failure, extremity amputations, and other chronic conditions. According to the World Health Organization estimates, India had 32 million diabetic subjects in the year 2000 and this number would increase to 80 million by the year 2030. The International Diabetes Federation (IDF) also reported that the total number of diabetic subjects in India is 41 million in 2006 and that this would rise to 70 million by the year 2025. By 2030 India, China and USA will have the largest population of diabetic people. It is estimated that every fifth person with diabetes will be an Indian [12]. The treatment of diabetes focuses on controlling blood sugar levels to prevent various symptoms and complications through medicine, diet, and exercise. The general approach for treating diabetes includes: Dietary management, Diabetes medical nutrition therapy, Blood glucose monitoring, Glycemic control, and Insulin therapy. Exercise in diabetic patients can improve insulin sensitivity, glycaemic control and lipid profile. Yoga has been applied in the field of therapeutics in modern times. Studies have been conducted to understand changes occurring during Yogic exercises (asans and pranayamas) [9].Yoga has thus aroused as a hope for the diabetic patients to have complication free life with relatively less medication [3]. The limited recorded evidences show the positive impact of Yogic exercises on studying blood sugar levels [8]. Some of the asans which have been found useful in treating diabetes are Surya Namaskara, Mandugasan, Kapalbhati, Bhoomi Naman, Pavanamukta Asana, Ardha Matsyendrasana, Paschimothan Asana, yoga nidra and meditation [3]. Since fuzzy tools can be used to deal with uncertain medical concepts and are much closer to human way of thinking. Jain, Ramesh [5] used the concept of fuzzy variables in decision making, Bellmen, R.E. and Zadeh, L.A. [2] proposed decision making system in fuzzy environment. Degani, Rosanna [4] used fuzzy methodologies in computerized ECG diagnosis and later on Warren, Jim [16] used fuzzy logic in designing a clinical decision support system. Jena, R.K.[6] produced soft computing methodologies in Bioinformatics, Polat, K. and Gϋne S.[11] developed an expert system approach based on principle component analysis and adopted neuro-fuzzy inference system to diagnosis of diabetes. Baskaran, A. et al [1] made a study on modeling and automation of diagnosis and treatment of diabetes. It is very much clear that applicability of soft computing system is increasing day by day to deal with the real world problems and medical science is now an open zone to carry out investigation with the help of soft models. It has been seen that fuzzy tools become more popular in medical sciences nowadays due to its acceptability to design and development of medical machines. In 2006, Pandey, D., Mahajan, Vaishali and Srivastava, Pankaj [10] developed rule based system for cardiac analysis. Further in 2012 Srivastava, Pankaj and Srivastava, Amit [14, 15] proposed soft computing risk assessment scheme for cardiac analysis and hypertension respectively. Recently, Srivastava Pankaj and Sharma Neeraja [13] designed a soft computing model for ECG beats classification and cardiac analysis. In the present paper we introduce a soft computing diagnostic system for detecting different phases of diabetes. A number of cases have been investigated on real clinical datas made available from the medical clinic of Motilal Nehru National Institute of Technology, Allahabad the help of the proposed diagnostic system. This model is user friendly and effective in comparison to other fuzzy models.

2. MATERIALS AND METHOD
A variety of factors that contribute to the onset of two main types of diabetes, type I and type II are: Hereditary or Inherited Traits, Age, Poor diet, Obesity and Fat distribution. Doctors use special tests in diagnosis of diabetes Fasting Blood Sugar (FBS), Postprandial Blood Sugar Test (PPBS), Random Blood Sugar Test (RBS), Oral Glucose Tolerance Test (OGTT), HbA1C test. Fuzzy tools are closer to human way of thinking, so applicability of fuzzy models is increasing day by day to deal with real world problems.

We have taken three main risk factors FBS, PPBS, and Physical Exercise (PE).

2.1 Input Variables

I. Age (years)
We have divided age factor in five fuzzy sets as below:

Young (Y)	**≤ 25**
Middle Aged (MA)	**25 to 50**
Aged (A)	**45 to 70**
Very Aged (VA)	**65 to 85**
Old (O)	**≥ 80**

The membership functions of these fuzzy sets are given below:

$$\mu_Y(x) = \begin{cases} 1, & x \le 15 \\ (x-15)/10, & 15 < x < 25 \\ 0, & x \ge 25 \end{cases}$$

$$\mu_{MA}(x) = \begin{cases} 0, & x \le 25 \text{ and } x \ge 50 \\ (x - 25)/5, & 25 < x < 30 \\ 1, & 30 \le x \le 45 \\ (50-x)/5 & 24 < x < 50 \end{cases}$$

$$\mu_A(x) = \begin{cases} 0, & x \le 45 \text{ and } x \ge 70 \\ (x-45)/5, & 45 < x < 50 \\ 1, & 50 \le x \le 65 \\ (65-x)/5 & 65 < x < 70 \end{cases}$$

$$\mu_{VA}(x) = \begin{cases} 0, & x \le 65 \text{ and } x \ge 85 \\ (x-65)/5, & 65 < x < 70 \\ 1, & 70 \le x \le 80 \\ (85-x)/5 & 80 < x < 85 \end{cases}$$

$$\mu_O(x) = \begin{cases} 0, & x \le 80 \\ (x-80)/5, & 80 < x < 85 \\ 1, & x \ge 85 \end{cases}$$

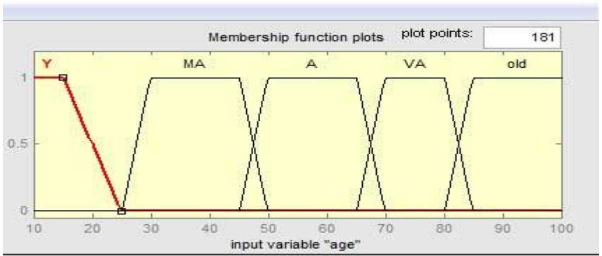

Fig 1: Membership Function for Age

II. FBS (mg/dl)

FBS measures blood glucose after when not eaten for at least 8 hours. It is often the first test done to check for pre diabetes and diabetes. FBS is classified in the following five fuzzy sets as follows:

Very Low (VL)	**20 to 40**
Low (L)	**40 to 65**
Normal (N)	**65 to 110**
High (H)	**110 to 200**
Very High (H)	**200 to 250**

The membership functions of FBS are as follows:
$\mu_{VL}(x) = \exp(((x-40) / 20)^2)-2$
$\mu_L(x) = \exp(((x-65) / 25)^2)-2$
$\mu_N(x) = \exp(((x-110) / 45)^2)-2$
$\mu_H(x) = \exp(((x-200) / 90)^2)-2$
$\mu_{VH}(x) = \exp(((x-250) / 50)^2)-2$

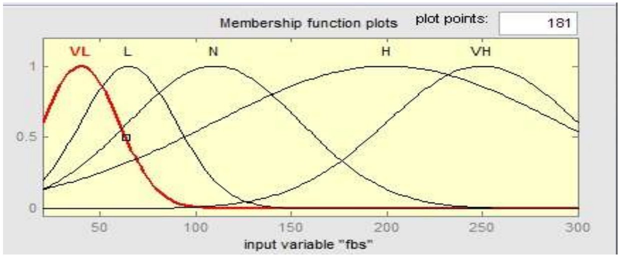

Fig 2: Membership Function for FBS

III. PPBS (mg/dl)

PPBS measures blood glucose exactly 2 hours after when start eating meal. It is also classified in five fuzzy sets are given below:

Very Low (VL)	**20 to 40**
Low (L)	**40 to 65**
Normal (N)	**65 to 140**
High (H)	**140 to 250**
Very High (H)	**250 to 400**

The membership functions of FBS are as follows:
$\mu_{VL}(x) = \exp(((x-40) / 20)^2)-2$
$\mu_L(x) = \exp(((x-65) / 25)^2)-2$
$\mu_N(x) = \exp(((x-140) / 75)^2)-2$
$\mu_H(x) = \exp(((x-250) / 110)^2)-2$
$\mu_{VH}(x) = \exp(((x-400) / 150)^2)-2$

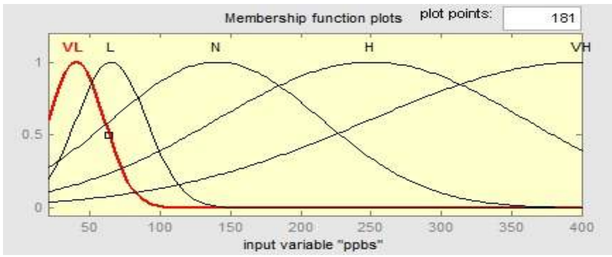

Fig 3: Membership Function for PPBS

IV. Physical Exercise (minutes)

Physical exercise is also categorized in following five fuzzy sets:

Little Effective (LE)	**≤ 10**
Slightly Effective (SE)	**10 to 25**
Very Effective (VE)	**25 to 45**
Very -Very Effective (VVE)	**45 to 65**
Extremely Effective (VE)	**≥ 65**

The membership functions of these fuzzy sets are given below:

$$\mu_{LE}(x) = \begin{cases} 1, & x \le 5 \\ (x-5)/10, & 5 < x < 15 \\ 0, & x \ge 15 \end{cases}$$

$$\mu_{SE}(x) = \begin{cases} 0, & x \le 10 \text{ and } x \ge 25 \\ (x - 10)/5, & 10 < x < 15 \\ 1, & 15 \le x \le 20 \\ (25-x)/5 & 20 < x < 25 \end{cases}$$

$$\mu_{VE}(x) = \begin{cases} 0, & x \le 20 \text{ and } x \ge 45 \\ (x-20)/5, & 20 < x < 25 \\ 1, & 25 \le x \le 40 \end{cases}$$

$$(45-x)/5 \qquad 40 < x < 45$$

$$\mu_{VVE}(x) = \begin{cases} 0, & x \leq 40 \text{ and } x \geq 65 \\ (x-40)/5, & 40 < x < 45 \\ 1, & 45 \leq x \leq 60 \\ (65-x)/5 & 60 < x < 65 \end{cases}$$

$$\mu_{O}(x) = \begin{cases} 0, & x \leq 60 \\ (x-60)/5, & 60 < x < 65 \\ 1, & x \geq 65 \end{cases}$$

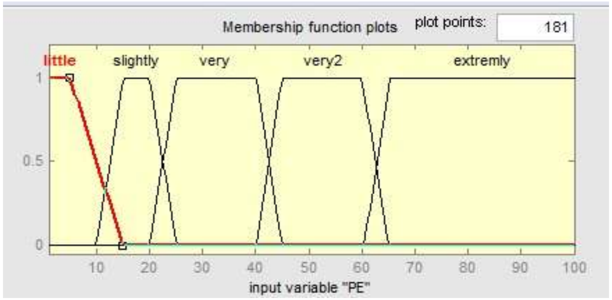

Fig 4: Membership Function for Physical Exercise

2.2 Output Variables

The output zone is classified in four different layers such as Normal, Pre Diabetes, Type-1 and Type-2 Diabetes.

2.3 Linguistic Strings

We have developed 625 linguistic strings to represent the state of the patient using his/her age, FBS, PPBS, and Physical Exercise (PE) as follows:

$J_1 = Y_{AGE}$ and VL_{FBS} and VL_{PPBS} and L_{PE}
$J_2 = Y_{AGE}$ and VL_{FBS} and VL_{PPBS} and S_{PE}
$J_3 = Y_{AGE}$ and VL_{FBS} and VL_{PPBS} and V_{PE}
$J_4 = Y_{AGE}$ and VL_{FBS} and VL_{PPBS} and VV_{PE}
$J_5 = Y_{AGE}$ and VL_{FBS} and VL_{PPBS} and E_{PE}
...
$J_{301} = A_{AGE}$ and N_{FBS} and VL_{PPBS} and L_{PE}
$J_{302} = A_{AGE}$ and N_{FBS} and VL_{PPBS} and S_{PE}
$J_{303} = A_{AGE}$ and N_{FBS} and VL_{PPBS} and V_{PE}
$J_{304} = A_{AGE}$ and N_{FBS} and VL_{PPBS} and VV_{PE}
$J_{305} = A_{AGE}$ and N_{FBS} and VL_{PPBS} and E_{PE}
...
$J_{621} = O_{AGE}$ and VH_{FBS} and VH_{PPBS} and L_{PE}
$J_{622} = O_{AGE}$ and VH_{FBS} and VH_{PPBS} and S_{PE}
$J_{623} = O_{AGE}$ and VH_{FBS} and VH_{PPBS} and V_{PE}
$J_{624} = O_{AGE}$ and VH_{FBS} and VH_{PPBS} and VV_{PE}
$J_{625} = O_{AGE}$ and VH_{FBS} and VH_{PPBS} and E_{PE}

2.4 Methodology

The above mentioned linguistic strings are used to represent the state of patients and help in constructing a utility matrix U of order 4 x 625. This utility matrix measures different layers of diabetes as outputs of the model. The utility matrix as follows:

$$U = \begin{bmatrix} 95 & 97 & 98 & 99 & 100 & \ldots & 9 & 10 & 12 & 15 & 19 \\ 45 & 44 & 43 & 42 & 41 & \ldots & 30 & 29 & 25 & 23 & 20 \\ 20 & 19 & 17 & 15 & 11 & \ldots & 25 & 23 & 22 & 80 & 79 \\ 8 & 7 & 5 & 3 & 1 & \ldots & 99 & 98 & 97 & 29 & 25 \end{bmatrix}_{4 \times 625}$$

The performance of decision making analysis of the proposed diabetic diagnostic system has been investigated in the six different cases whose datas have been collected from Motilal Nehru National Institute of Technology's medical clinic. These cases are as follows:

Case 1

The input variables are:
Age= 35yrs, FBS= 76 mg/dl, PPBS= 221mg/dl, PE=32 min.

Fuzzy sets for these variables are as follows:

Age = {(0, Y), (1, MA), (0, A), (0, VA), (0, O)}

FBS= {(0.1908, VL), (0.9077, L), (0.7517, N), (0.3871, H), (0.0023, VH)}

PPBS= {(0, VL), (0, L), (0.517, N), (0.3871, H), (0.0023, VH)}

PE = {(0, L), (0, S), (1, V), (0 VV), (0, EE)}

The state of patient in the form of fuzzy set is represented as:
X = {(0.1908, J_{138}), (0.1908, J_{143}), (0.1908, J_{148}), (0.5581, J_{163}), (0.9077, J_{168}), (0.4907, J_{173}), (0.5581, J_{188}), (0.7517, J_{193}), (0.4907, J_{198}), (0.3871, J_{213}), (0.3871, J_{218}), (0.3871, J_{223}), (0.0023, J_{238}), (0.0023, J_{243}), (0.0023, J_{248})}

Now we use utility matrix to obtain required utility sets as per output. These are as follow:

U_1 = {(0.0023, 3), (0.0023, 9), (0.4907, 12), (0.6252, 17), (0.1908, 20), (0.7517, 24), (0.1908, 26), (0.4907, 33), (0.3871, 43), (0.5581, 52), (0.9077, 58), (0.5581, 67), (0.1908, 77)}

U_2 = {(0.0023, 23), (0.0023, 25), (0.0023, 35), (0.4907, 36), (0.7517, 38), (0.5878, 42), (0.3871, 47), (0.3871, 47), (0.5581, 56), (0.1908, 59), (0.5581, 63), (0.9077, 65), (0.3871, 88), (0.1908, 70)}

U_3= {(0.7517, 22), (0.6424, 23), (0.3871, 26), (0.4918, 28), (0.9670, 33), (0.7474, 35), (0.3871, 37), (0.0023, 85), (0.0023, 92)}

U_4 = {(0.1908, 23), (0.0023, 29), (0.3871, 30), (0.0023, 33), (0.8047, 35), (0.1908, 38), (0.9077, 39), (0.4907, 69), (0.7517, 70), (0.1908, 74), 0.3871, 83), (0.4907, 84), (0.3871, 85), (0.0023, 97)}

The maximizing utility sets corresponding to each output are as follows:

U_{1M} = {(0.0010, 3), (0.0086, 9), (0.0153, 12), (0.0307, 17), (0.0425, 20), (0.0612, 24), (0.0718, 26), (0.1157, 33), (0.1965, 43), (0.2874, 52), (0.3579, 58), (0.4771, 67), (0.6301, 77)}

U_{2M} = {(0.0562, 23), (0.0664, 25), (0.1302, 35), (0.1377, 36), (0.1535, 38), (0.1874, 42), (0.2348, 47), (0.2449, 48), (0.3333, 56), (0.3700, 59), (0.4218, 63), (0.4490, 65), (0.8230, 88), (0.5208, 70)}

U_{3M} = {(0.0514, 22), (0.0562, 23), (0.718, 26), (0.0833, 28), (0.1159, 33), (0.1302, 35), (0.1455, 37), (0.7679, 85), (0.8996, 92)}

U_{4M} = {(0.0562, 23), (0.0894, 29), (0.0957, 30), (0.1157, 33), (0.1302, 35), (0.1535, 38), (0.1617, 39), (0.5060, 69), (0.5208, 70), (0.5820, 74), 0.7322, 83), (0.7499, 84), (0.7679, 85), (1, 97)}

We now develop optimal utility sets with the help of above mentioned utility sets and maximizing utility sets, which are as given below:

U_{1O} = {(0.0010, 3), (0.0023, 9), (0.0153, 12), (0.0307, 17), (0.0425, 20), (0.0612, 24), (0.0718, 26), (0.1157, 33), (0.1965, 43), (0.2874, 52), (0.3579, 58), (.4771, 67), (.1908, 77)}

U_{2O} = {(0.0023, 23), (0.0023, 25), (0.0023, 35), (0.1377, 36), (0.1535, 38), (0.1874, 42), (0.2348, 47), (0.2449, 48), (0.3333, 56), (0.1908, 59), (0.4218, 63), (0.4490, 65), (0.3871, 88), (0.1908, 70)}

U_{3O} = {(0.0514, 22), (0.0562, 23), (0.718, 26), (0.0833, 28), (0.1159, 33), (0.1302, 35), (0.1455, 37), (0.0023, 85), (0.0023, 92)}
U_{4O} = {(0.0514, 23), (0.0023, 29), (0.0957, 30), (0.0023, 33), (0.1302, 35), (0.1535, 38), (0.1617, 39), (0.4907, 69), (0.5208, 70), (0.1908, 74), 0.3821, 83), (0.4907, 84), (0.3871, 85), (0.0023, 97)}

The decision making process of the diagnostic system yields an optimal alternative fuzzy set that provides different phases of diabetes.
A_O = {(0.4771, Normal), (0.4490, Pre diabetes), (0.1455, Type-1), (0.5208, Type-2)}

The decision layer of the system for concerned patient is depicted in the following graphical sketch:

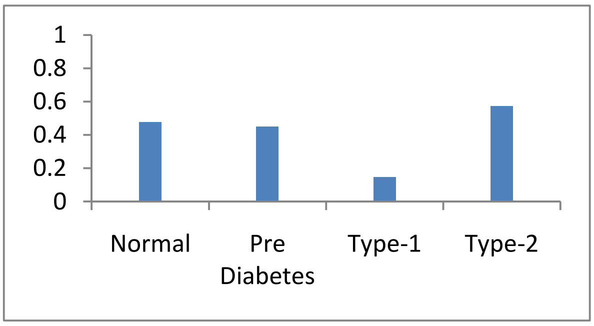

Fig 5: Output of Case 1

The graphical sketch clearly indicates that the patient is having a close chance of Type-2 diabetes.

Case 2

The input variables are:
Age= 33yrs, FBS= 139 mg/dl, PPBS= 148mg/dl, PE= 15min.

Fuzzy sets for these variables are as follows:
Age = {(0, Y), (1, MA), (0, A), (0, VA), (0, O)}
FBS= {(0, VL), (0.0125, L), (0.8125, N), (0.7948, H), (0.0851, VH)}

PPBS= {(0, VL), (0.004, L), (0.9943, N), (0.6506, H), (0.2439, VH)}

PE = {(1, L), (0, S), (0, V), (0 VV), (0, EE)}

The state of patient in the fuzzy set is represented as:

X = {(0.004, J_{156}), (0.0125, J_{161}), (0.0125, J_{166}), (0.0125, J_{171}), (0.004, J_{181}), (0.8125, J_{186}), (0.6506, J_{191}), (0.2439, J_{196}), (0.004, J_{206}), (0.7948, J_{211}), (0.6506, J_{216}), (0.2439, J_{221}), (0.004, J_{231}), (0.0851, J_{236}), (0.0851, J_{241}), (0.0851, J_{246})}

Applying same procedure as above, the optimal alternative is as follows:

A_O = {(0.2500, Normal), (0.4225, Pre diabetes), (0.8123, Type-1), (0.6506, Type-2)}

The decision layers of the system for the concerned patient are depicted in the following graphical sketch:

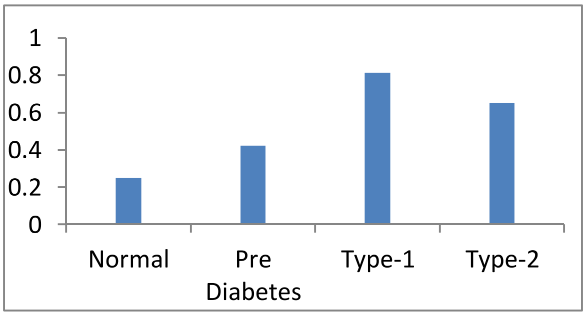

Fig 6: Output of Case 2

The graphical sketch clearly indicates that the patient belongs to the phase of Type-1 diabetes.

Case 3

The input variables are:
Age= 62yrs, FBS= 189 mg/dl, PPBS= 278mg/dl, PE=10 min.

Fuzzy sets for these variables are as follows:
Age = {(0, Y), (0, MA), (1, A), (0, VA), (0, O)}

FBS= {(0, VL), (0, L), (0.2142, N), (0.9926, H), (0.4751, VH)}

PPBS= {(0, VL), (0, L), (0.184, N), (0.9681, H), (0.7184, VH)}

PE = {(1, L), (0, S), (0, V), (0 VV), (0, EE)}

The state of patient in the fuzzy set is represented as below:

X = {(0.1840, J_{311}), (0.2142, J_{316}), (0.2142, J_{321}), (0.184, J_{336}), (0.9681, J_{341}), (0.7184, J_{346}), (0.184, J_{361}), (0.4751, J_{366}), (0.4751, J_{371}))}

The optimal alternative is given below:

A_O = {(0.184, normal), (0.3600, pre diabetes), (0.4751, Type-1), (0.9025, Type-2)}

The decision layers of the system for the concerned patient are depicted in the following graphical sketch:

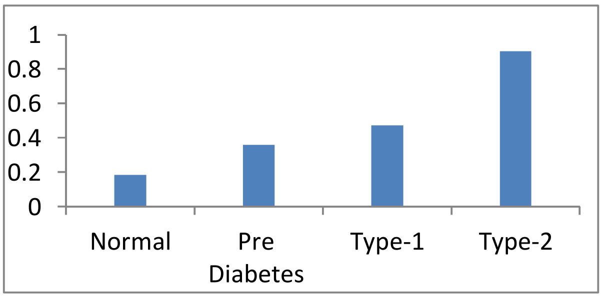

Fig 7: Output of Case 3

The graphical sketch shows that the patient belongs to the phase of Type-2 diabetes.

Case 4

The input variables are:
Age= 54yrs, FBS= 128 mg/dl, PPBS= 194mg/dl, PE=10 min.

Fuzzy sets for these variables are as follows:

Age = {(0, Y), (0, MA), (1, A), (0, VA), (0, O)}

FBS= {(0, VL), (0.0418, L), (0.9231, N), (0.7261, H), (0.0510, VH)}

PPBS= {(0, VL), (0, L), (0.7717, N), (0.8785, H), (0.3894, VH)}

PE = {(1, L), (0, S), (0, V), (0 VV), (0, EE)}

The state of patient in the fuzzy set is represented as:

X = {(0.0418, J_{286}), (0.0418, J_{291}), (0.0418, J_{296}), (0.7717, J_{311}), (0.8785, J_{316}), (0.3894, J_{321}), (0.7261, J_{336}), (0.7261, J_{341}), (0.3894, J_{346}), (0.051, J_{361}), (0.051, J_{366}), (0.051, J_{371}))}

The optimal alternative is as follows:

A_O = {(0.25, normal), (0.5625, pre diabetes), (0.7261, Type-1), (0.7261, Type-2)}

The decision layers of the system for the concerned patient are depicted in the following graphical sketch:

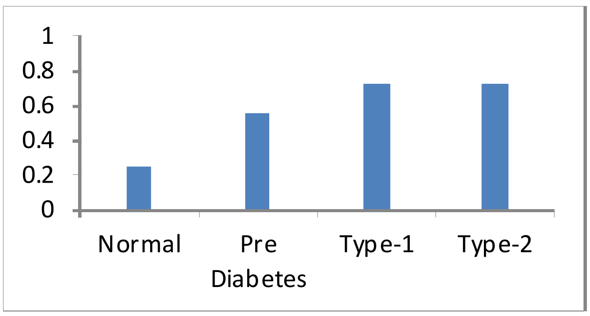

Fig 8: Output of Case 4

The graphical sketch indicates that the patient is having equal chances of Type-1 and Type-2 diabetes.

Case 5

The input variables are:
Age= 69yrs, FBS= 251 mg/dl, PPBS= 355mg/dl, PE=10 min.

Fuzzy sets for these variables are as follows:
Age = {(0, Y), (0, MA), (0, A), (0.2, VA), (0, O)}

FBS= {(0, VL), (0, L), (0.0074, N), (0.8517, H), (0.9998, VH)}

PPBS= {(0, VL), (0, L), (0.0164, N), (0.6341, H), (0.9560, VH)}

PE = {(1, L), (0, S), (0, V), (0 VV), (0, EE)}

The state of the patient in the fuzzy set is represented as below:

X = {0.0074, J_{436}), (0.0074, J_{441}), (0.0074, J_{446}), (0.0164, J_{461}), (0.2000, J_{466}), (0.2000, J_{471}), (0.0164, J_{486}), (0.2000, J_{491}), (0.2000, J_{496})}

The optimal alternative is given below:
A_O = {(0.1773, normal), (0.2000, pre diabetes), (0.2000, Type 1), (0.36, Type-2)}

The decision layers of the system for the concerned patient are depicted in the following graphical sketch:

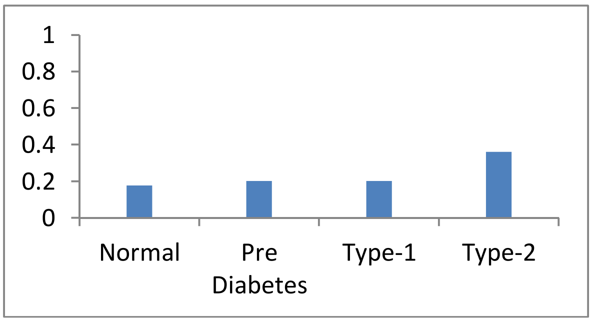

Fig 9: Output of Case 5

The graphical sketch shows that the patient belongs to the phase of Type-2 diabetes.

Case 6
The input variables are:
Age= 75yrs, FBS= 72.6mg/dl, PPBS= 118mg/dl, PE=5 min.

Fuzzy sets for these variables are as follows:
Age = {(0, Y), (0, MA), (0, A), (1, VA), (0, O)}

FBS= {(0.2649, VL), (0.9548, L), (0.7080, N), (0.3672, H), (0.0018, VH)}

PPBS= {(0, VL), (0.1057, L), (0.9579, N), (0.4868, H), (0.1708, VH)}

PE = {(1, L), (0, S), (0, V), (0 VV), (0, EE)}

The state of the patient in the fuzzy set is represented as below:

X = {(0.1057, J_{381}), (0.2649, J_{386}), (0.2649, J_{391}), (0.1708, J_{396}), (0.1057, J_{406}), (0.9548, J_{411}), (0.4868, J_{416}), (0.1708, J_{421}), (0.1057, J_{431}), (0.7080, J_{436}), (0.4868, J_{441}), (0.1708, J_{446}), (0.1057, J_{456}), (0.3672, J_{461}), (0.3672, J_{466}), (0.1708, J_{471}), (0.0018, J_{481}), (0.0018, J_{486}), (0.0018, J_{491}), (0.0018, J_{496})}

The optimal alternative is given as below:
A_O = {(0.3383, normal), (0.6498, pre diabetes), (0.3672, Type-1), (0.6227, Type-2)}

The decision layers of the system for the concerned patient are depicted in the following graphical sketch:

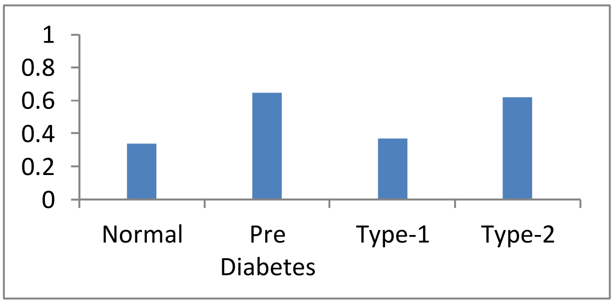

Fig 10: Output of Case 6

The graphical sketch shows that the patient comes under the purview of Pre Diabetes phase.

3. CONCLUSION

The output of the soft computing diagnostic system for various patients has been validated with the help of medical experts. The application of such system will be helpful in designing and development of machine that will work as a referral system in between patients and medical experts.

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5. REFERENCES

[1] Baskaran, A., Karthikeyan, D., and Swamy, A.T. (2010). Modeling and Automation of Diagnosis and Treatment of Diabetes, Lecture Notes in Computer Science, Vol. 6457, pp. 339-348.

[2] Bellman, R.E. and Zadh, L.A. (1970). Decision Making in a Fuzzy Environment, Management Science, Vol. 17, No. 4, pp. B141-B164.

[3] Clinical Research on the Benefits of Yoga Practice on Diabetes. (2009).The Effects of Exercise and Yoga on Diabetes, Health Administrator, Vol. XXII, No. 1&2, pp. 42-45.

[4] Degani, Rosanna. (1992). Computerized Electrocardiogr-am Diagnosis: Fuzzy Approach, Methods of Information in Medicine, Vol. 31, pp. 225- 233.

[5] Jain, Ramesh. (1967). Decision making in the Presence of Fuzzy Variables, IEEE Transactions on Systems, Man, and Cybernetics, Vol. 6, No. 10, pp. 698-703.

[6] Jena, R. K and et.al.(2004).Soft Computing Methodologies in Bioinformatics, European Journal of Scientific Research Vol. 26, pp. 183-203.

[7] Klire, George.J. and Yuan, Bo.(2009).Fuzzy Sets and Fuzzy Logic: Theory and Applications, PHI Learning Private Limited: New Delhi.

[8] Lamb, Trisha. (2006). Yoga and Diabetes, International Association of Yoga Therapists.

[9] Malhotra, V. and et al.(2004). Effect of Yoga Asans and Pranayama in Non-Insulin Dependent Diabetes Mellitus, Indian Journal of Traditional Knowledge, Vol. 3, No. 02, pp. 162-167.

[10] Pandey D., Mahajan, Vaishali and Srivastava Pankaj (2006). Rule Based System for Cardiac Analysis, NATL ACAD SCI LETT, Vol. 29, No. 7 & 8, pp. 299-309.

[11] Polat, K. and Güne, S.(2007). An Expert System Approach Based on Principal Component Analysis and Adaptive Neuro-Fuzzy Inference System to Diagnosis of Diabetes Disease, Digital Signal Processing, Vol. 17, No. 04, pp. 702-710.

[12] Sandeep, S., Ganesan, A. and Mohan, V. Development and Updation of the Diabetes Atlas of India, Madras Diabetes Research Foundation, Chennai.

[13] Srivastava, Pankaj and Sharma, Neeraja. Soft Computing Criterion for ECG Beats Classification and Cardiac Analysis, Communicated.

[14] Srivastava, Pankaj and Srivastava, Amit. (2012). A note on Soft Computing Approach for Cardiac Analysis, J. Basic. Appl. Sci. Res., Vol. 2, No. 1, pp. 376-385.

[15] Srivastava, Pankaj and Srivastava, Amit.(2012). Spectrum of Soft Computing Risk Assessment Scheme for Hypertension, International Journal of Computer Applications (0975-8887), Vol. 44, No. 17, pp. 23-30.

[16] Warren, Jim, Beliakov, Gleb and Berend van der Zwaag. (2000). Fuzzy Logic in Clinical Practice Decision Support Systems, 33rd Hawaii International Conference on System Sciences, Vol. 05, pp. 1-10.