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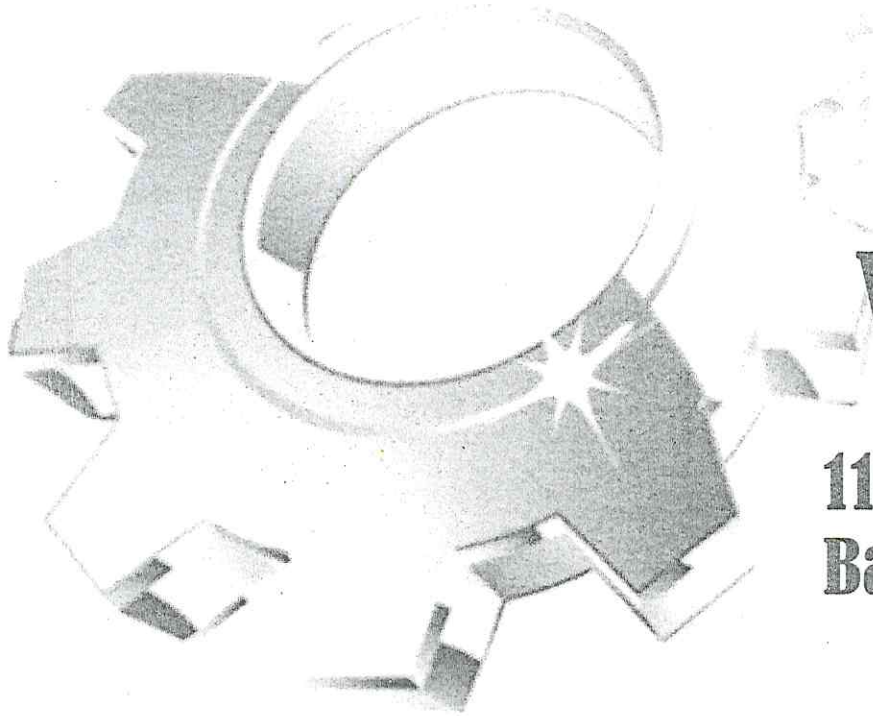

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APPLICATION OF FUZZY LOGIC FOR RISK DETERMINATION OF TYPE 2 DIABETES DISEASE

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Diabetes is a disease caused by insufficient production of insulin by the organ called pancreas. If the insulin secretion in the patient is absent or too small, then it is called diabetes type 1; if the amount of insulin or its effect is insufficient, it is called diabetes type 2.

Nowadays, the topic of diabetes type 2 is becoming increasingly prevalent, even at very young ages. Of course, this spreading has multiple causes. People with diabetes in their family, fat people, people living under stress, are more likely to be sick with diabetes. It is sufficient to several values in the patient's blood analysis for the determination of diabetes type 2. However, determining the exact value of the risk of this disease is difficult for some reasons.

In this study, a fuzzy control system is presented to aid physicians in the diagnosis and to identify a risk value of type 2 diabetes.

Fuzzy systems have become increasingly used in medicine. A number of studies have been conducted on the diagnosis of both types of diabetes mellitus and other according procedures [1, 2, 5–7].

The diagnosis of diabetes mellitus is made by evaluating the symptoms of the disease and blood glucose measurements together. The "fasting blood sugar" measured after at least 8 hours of fasting should be below 100 mg/dl. Diabetes is diagnosed if any of the following conditions exist: (1) The blood sugar level measured at any time of the day exceeds 200 mg/dl and diabetic complaints; (2) The fasting blood sugar level is 126 mg/dl or more; (3) The blood sugar level for the 2nd hour after the test for a sugar test using 75 g of glucose solution is 200 mg/dl or more; (4) The value of the component of glycosylated hemoglobin (HbA1c) exceeds 6.5 mg/dl [4].

The following factors can play a role in diabetes: (a) genetic factors; (b) being overweight and eating high calorie; (c) inactivity; (d) abnormal amount of glucose produced in the liver; (e) metabolic syndrome; (f) delivering a child over 4 kilos; (g) high blood pressure and high stress; (h) the attack of the immune system to the beta cells with error; (i) exposure to certain harmful microorganisms or environment containing toxins.

In order to be able to diagnose diabetes, you need to look at the value of HbA1c, which gives information on the fasting blood sugar, the amount of sugar in the blood serum, the percentage of blood cells covered with glucose in the stomach.

To determine the risk of type 2 diabetes we designed a simple fuzzy expert system. The inputs of such a system will be the fasting and the satiety blood sugar levels, HbA1c and the weight of the patient and the output will be the percentage of risk of diabetes. All inputs and outputs are divided into 4 fuzzy sets for more precise examination of the results of the blood test of the person [3].

As an example (Table 1), a fuzzy membership "Low" status of fasting blood sugar amount values, includes lower numerical values in the normal human fasting blood sugar value. That is, the range of 50 mg/dl to 90 mg/dl was defined as the low range. Secondly, it is a "normal" fuzzy

set, in which the fasting blood sugars range that a normal person should have in the test result (from 70 mg/dl to 130 mg/dl). Thirdly, it is a "High" membership, in which the numerical range of blood test values (from 110 mg/dl to 170 mg/dl) was determined to be higher than the normal value of fasting blood sugar. The last fourth member is the fasting blood sugar entry, "Very High", contains values that we can say critical (no more than 150 mg/dl to 200 mg/dl and over).

Table 1. Min and max value range of inputs and outputs of generated system [3].

Inputs and Output	Low	Normal	High	Very High
Fasting blood sugar (mg/dl)	50-90	70-130	110-170	150-200 and over
Satiety blood sugar (mg/dl)	80-120	100-160	140-200	180-230
HBA1C (%)	1-4,5	2,5-8	6-11,5	9,5-15
Weight (kg)	35-70	50-105	140-200	180-230
Percentage of Risk of Diabetes (%)	1-30	26-59	55-88	85-100

The following 1 to 4 formulas were obtained for the membership functions of the fasting blood glucose levels "Low", "Normal", "High" and "Very High" [3]:

Figure 1 graphically depicts the Fasting Blood Glucose entry organized according to these formulas.

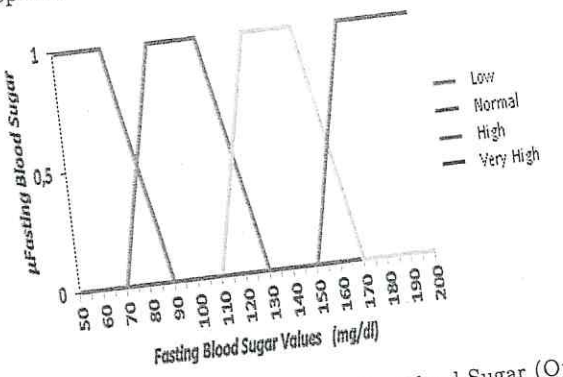

Figure 1. Graphical Presentation of Fuzzy Fasting Blood Sugar (One of the Inputs).

The output value of this system (Diabetes Risk) has also been specified as 4 membership functions Low, Normal, High and Very High (Fig.2).

$$\mu_{Low}(x) = \begin{cases} 1, & \text{if } 50 \le x \le 70 \\ (90-x)/(90-70), & \text{if } 70 < x \le 90 \end{cases} \quad (1)$$

$$\mu_{Normal}(x) = \begin{cases} (x-70)/(90-70), & \text{if } 70 \le x < 90 \\ 1, & \text{if } 90 \le x \le 110 \\ (130-x)/(130-110), & \text{if } 110 < x \le 130 \end{cases} \quad (2)$$

$$\mu_{High}(x) = \begin{cases} (x-110)/(130-110), & \text{if } 110 \le x < 130 \\ 1, & \text{if } 130 \le x \le 150 \\ (170-x)/(170-150), & \text{if } 150 < x \le 170 \end{cases} \quad (3)$$

$$\mu_{VeryHigh}(x) = \begin{cases} (x-150)/(170-150), & \text{if } 150 \le x < 170 \\ 1, & \text{if } x \ge 170 \end{cases} \quad (4)$$

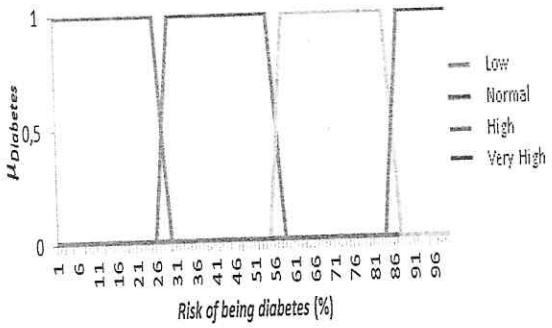

Figure 2. Graphical Presentation of Fuzzy Risk of being Diabetes (Output).

The numbers of the inputs membership function is 4 (Fasting Blood Sugar, Satiety Blood Sugar, HbA1c, and Weight), and each of them has 4 fuzzy values (Low, Normal, High and Very High), so we will have 4*4*4*4=256 fuzzy rules must be written to evaluate all conditions of the input variables.

The developed fuzzy rules which will fire by the obtained membership degrees were arranged by the aid a doctor. To determinate Diabetes Risk, we have used Matlab fuzzy toolbox. Let us see the next examples [3].

Example 1: Fasting Blood Sugar = 125 mg/dl, saturation blood sugar = 155 mg/dl, HbA1c = 8% and Weight = 90 kg. In this case, when the system will start, five rules will be put into action, and the system will find the diabetes ratio as 71.3%. Here the Mean of a Maximum method is chosen as the defuzzifier. If we use the Centroid method as a defuzzifier, the risk of diabetes will be 57%.

Example 2: Fasting Blood Sugar=200 mg/dl; Satiety Blood Sugar=230 mg/dl, HbA1c=%7, and Weight=85 kg. For this patient, five rules will fire and the system finds Diabetes Risk as % 92.7.

So, the projected fuzzy expert system helps doctors when they take a decision about the severity of the disease type 2 diabetes.

Keywords: Diabetes type 2, fuzzy expert system, blood glucose, diabetes risk.

AMS Subject Classification: 93C42.

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