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DESIGNING A RULE BASED FUZZY EXPERT CONTROLLER FOR EARLY DETECTION AND DIAGNOSIS OF DIABETES

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ABSTRACT

It can be easily inferred that improvement in Technology has grown manifold over the years. A large variety of applications have become more compact and concise. Medical field is no exception. However, success rate in medical field has still not reached acceptable limits. The work carried out aims at providing necessary support and assistance to the doctor in getting reliable results. Four specific diseases have been taken into consideration, namely heart disease, kidney disease, diabetic retinopathy and joint disease. A wide variety of parameters have been taken into consideration. A fuzzy expert system has been designed to identify the relationships based on patient's data. This system is in turn used to identify mechanisms for effective disease support application.

Keywords: fuzzy logic, expert systems, rule extraction, fuzzy control, diabetes application.

INTRODUCTION

A large category of disease is prevalent over a wide range of people across the world. Some diseases are curable while some continue to exist for a life time. The problem is more complicated with a delay in detection of incurable diseases. One such incurable disease is diabetes. An early detection of the same can go a long way in providing suitable treatment to keep things under control.

Human body has the ability to convert glucose (sugar) to energy. The presence of diabetes affects the conversion process. Glucose is the main fuel of human body. After taking food, it is digested and converted into fat, proteins and carbohydrates. Food that affects blood sugar includes carbohydrates. This carbohydrate is converted into glucose and fructose. This hormone - insulin is needed when glucose to be transferred from the blood into cells. Insulin is produced by the beta cells in pancreas. This process in impaired. There are two types of diabetes namely Type-I and Type-II.

Diabetes Type-I is formerly insulin dependent diabetes or juvenile diabetes. It is a form of diabetes mellitus that results from autoimmune destruction of insulin producing beta cells of pancreas. The symptoms of Type-I diabetes are polyuria (frequent urination), polydipsia (increased thirst), polyphagia (increased hunger) and weightless. Roughly 10% of the population suffer from Type-I diabetes.

Human body not able to produce insulin for proper functions or our body cells do not react to insulin (insulin resistance).It is a metabolic disorder that is characterized by high blood glucose in the context of insulin resistance and relative insulin deficiency.

For this, Type-II diabetes includes polyuria, polydipsia, polyphagia, inchiness, peripheral neuropathy and vaginal infection. As 90% of the patients suffering from diabetes belong to category of Type-II diabetes, the work is focused on early detection of the same by considering a wide range of factors.

Literature survey

The concept of fuzzy logic was first introduced by Lotfi Zadeh. Although it existed only as a concept in early years, applications started being developed in Europe, as early as in 1970. The early known applications focused on "control aspects". Detailed modeling of such systems began in 1980.During this period, a number of models incorporating fuzzy logic began to be developed. However, a considerable number of applications began to be developed only from early 2000A.D.

In the year 2000, fuzzy technique began to make its usage felt in business and finance applications. During this period, fuzzy techniques began to make its presence felt in a number of medical application and using "soft computing" techniques. In the year 2003, Buisson and Garel developed fuzzy algorithms coupled with heuristic search techniques. They have been used in determining the nutrional habits. In the year 2004, Xiaoguang and John proposed the design of a fuzzy classifier from data. During the same year, Zarkkogianni, Vazeou, Mougiakakou and Nikita developed "an Insulin Infusion Advisory system based on Auto tuning Non-linear model which is a type of predictive control dealing with a considerable amount of fuzzy systems and also handling missing data. This in turn has been demonstrated by Chee-PengLim, JennHwai Leong in the paper "A hybrid network system for pattern classification with missing features" published in the year 2005.

The early known work on fuzzy models for diabetic applications started in the year 2006.Campos-Delgado, Hernandez-Ordanze, Fematand R. Gordillo-Moscoco designed a "fuzzy based controller for glucose regulation in Type-I diabetic patients by subcutaneous route", in the year 2006.Osareh, Shadgar and Markham developed a computation intelligence based approach for detection of exudates in Diabetic Retinopathy Images in the year 2009. Fenglin, Haoying developed a feedback mechanism for fuzzy discrete-Event systems in the year 2010. A detailed focus on a fuzzy Expert system models

for diabetes has been carried out in the year 2011 by Chang-Shing Lee and Mei-Hai-Wang. They concentrated on accurate decision making. With this perspective in mind, the proposed work focuses on designing a fuzzy expert system for predicting the level of diabetes in patients

Introduction to fuzzy logic

It has been known from time immemorial that technology has been advancing at a rapid pace. With more and more real time system being modeled, focus has shifted from accuracy to speed. Most of the ontological systems focus on vague set of information. This in turn brings into perspective usage of fuzzy logic, with a wide range of applications. Usage of fuzzy logic has been augmented appreciably. More and more applications deals with the practice of fuzzy logic, blended with neuro computing and genetic algorithms.

Fuzzy logic is one of the ideal methods to map representation of input to outputs. There are varieties of general inspections about fuzzy logic. It is abstractly easy to empathize. It deals with acceptance of imprecise statistical factors. It may have two distinct consequences. In one aspect, fuzzy logic is a coherent system, which is augmentation of multivalued logic or rationality, in a restricted view. In other aspects, fuzzy logic related with the theory of fuzzy sets relating to the input and output with imprecise boundaries in that degree of membership is a major matter. It is compact and can be analyzed in detail. This analysis is estimated to a certain extent that is predetermined and precise as opposed to conventional binary set where variables may takes a value of true or false. Fuzzy logic has been prolonged to hold the perceptions of partial truth, where the truth value may vary between completely true and complete false. It is used to find the membership function of input and output data. During fuzzification, the input factor is translated into truth values. Input factor of imprecise data are assigned to degree of memberships in various classes and then creating fuzzy sets. In rule evaluation method, the output data truth values are computed. The result are then figured together to generate a set of “fuzzy output” and forming fuzzy rules. In defuzzification technique, the truth values are translated into output data. Fuzzy outputs are then pooled into discrete values needed to initiate control mechanism.

Identification of parameters

Table-1 dealt with general characteristic of diabetes. It now becomes essential; to identify all possible factors affecting diabetes. The ease of identification is further enhanced by identifying its relationship with other diseases.

It has been observed that, the diabetes patients are much more affected by the diseases easily like heart disease, kidney disease, diabetic retinopathy and neuropathy as opposed to normal individuals. This work hence focuses also on parameters affecting heart and kidney diseases. This in turn could help in accessing the input parameters better.

Studies have shown that 347 million people worldwide have diabetes. In 2004, 3.4 million died from the consequence of high fasting blood sugar. In Type -2 diabetes, 90% of people suffer from diabetes around the world. The presence of diabetes could lead damage in heart, blood vessels, eyes, kidneys and nerves. 60-70% of people with diabetes suffer from nerves damage neuropathy. In 2004, 68% of heart ailments results from diabetes related problems. 10% of strokes result from diabetes related problems. Adult with diabetes have heart disease death rates about 2 to 4 times higher than adults without diabetes. The occurrence of stroke is 2 to 4 times higher than people without diabetes. In 2005 to 2008, 28.5% of people with diabetes suffer from diabetic retinopathy. 4.4% with diabetes has advanced diabetic retinopathy. This in turn could lead to reduction in vision. In 2008, 44% of people suffering from diabetic also suffer from kidney failures.

It is enormously vital to take into consideration all symptoms that show a substantial role in the cause of diabetes. Moreover, the extent of seriousness also needs to be assessed.

Taking all these aspects into consideration, a set of input and output parameters have been taken into account. The corresponding parameters are listed in Table-1.

Choice of membership function

A membership function (MF) is a curve that maps each aspect to a crisp value. However, the value is not definite and ranges between 0 and 1. It is desirable to identify the possible membership functions to be chosen for each parameter. However, sufficient research has not been conducted, which identifies in precise terms the choice of the membership function. Apart from the number of membership functions, a number of other factors behavioural aspects, each fuzzy variable encountered in the problem is represented using Triangular (Waist circumference (Men), Glucose (FBS), Glucose (BBPS), Cholesterol, BP1), and Trapezoidal (Creatine, Urine albumin, Urea, Sodium, Potassium). The only constraint is that any membership function has to satisfy is that its values must be in the 0 to 1 range.

Table-1. Parameter and their corresponding functions.

Type (Input/output)	Parameter	Factor on which it depend
Input	Age	Age of the patient
	Waist circumference	Waist hip ratio of the patient
	BMI	Weight and height of the patient
	Glucose (FBS, PPBS, RBS)	Level of glucose of the patient
	Creatine	Level of creatine of the patient
	Urine albumin	Level of urine albumin of the patient
	Cholesterol	Level of fat of the patient
	Blood pressure	Level of blood pressure of the patient
	Urea	Urea level in blood
	Sodium	Sodium level in blood
	Potassium	Potassium level in blood
Output	Heart disease	
	Kidney disease	
	Diabetic retinopathy	
	Stroke	
	Joint disease	
	SLE	
	PVD	
	Hyper Tension	

Triangular membership function

It is potted using three variables a, b and c in the x-axis, where a, c are the lower boundary and the upper boundary, whose membership degree is zero. b is the centre point, its membership degree is one. A sample Triangular membership represent has been shown in Figure-1.

For example, the fuzzy variable Glucose (FBS) can be classified into fuzzy modifiers very low, low, medium, high and very high as shown in Figure-2.

$$\mu A(x) = \begin{cases} 0, & x \le a \\ \dfrac{x-a}{m-a}, & a \le x \le m \\ \dfrac{b-x}{b-m}, & m \le x < b \\ 0, & x \ge b \end{cases}$$

If the amount of Glucose (FBS) consumed in between 0 to 80 mg\dL, so it is considered to be very low.

If it is between 50 to 130mg\dL, it is considered low. Value varies from 80 to 150 mg\dL, it is considered as medium and those between 130 to 180 mg\dL are considered as high. The mean value ofeach modifier's range has a membership degree of 1.

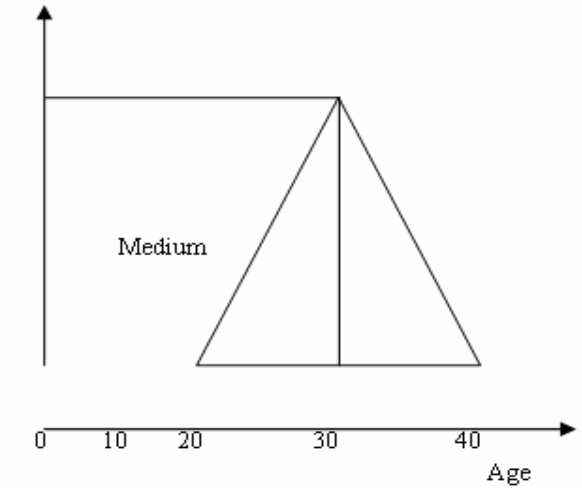

Figure-1. Triangular membership function.

Trapezoidal membership function

It is plotted using four variable a, b, c and in the axis where and d are the lower boundary and upper boundary whose membership degree whose membership degree is zero, b and c are intermediate boundaries where the membership degree is 1. A trapezoidal membership function represented has been shown in Figure-3.

$$\mu A(x) = \begin{cases} 0, & x \le a \\ \frac{x-a}{b-a}, & a \le x \le b \\ 1, & b \le x \le c \\ (d-x)/(d-c), & c \le x \le d \\ 0, & d \ge x \end{cases}$$

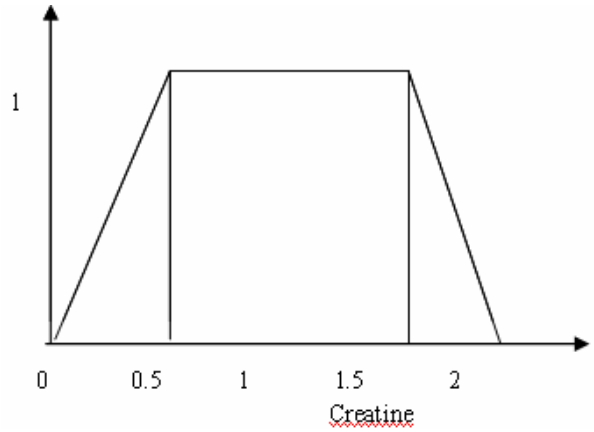

Figure-2. Trapezoidal membership function.

For example, the fuzzy variable creatine can be classified into low, normal, high as shown in Figure-4. If the creatine is between 0 to 0.25mg\dL, it is considered as low. If it is between 0.15 to 2.5 mg\dL, it is considered to be normal. If it is between 2to 2.5 mg\dL, it is considered to be high. Each fuzzy modifier has a membership degree of 1 for a range of value. Hence, trapezoidal membership function is chosen.

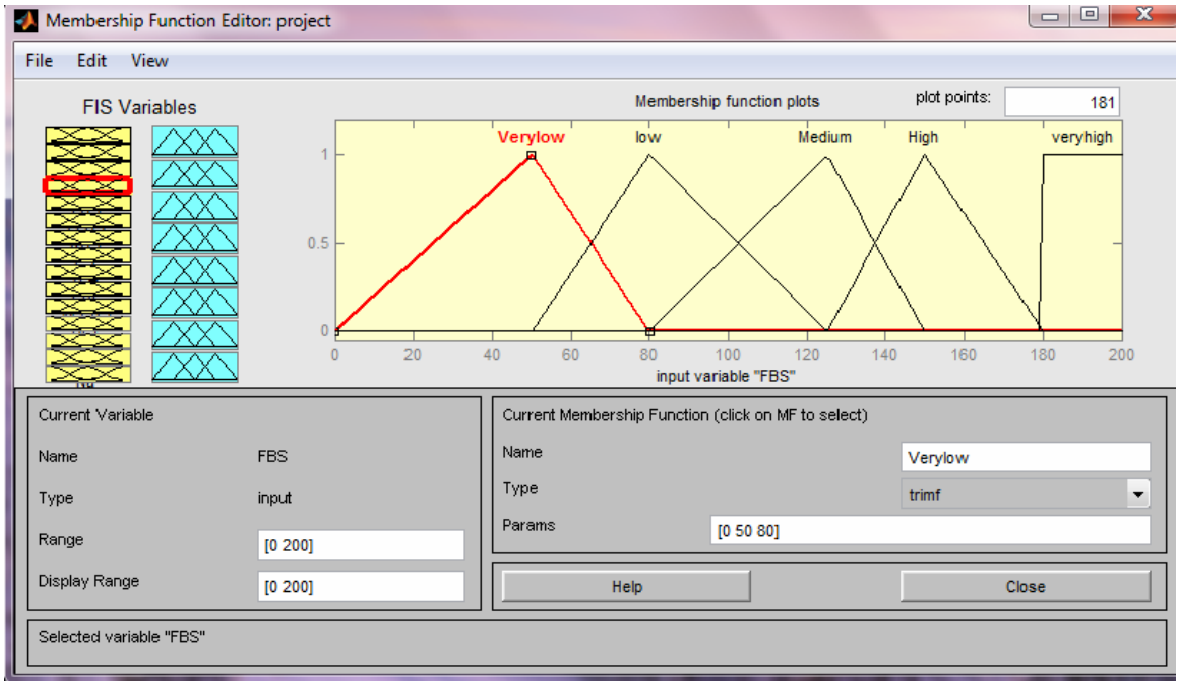

Figure-3. Membership function for glucose (FBS).

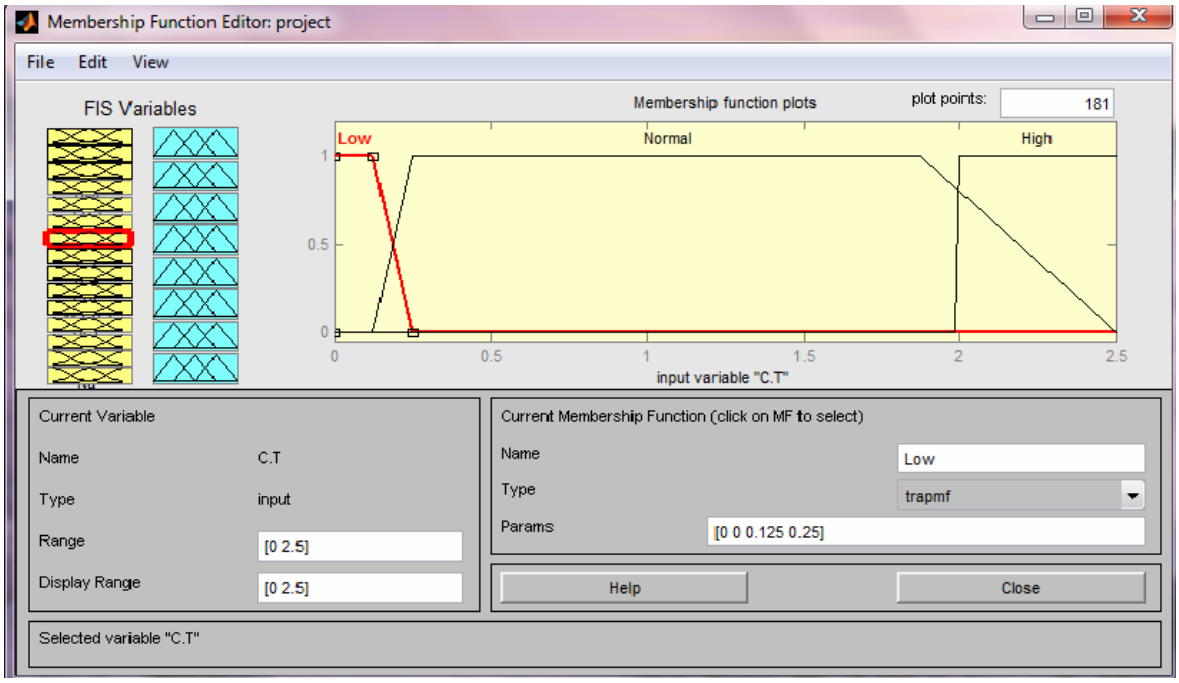

Figure-4. Membership function for creatine.

The fuzzy variable 'BMI' has a combination of both trapezoidal and triangular membership functions. This is shown in Figure-5. The fuzzy modifiers 'low' and 'very high' are represented as trapezoidal membership function. Since a range of values has truth value of 1. The fuzzy modifiers 'medium' and 'high' are represented as a triangle. Since each of its have a definite truth values of 1.

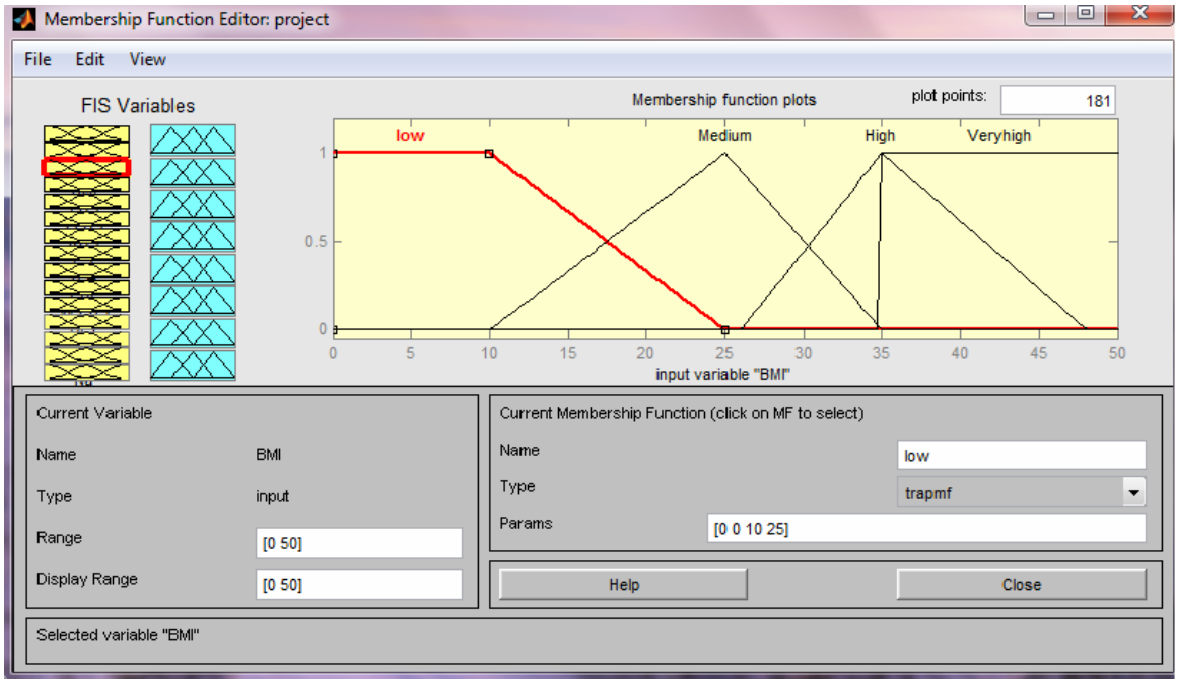

Figure-5. Membership function for BMI.

Design of fuzzy logic controller

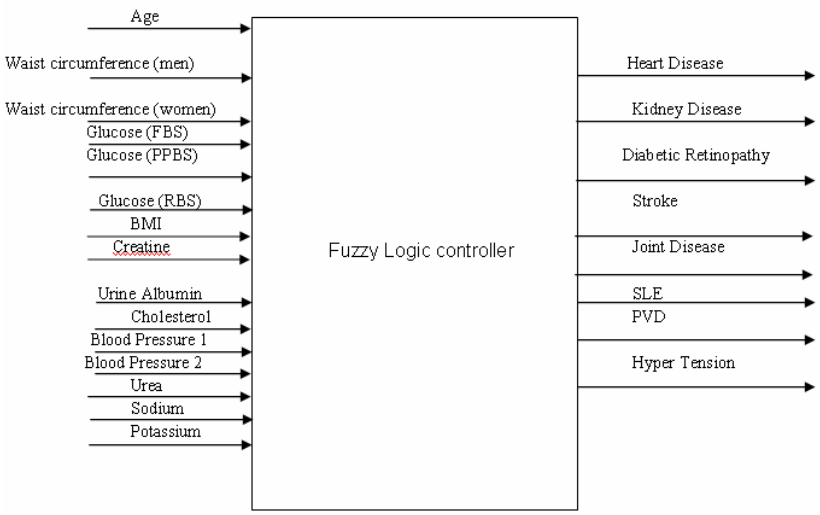

Figure-6. Fuzzy logic controller.

Having pruned the list of factors to be considered, a fuzzy logic controller has been designed as shown in Figure-6.

A choice needs to be made in the design of inference engine. A Mamdani or Takagi Sugeno model can be developed. It has been inferred through studies that Sugeno model is suitable for functional analysis. Besides, the output membership functions are either linear or constants.

The characteristics of parameters obtained from various patients do not satisfy the property of linearity. Hence it is proposed to go in for a Mamdani model.

The structure of the model is shown in a Figure-7.

Mamdani model is intuitive and well suited to human input. The characteristics of various patients have been fed into the system. The speciality of this approach is that the system could handle missing values without sacrificing its behavior. This aspect provides added relevance when particular factor value is not found in a patients report or also when erroneous values have been provided. In the reports collected from a reputed hospital for one of the patients aged 64, creatine has not been measured. The system is still able to handle the same and make suitable predictions.

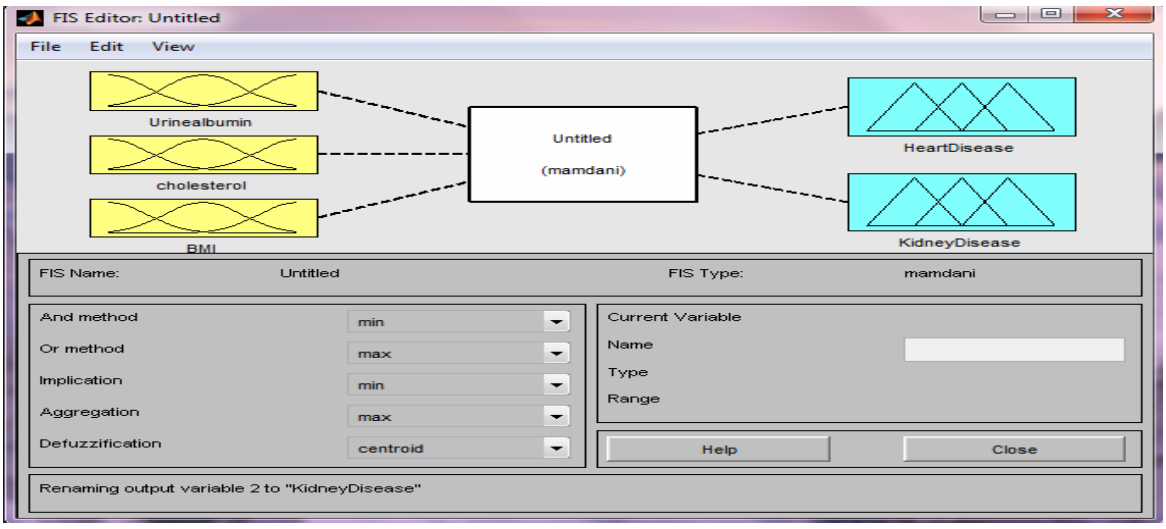

Figure-7. Structure of Mamdani model.

Sensitivity analysis

It has been observed that some of the parameter hardly plays any role in identifying the presence or absence of diabetes. These parameters include Sodium and Potassium. These parameters in turn can be pruned out of the system and can be omitted from further consideration.

Through appropriate experimentation, highly sensitive and insensitive parameters are identified. The non pruned factors have been taken and simulated to produce the necessary results for a number of patients. This has been illustrated in Figure-8.

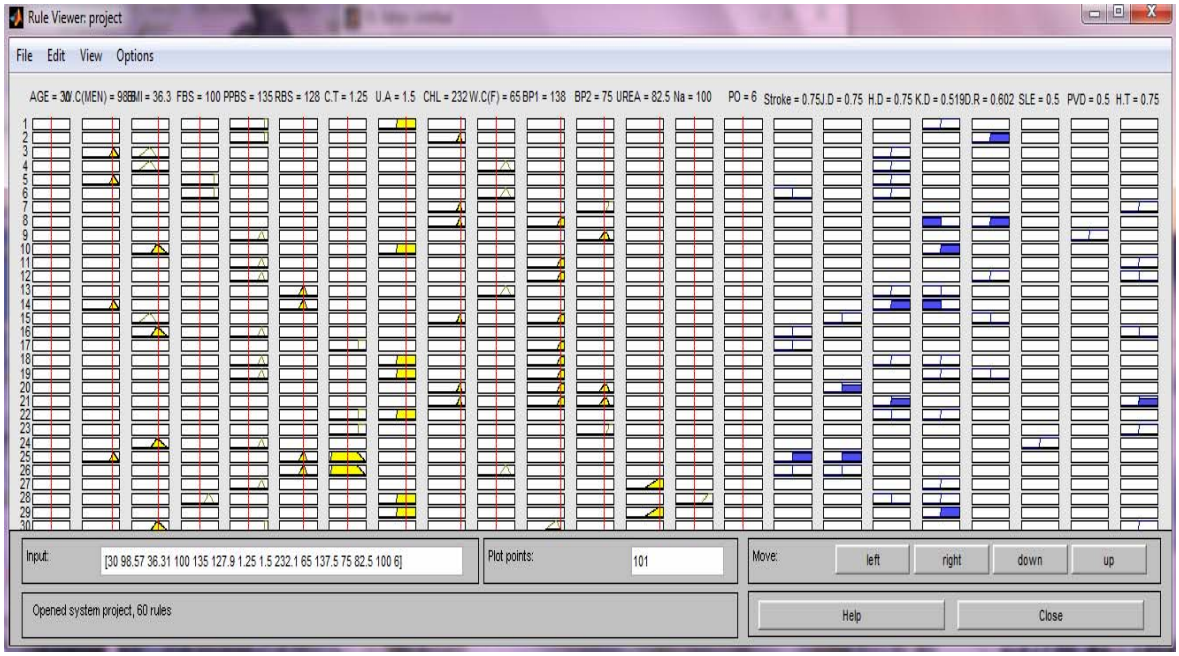

Figure-8. Sensitivity analysis.

Diagnosis of fuzzy logic controller

With a wide range of inputs and outputs taken into consideration, it becomes essential to find the various ways in which the various factors interact with each other. Sufficient care has been taken to ensure that the detection of a particular disease is effectively evaluated with data from a large number of patients. It has been observed that there is a significant effect in the presence of kidney disease with variations in creatine. Besides, variations in values of urine albumin also play a role in affecting the same. The presence of stroke is influenced by factors like age and waist circumference. Variations in level of cholesterol and blood pressure 2 have a profound influent of diabetes in patients. Besides, cholesterol along with blood pressure 1 also has a significant effect on hyper tension. The relation of BMI and Urine albumin of Kidney disease is shown in Figure-9

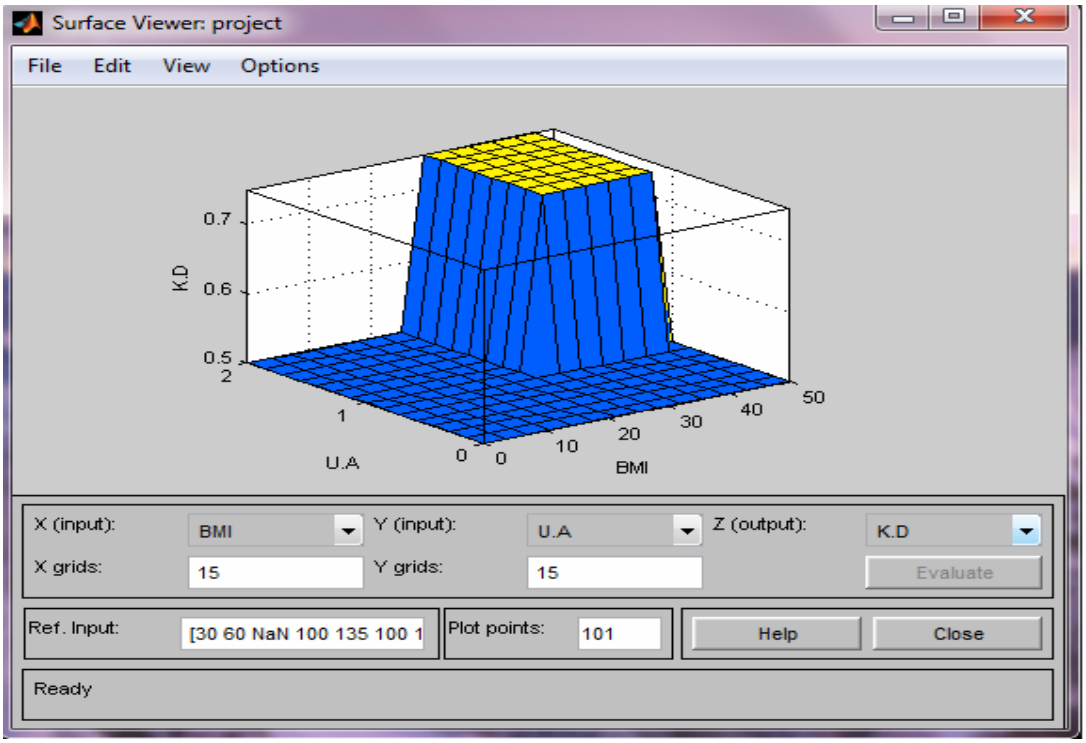

Figure-9. Relationship of BMI and Urine albumin of Kidney disease.

CONCLUSIONS AND RECOMMENDATIONS

An efficient fuzzy logic system has been designed to identify the factors that could lead to diabetes. The work carried out has performed extensive sensitivity analysis to accurately identify heart, kidney, and eye disease of all possible interactions among various factors that could in turn assist the doctors in providing suitable treatment. As the given set of information has been tested with sixty patients, sufficient validation has been done. It has been observed that some of the parameters like BMI and Creatine have definite values and its effect could be observed better by designing a suitable neural network. The improvement in efficiency of the same is left for further investigation.

However, despite these minor hiccups, the designed tool can be handling for the doctors in making good assessments.

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