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A Fuzzy Expert System for Risk Self-Assessment of Chronic Diseases

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Abstract: *Non communicable diseases, also known as chronic diseases are leading causes of death in the world. Even though advancements in the field of medicine make it easier to treat chronic diseases, there are still insufficiencies regarding the determination and evaluation of its risk factors. In this study, various risk factors used to diagnose were investigated by taking into consideration the individuals with common symptoms and complaints about chronic diseases. Accordingly, risk factors of them were determined. In addition, total chronic disease risk levels of individuals were determined with fuzzy expert system approach. The designed system operates with rule base established via knowledge acquired from medical experts. The system provides risk self-assessment to decrease the risk. Thus, an increase in the number of people suffering from chronic diseases can prevent or retard.*
Keywords- *Chronic diseases, fuzzy expert system, fuzzy logic, risk assessment.*

I. Introduction

Over the last years, health systems have developed significantly. People are not healthy completely, in spite of this developments [1].

Non communicable diseases (NCDs), are prolonged in duration, do not resolve spontaneously, and are rarely cured completely [2]. Examples of non-communicable diseases include cardiovascular diseases, cancer, stroke, asthma, and diabetes.

Fuzzy logic was first developed in the 1960s as a mathematical modeling approach by Zadeh. In the 1970s, Mamdani and Assilian succeeded in controlling a steam engine via fuzzy system model. Interest in fuzzy logic increased following the successful applications in the coming years after which in 1989 laboratory for interchange fuzzy engineering (LIFE) laboratories were established as an international study environment by 51 companies including leading brands such as Thomson, Hitachi, IBM, Fizzy drinks SGS, Toshiba [3]. Studies on fuzzy logic continued during the following years as well. For example, Allahverdi et al. designed a fuzzy expert system to determine the risk of coronary heart disease [4]. Schuster et al. evaluated the coronary heart disease risk using fuzzy logic via a decision support system [5]. Pal et al. examined CAD via fuzzy expert system approach using clinical parameters. They developed a fuzzy expert system to support doctors about risk assessment [6]. Khatibi et al. used a fuzzy evidential hybrid inference engine to evaluate the coronary heart disease risk [7]. Muthukaruppan et al. designed fuzzy expert system based hybrid particle optimization for the diagnosis of CAD [8]. Duarte et al. applied clinical-epidemiologic data and treadmill test results on fuzzy set theory for the selection of myocardium perfusion scintigraphy patients [9]. Adeli et al. designed a fuzzy expert system for the diagnosis of heart disease [10]. Sikchi et al. designed a generic fuzzy expert system for heart diseases. It was used as a supportive tool for the diagnosis of heart diseases [11]. Parvin et al. designed a fuzzy database for the diagnosis of heart disease. When there is a uncertainty in data used for diagnosis, the database based on fuzzy logic approach provide accurate data for decision makers [12]. Maranate et al. conducted a study to prioritize risk factors of obstructive sleep apnea by using fuzzy analytic hierarchy process based on normalized weight vector [13]. Sharma et al. performed a study to detect CAD in early stage. Fuzzy system was used for processing images about coronary artery blockage [14].

The aim of this study is to enable individuals to assess their risks themselves about chronic diseases. Hence, a fuzzy expert system was developed. The system gives total chronic disease risk level for each individual. In addition, it also provides customized advice to decrease the risk. Usage of this system can raise awareness in public regarding chronic diseases. Thus, suffering from chronic diseases of individuals can prevent or retard.

II. Materials and Methods

Chronic Diseases

According to the knowledge acquired by doctors, common chronic diseases have been classified as coronary artery disease, cerebrovascular disease, diabetes and chronic obstructive pulmonary disease. They were explained below.

Coronary Artery Disease (CAD): CAD is one of the important chronic diseases in the world. It occurs when the arteries that feed the heart known as coronary arteries narrow or are blocked thus resulting in the partial or complete cessation of blood flow. If this disease is not noticed beforehand and if the necessary precautions are not taken, this might lead to the cessation of blood flow due to embolism as well as rhythm disorders in the heart leading to myocardial infarctions and death [15].

Chronic Obstructive Pulmonary Disease (COPD): COPD is an important disease which is related to respiratory directly. It is third death cause in the United States. There are millions of people in the world suffer from COPD. It develops slowly. Its symptoms can affect daily activities negatively [16].

Diabetes: Diabetes is a disease characterized by high blood glucose levels. The American Diabetes Association categorizes diabetes as type-1 diabetes and type-2 diabetes. Type-1 diabetes is generally diagnosed in children. Type-2 diabetes is the most common form of diabetes. Insulin secretory defect causes type-2 diabetes [17].

Cerebrovascular Disease: A neurologic symptom or symptom complex caused by cerebral ischemia or hemorrhage is generally named a cerebrovascular accident. Important clinical characteristics are dramatic or subacute onset and (except for subarachnoid hemorrhage) focal neurologic deficit. Damage level of the disease depends on when it is diagnosed. Apart from the common features, it is divided into groups in terms of symptoms [18].

Fuzzy Expert System Structure

The application of fuzzy logic principles in a system that will be set up during the decision making stage for the diagnosis of chronic diseases will enable the elimination of the negative aspects of the classical logic principles. In the set theory which is the foundation of classical logic, an object either belongs to a set or does not belong to a set. Thus, we can state that the degree of membership for classical sets is either 1 or 0. No other degree of membership can be considered. This leads to mistakes in the determination of the risk levels of patients. On the other hand, the degree of membership in fuzzy set theory can take on values between 0 and 1. In other words, degree of membership takes on values between the interval of [0, 1] and is shown as $\mu(x)$. This gives more accurate results for determining the risk levels of individuals [19].

Fuzzy expert system is an artificial intelligence technology that enables the processing of uncertainties, contradictions and linguistic expressions in the computer environment. A fuzzy system consists of four elements which are fuzzification, knowledge base, inference mechanism and defuzzification. Main structure of fuzzy expert system was shown in Figure 1. The first step of this system is to determine the input variables and to fuzzify the input values. The second step is to form a knowledge base via expert knowledge. The relationships between input and output values are determined at this step. The values acquired based on the rules generated using expert knowledge are processed at the inference mechanism as the third step. Finally, fuzzy output values are sent to the defuzzying unit to obtain net values.

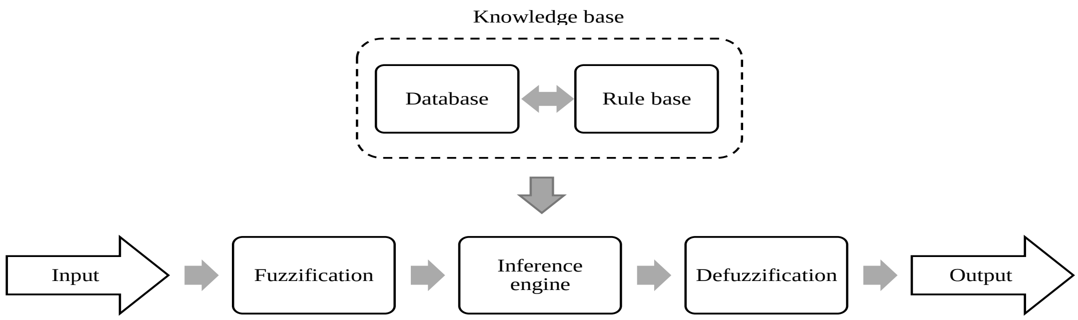

Figure 1. Structure of fuzzy expert system

The membership functions of the input variables are generated using the knowledge acquired by experts. In this study, triangular and trapezoidal membership functions were used from among the various membership functions. Because these represented the knowledge acquired from experts best. There are three parameters as a1, a2 and a3 for the triangular membership function as the corners of the triangle. a, b, c and d have four parameters as the corners of the trapezoidal membership function. These are presented in Figure 2.

$$\mu(X_i) = \begin{cases} 0 & ,x < a_1 \; and \; x > a_3 \\ \dfrac{x - a_1}{a_2 - a_1} & ,a_1 < x < a_2 \\ \dfrac{a_3 - x}{a_3 - a_2} & ,a_2 < x < a_3 \end{cases}$$

$$\mu(X_i) = \begin{cases} 0 & ,x < a \; and \; x > d \\ \dfrac{x - a}{b - a} & ,a < x < b \\ 1 & ,b < x < c \\ \dfrac{d - x}{d - c} & ,c < x < d \end{cases}$$

Figure 2. Triangular and trapezoidal membership functions

The knowledge base that includes the expert knowledge for chronic diseases is the interface enabling the use of linguistic expressions by fuzzy logic control. It has two parts as data base and rule base. Data base covers the linguistic definitions of the input and output values, the membership functions, information related with the variables and the definitions of the fuzzy functions used in fuzzy logic control. Whereas rule base includes the inspection rules determined by experts for chronic diseases. These rules explain the logical relationships between the input and output parameters of chronic diseases. The rules are generated by the "if-then" commands.

Inference unit is the main block where the control function is executed and the decision making process occurs. Decision is made by processing the rules obtained from the knowledge base and the fuzzy inputs acquired from the fuzzification interface. Fuzzy results are obtained after decision is made via the selected logical inference mechanism. Different methods are used in the rule base according to the modeling type of the knowledge. These are Mamdani and Sugeno methods. The fuzzification of input variables and the operations related with fuzzy logic are the same in these two methods. The difference between the two is the membership function. In the Mamdani method, it is determined how effective each rule is on the output after the rules are passed through the min operator. The fuzzy result is obtained after max operator is used on these outputs. As a result, a fuzzy set is obtained. Whereas the Sugeno method yields a precise output even though the input variables are a fuzzy set [20].

The fuzzy values obtained from the inference mechanism are transformed into net values via the defuzzification interface. There are many methods of defuzzification. The most frequently used among these is the center of gravity method. Here, the center of gravity of the area limited with the membership function is defined as the most distinct shard value. Finally, the obtained value is the output of the system and gives total chronic diseases risk level as a percentage.

III. Case Study

The fuzzy expert system was developed by using Matlab fuzzy logic toolbox. The first step of the fuzzy expert system is determining the input and output values. There are four input variables and one output variable in the system. The values of the input parameters were generated according to the knowledge acquired from the doctors.

Fuzzy rule base was set up after establishing the membership functions of the variables in order to understand the relationships among them. The rule base of the fuzzy model generated for the application was set up solely based on expert knowledge and experiences. Current input variables were separated into three fuzzy sets thus acquiring 3^4=81 rules from the interaction among them. The sample rules which use the input and output values are given in Figure 3.

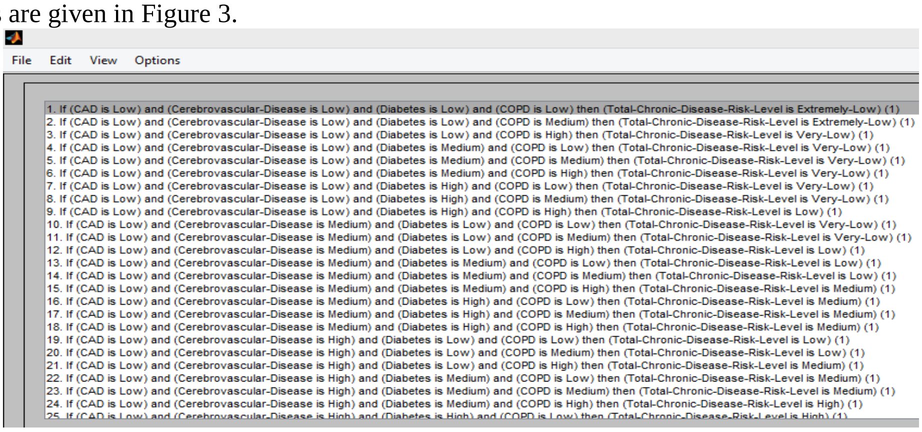

Figure 3. Sample rules from rule base of the system

Mamdani approach was used as inference mechanism in the designed system. Logical combinations of the inputs were generated in the system for all rules with and operator. In addition, max method was used for the addition operation of the rules. Fuzzy values acquired as a result of inference were sent to the defuzzification unit and transformed into real numbers. Center of gravity method was used in the defuzzification sub-system. The surface viewer samples of the variables in the system are given in Figure 4 and 5.

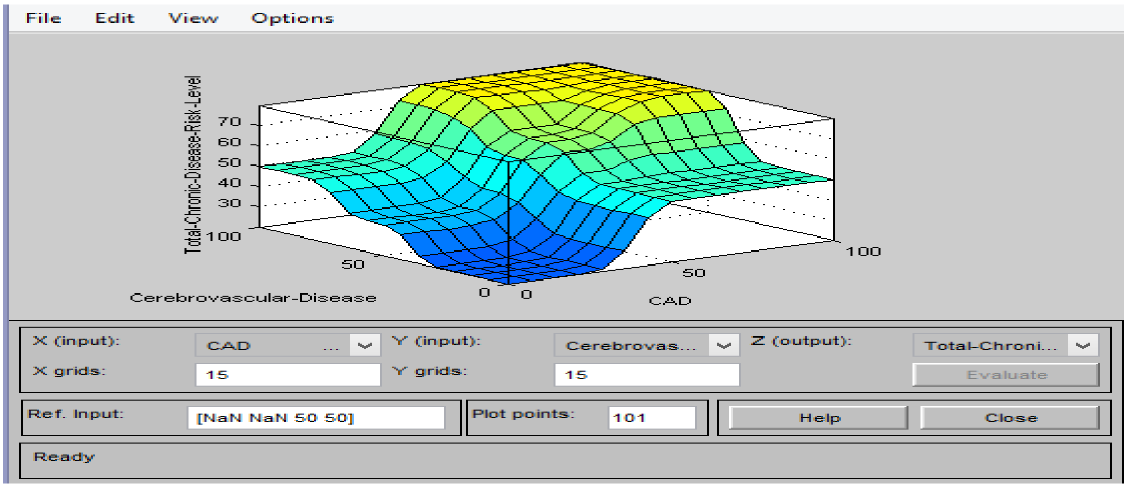

Figure4. Surface viewer for CAD and cerebrovascular disease factors

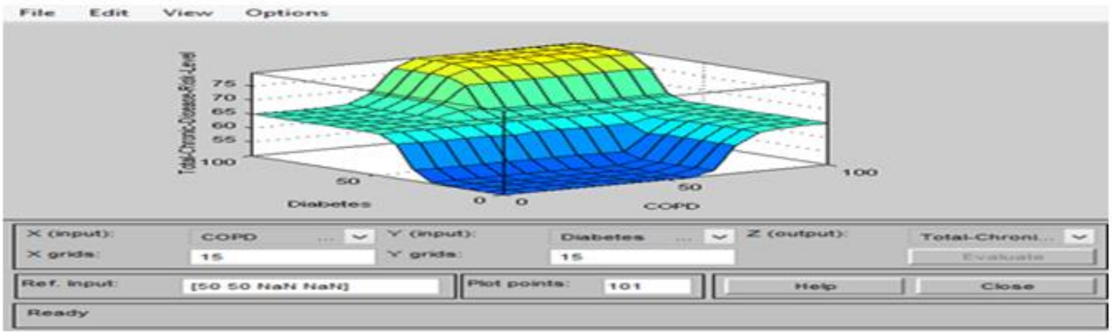

Figure 5. Surface viewer for Diabetes and COPD factors

IV. Results And Discussion

The system was tested with the values in Table I. The result is shown in Table I and Figure 6. According to the result, total chronic diseases risk level was determined as 76% by using the medical data for the system test.

Table I. System Testing

CAD	Cerebrovascular Disease	Diabetes	COPD	Total Chronic Diseases Risk Level
65	75	50	40	76%

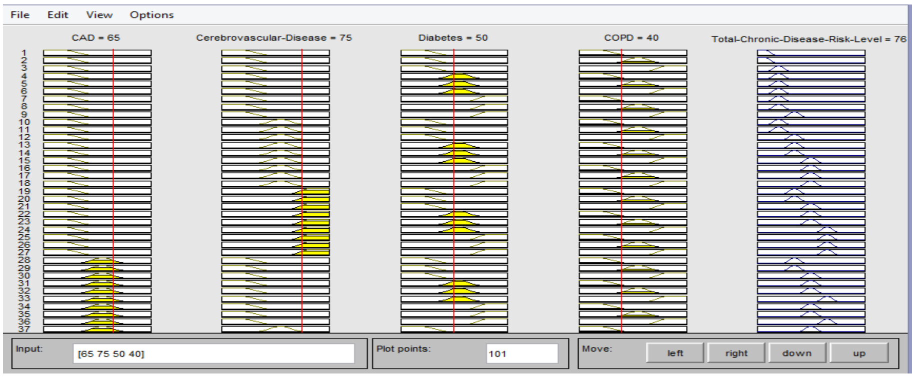

Figure 6. Result of the test values in the system

The expert system also provides a personalized clues and recommendations to decrease the chronic diseases risk level in individuals. Examples of these were presented in Table II.

Table II. Recommendations to decrease the risk

You should quit smoking if you do	You can get help from polyclinics to stop smoking.
Visit your doctor regularly	Visit your doctor for regular controls in order to decrease your cholesterol, control your tension and regulate your blood sugar.
Eat healthily	A dietician can help you about making the right changes in your diet.
Carry out physical activities	Carrying out physical activities will help you to reach a healthy weight or to preserve your current weight. In addition, it will also contribute to balancing out the other risk factors.
Do not stress out	You should brush aside the thoughts and problems in your mind and try to relax. In addition, you should spend more time for your hobbies and do things that make you feel happy.
Do not consume too much alcohol	Over-consumption of alcohol triggers hypertension thus resulting in imbalances in the heart rate. Alcohol should be limited to at most one glass per day.

V. Conclusion

In this study, a fuzzy expert system was developed to determine the total chronic diseases risk level of the individuals. The effect levels of the factors in causing chronic diseases and their effects on each other have various uncertainties. Thus, fuzzy logic approach was used while designing the expert system. Besides, it is based on knowledge and experience acquired from specialist doctors because they are used for building fuzzy sets and rule base.

Developed system tests the individual with medical data and gives the risk value of the individual as a percentage. In addition, it also provides personalized recommendations to decrease the risk. Individuals can assess their total chronic diseases risk level and decrease this risk thanks to the designed system. It can be used easily since it is easy to understand and fast. However, this system does not aim to take the place of hospital tests or doctor inspections.

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