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FUZZY EXPERT SYSTEM APPROACH FOR DETERMINING THE CARDIOLOGICAL RISK FACTOR

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1. The General Structure of the Developed Fuzzy Expert System Software

A fuzzy expert system consists of four main parts: a fuzzifier, fuzzy rule base, fuzzy inference mechanism and a defuzzifier [1-3]. In the constructed Fuzzy Expert System (FES) software, cardiological symptoms named as arrhythmia strength (percentage), arteriosclerosis strength (percentage), systolic blood pressure and the ratio of forced expiratory volume (FEV_1) to forced vital capacity (FVC) are used as the input variables. Arrhythmia, arteriosclerosis and blood pressure and FEV_1/FVC ratio are depicted by 4 linguistic variables named as "Low, Medium, High and Very High". The output of the developed FES is cardiologic risk factor which is depicted by 6 linguistic variables named as "Very Low, Low, Medium, High, Very High and Extremely High". The rule base consists of 256 rules and Mamdani inference mechanism is used as the inference mechanism. The center of sums method is used for defuzzification. The rule base is constructed in the Microsoft Excell table and can be changed by the user for the test processes. The rules are derived from the Micosoft Excel table by the prepared software and this specification provides the flexibility and adaptation to new situations. The fired rules and the firing levels of each rule are also shown by the designed software. The membership degrees calculated by the FES are also shown via the listboxes in the designed software. Visual C# programming language is used for implementing the fuzzy expert system software.

The term "arrhythmia" refers to any change coused in the normal sequence of electrical impulses of the heart. The electrical impulses of heart may be too fast, too slow, irregular– causing the heart to beat too fast, too slowly, or erratically. The other organs may be damaged for the irregular circulation of blood in the body. Arteriosclerosis is the hardening and thickening of the walls of the arteries. Arteriosclerosis can occur due to of fatty deposits on the inner lining of arteries (atherosclerosis), calcification of the wall of the arteries, or thickening of the muscular wall of the arteries from chronically elevated blood pressure. Arteriosclerosis is accepted as the second input variable for the constructed FES based software. Although atherosclerosis is often considered as a heart problem, it can affect arteries anywhere in the human body. The third input variable is systolic blood pressure that is also a significant variable affecting cardiological risk factor [4-5]. The fourth input variable named as the ratio of forced expiratory volume to forced vital capacity. Forced expiratory volume in one second (FEV_1) is the maximum volume of air that can forcibly blow out from the lungs in the first moment during the FVC test and measured in litres. Along with FVC it is considered one of the primary indicators of lung function. Forced vital capacity (FVC) is the volume of air that can forcibly be blown out after full inspiration, measured in litres. The ratio of FEV_1 to FVC is a significant parameter that defines the shortness of breath syndrome observed in Cardiological diseases.

2. Membership Functions of the Fuzzy Expert System

The FES consists of four input variables named as arrhythmia strength (%), arteriosclerosis strength (%), blood pressure (cm Hg) and the ratio of FEV_1 to FVC (%). The membership functions of the input variables of the developed FES are shown in Figures 2.1a-2.1d. The severity of the arrhythmia and arteriosclerosis disease is depicted by the percentage value in the membership functions. The cardiological risk rate (%) is accepted as the output variable in the designed software and the output variable is depicted in Figure 2.2. The general appearance of designed software is shown in Figure 2.3. According to data used in this examle (arrhythmia strength is 45%, arteriosclerosis strength is 35%, blood pressure is 15 cm Hg and the ratio of FEV_1 to FVC (%) is 45), the calculated risk factor is 70 %.

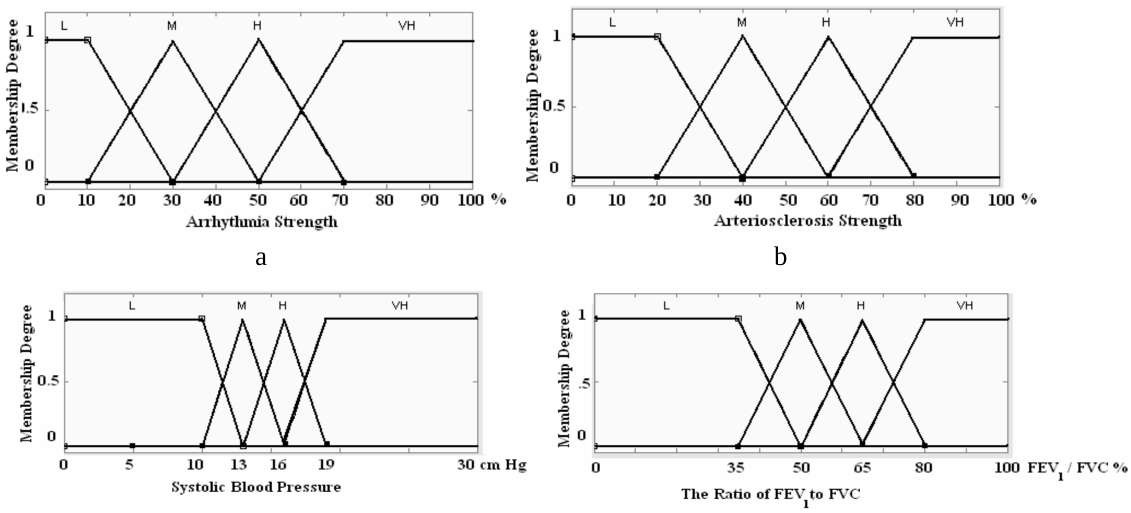

Figure 2.1 The membership functions of the input variables a) Arrhythmia (percentage (%) of the severity of the disease) b) Arteriosclerosis Strength (%) c) Systolic Blood Pressure (cm Hg)d) FEV_1/FVC ratio (%)

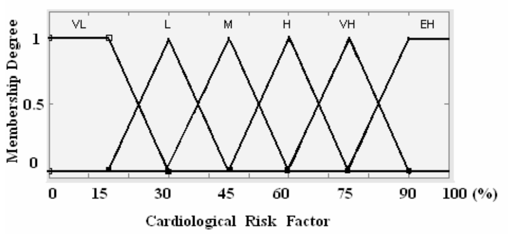

Figure 2.2 Membership functions of the output variable named as Cardiological Risk Factor (%)

3. Mamdani Inference Mechanism

Mamdani inference system is used in prepared FES due to its simpicity. Mamdani inference system can be summarized as follow (3.1 – 3.3). This implication system uses implication method as minimum, and aggregation method as the maximum [1-3]. Mamdani inference mechanism is a successful and suitable approach to transfer the expert intuition and knowledge to the inference mechanism [6-10].

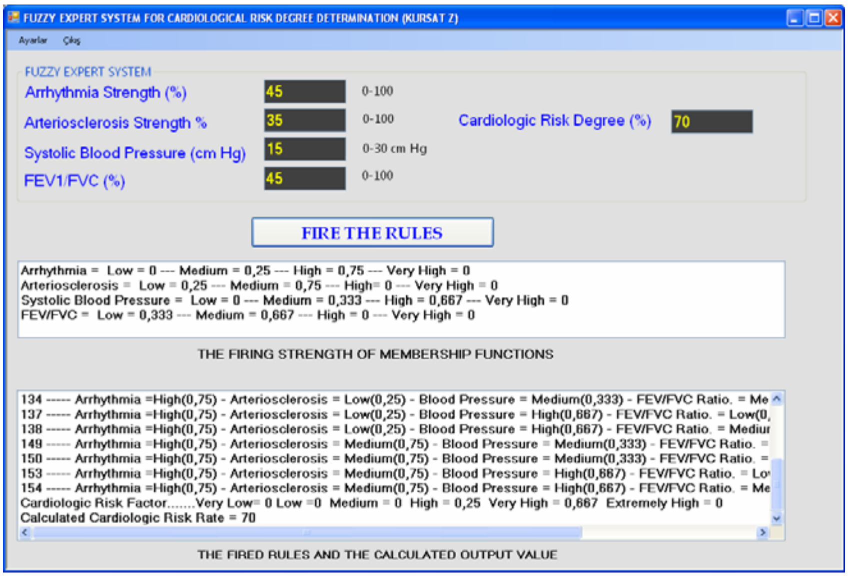

Figure 2.3 The general structure of the fuzzy expert system

Ri = If x= Ai and y= Bi , then z= Ci
i=1,2,....,n $x \in U$

$$\alpha_i = \mu_{Ai}(x_o) \wedge \mu_{Bi}(y_o) \quad \ldots\ldots 3.1$$

$$\mu_{CI}(z) = \alpha_i \wedge \mu_{Ci}(z) \quad \ldots\ldots 3.2$$

The total result is derived from the individual rules in the rule base.

$$\mu C'(z) = \bigvee_{i=1}^{n}[\alpha_i \wedge \mu_{Ci}(z)] \quad , \quad C' = \bigcup_{i=1}^{n} C_i' \quad \ldots\ldots 3.3$$

4. Constructed Rule Base and Defuzzification Method

The rule base consists of 256 rules. Some of the rules are expressed as below:

Rule 133: If Arrhytmia is High, Arteriosclerosis is Low and Blood Pressure is Medium and FEV_1/FVC ratio is Low then the Cardiological Risk Factor is Very High.

Rule 222: If Arrhytmia is Very High, Arteriosclerosis is Medium and Blood Pressure is Very High and FEV_1/FVC ratio is Medium then the Cardiological Risk Factor is Extremely High.

The center of sums defuzzification method was used in the software. This process involves the algebraic sum of individual output fuzzy sets like c_1 and c_2 instead of their union. Defuzzified value denoted as z* is calculated by the formula 4.1. $\overline{z}$ is the distance to the centroid of the respective membership functions [1-3].

$$z^* = \frac{\int_z \overline{z}.\sum_{k=1}^{n} \mu c_k(z).dz}{\int_z \sum_{k=1}^{n} \mu c_k(z).dz} \quad \ldots\ldots 4.1$$

5. Conclusions

Successful results were obtained when the designed Fuzzy Expert System is tested. Some of the results derived from the constructed FES are shown in Figure 5.1.a and 5.1.b. In Figure 5.1.a, the ratio of cardiological risk versus the input variables Arrhythmia and arteriosclerosis strength is shown when systolic blood pressure is 10 cm Hg and FEV_1/FVC is %35. Figure 5.1.b depicts the Cardiological risk factor according to Arrhythmia percentage and FEV_1/FVC ratio when the Arteriosclerosis strength is %20 and Systolic Blood Pressure is 10 cm Hg (110 cm Hg). The obtained results showed that designed FES has capability and qualification for supporting cardiologists.

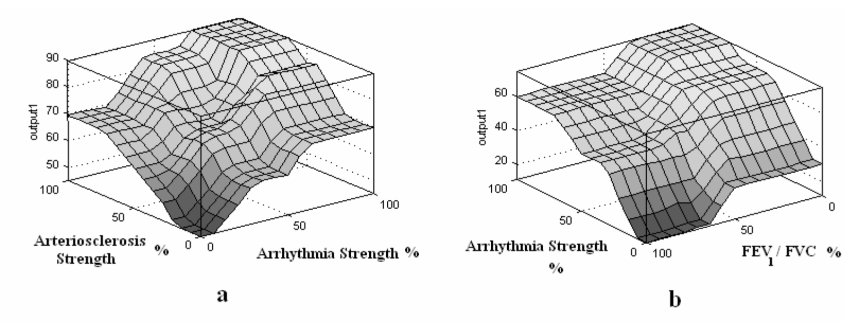

Figure 5.1 a) Three dimensional graphic of Cardiological Risk factor according to input variables Arteriosclerosis Strength and Arrhythmia Strength. b) Three dimensional graphic of Cardiological Risk factor according to Arrhythmia Strength and FEV_1/FVC ratio.

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References

1. N.Allahverdi, "Expert Systems. An Artificial Intelligence Application" (In Turkish), Istanbul: Atlas, 2002, 248 p.
2. C.V. Altrock, "Fuzzy logic and Neuro Fuzzy applications explained", Prentice Hall PTR, 1995, 368 p.
3. N. Baykal, T. Beyan, "Fuzzy Logic Expert Systems and Controllersr", Bıçaklar Book Store, 2004, 509 p.
4. Mayo Foundation for Medical Education and Research, www.mayoclinic.com, Last access: April 2010.
5. Medical Dictonary Definitions, www.medterms.com, Last access: April 2010.
6. J. Zhu, Fuzzy Control Principle and Application, Publishing House of Mechanic Industry, Beijing, 1995.
7. S. Liu, and etc., "Fuzzy Control Technology", Publishing House of China Textile, Beijing 2001.
8. P.K. Lim, N.R. Spooner, "Climatic Control of Storage Chamber using fuzzy Logic", Proceedings of the 2nd New Zealand Two-Stream International Conference on Artificial Neural Networks and Expert Systems, IEEE, 1995.
9. H.B. Kazeiman," Developments of fuzzy PID controllers", Expert Systems, Vol. 22, No 5, 2005, pp. 254-264.
10. Kaur, G., Chauhan, A., Subramanyam, P.V., Fuzzy Logic Temperature Controller, International Conference on Granular Computing, Vol. 2, No 492-495, 2005.