A Fuzzy Expert System Design for Diagnosis of Prostate Cancer

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Abstract: *In this study a fuzzy expert system design for diagnosing, analyzing and learning purpose of the prostate cancer diseases was described. For this process it was used prostate specific antigen (PSA), age and prostate volume (PV) as input parameters and prostate cancer risk (PCR) as output. This system allows determining if there is a need for the biopsy and it gives to user a range of the risk of the cancer diseases. There was observed that this system is rapid, economical, without risk than traditional diagnostic systems, has also a high reliability and can be used as learning system for medicine students.*

Keywords: *Fuzzy logic, expert system, prostate cancer, prostate specific antigen, prostate volume.*

INTRODUCTION

In recent years, the methods of Artificial Intelligence have largely been used in the different areas including the medical applications. In the medicine area, many expert systems (ESs) were designed. ONCOCIN and ONCO-HELP are the ESs for diagnosis of the general cancer diseases [2, 3]. For example, ONCO-HELP is a multimedia knowledge-based decision support system for individual tumor entities. It makes individual and prognosis-oriented treatment of patient's tumor possible (if corresponding predictor's respective prognostic factors are known). Trough registration of individual patient data over tumor type, histology, metastatic type, methathesis localization and amount, as well as corresponding laboratory parameters together with a corresponding knowledge based on a patient individual prognosis-score can be determined. Using this score, a therapy concept is drafted. Onco-Help evaluates this concept by using therapy controls with regards to tumor progression/regression and side effects of the therapy. Consequently, a concept modification or a different therapy is proposed [3].

Soft computing technology is an interdisciplinary research field in computational science. Various techniques in soft computing such as ESs, neural networks, fuzzy logic, genetic algorithms, Bayesian statistics, khaos theory, etc, have been developed and applied to solve many challenging tasks in medicine and engineering design. There are some publications in the area prostate cancer prognosis or diagnosis by aid of soft computing methods [1, 4, 6, 8, 9, 10]. In the study [10] a fuzzy logic based method for prognostic decision making in breast and prostate cancers is developed. In the study [6] five different trainable neuro-fuzzy classification algorithms based on different approaches to organize and classify biological data sets by the construction of a fuzzy interference system were investigated. The best classifier based on a mountain clustering algorithm reached recognition rates above 86 % in comparison to the Bayes classifier (79 %) and the KNN classifier (78 %). These results suggest that neuro-fuzzy algorithms have the potential to improve common classification methods significantly for the use in ultrasonic tissue characterization.

As seen in these studies, it is not quite possible to diagnose of prostate cancer fully based on only ultrasonography and image processing. We have developed a rule-based fuzzy expert system (FES) that uses the laboratory and other data and simulates an expert-doctor's behavior. As known when the prostate cancer can be diagnosed earlier, the patient can be completely treated. If there is a biopsy for diagnosing, the cancer may spread to the other vital organs [7]. For this reason the biopsy method is undesirable. As laboratory data, prostate specific antigen (PSA) and prostate volume (PV) and age of the patient are used. Using this data and help from an expert-doctor, the fuzzy rules to determine the necessity of biopsy and the risk factor was developed. The developed system gives to the user the patient possibility ratio of the prostate cancer. The system was developed by aid of the Matlab 6.5. Comparison the results of the developed FES with the data of 4641 patients from the literature [5] was shown that the FES gives close results. Additionally, the FES is rapid, economical, without risk compared to traditional

diagnostic systems, and it has also a high reliability and can be used as learning system for medical students.

The paper is organized as bellow: In the second part, material and used methods are described. Then the developed system is discussed and a conclusion is given.

MATERIALS AND METHODS

The clinics and laboratory data for the developed system were taken from the literature [5] and [10] in this study. For the design process prostate specific antigen (PSA), age and prostate volume (PV) are used as input parameters and prostate cancer risk (PCR) is used as output. For fuzzification of these factors the linguistic variables very small (VS), small (S), middle (M), high (H), very high (VH), very low (VL) and low (L) were used. For the inference mechanism the Mamdani max-min inference was used.

Fuzzy Expert System

The units of the used factors are: PSA (ng/ml), age (year), PV (ml) and PCR (%). Parts of the developed fuzzy rules are shown in the Table 1. Total of 80 rules are formed.

Table 1. Fuzzy rules

Rule No	PSA	Age	PV	PCR
Rule 1	VL	Very young	VS	VL
…				
Rule 43	VL	MA	H	VL
…				
Rule 77	VH	Old	VS	H
…				

For example, Rule 1, Rule 43 and Rule 77 can be interpreted as follows:

Rule 1: If PSA=VL and Age=Very Young and PV=VS, then PCR=very low, i.e. if the patient's PSA is very small and patient is very young and patient's PV is very small, then patient's prostate cancer risc is very low.

Rule 43: If PSA=VL and Age=Middle Age and PV=H, then PCR=VL, i.e. if the patient's PSA is very low and patient has middle age and patient's PV is high, then patient's prostate cancer risc is very low.

Rule 77: If PSA=VH and Age=Old and PV=VS, then PCR=VH, i.e. if the patient's PSA is very high and patient is old and patient's PV is very small, then patient's prostate cancer risk is high.

Fuzzfication of the used factors are made by aid of the follows functions. These formulas are determined by aid both of the expert-doctor and literature [5].

$$PSA(A)=\begin{cases} a; & 0<a<16 \\ 1; & 50\le a \end{cases} \qquad Age(B)=\begin{cases} 1; & 65\le b \\ b; & 0<b<65 \end{cases}$$

$$PV(C)=\begin{cases} c; & 3.8\le c\le 308 \\ 0; & c<3.8 \\ 1; & c>308 \end{cases} \qquad PCR(D)=\begin{cases} z; & 0\le d\le 100 \\ 0; & d<0 \\ 0; & d>100 \end{cases} \qquad (1)$$

Developed FES has a structure shown as in the Fig.1.

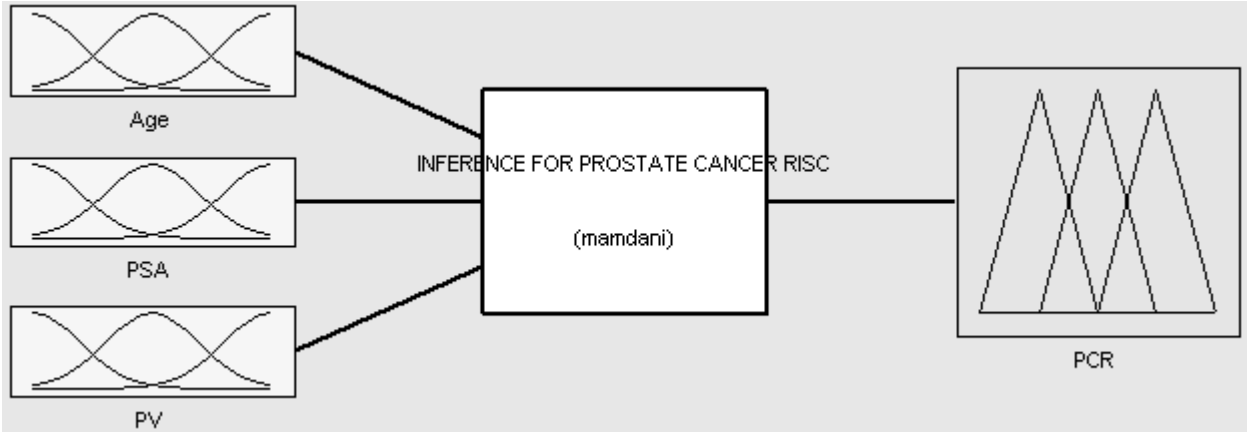

Fig. 1. The structure of the FES

Structure of the Fuzzy Factors

The memberships of the used factors are obtained from the formulas (1) and shown in the Fig. 2 – Fig. 5.

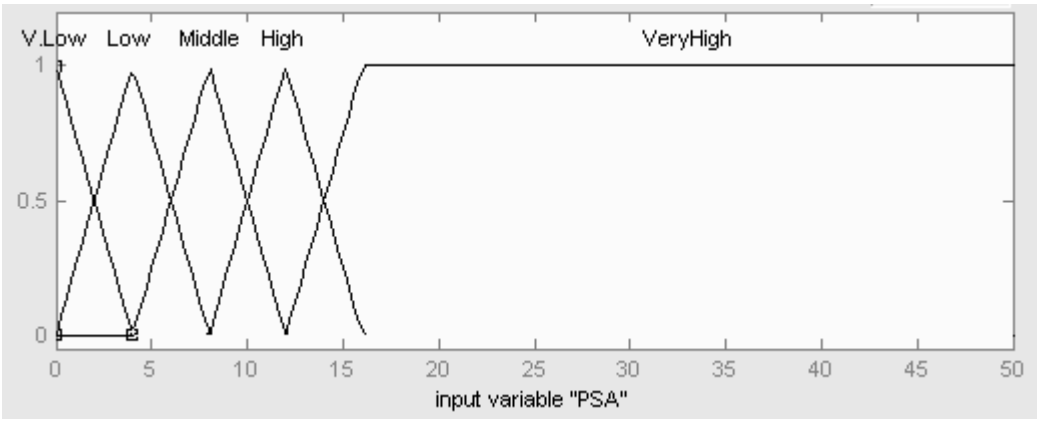

Fig. 2. The membership function of the PSA

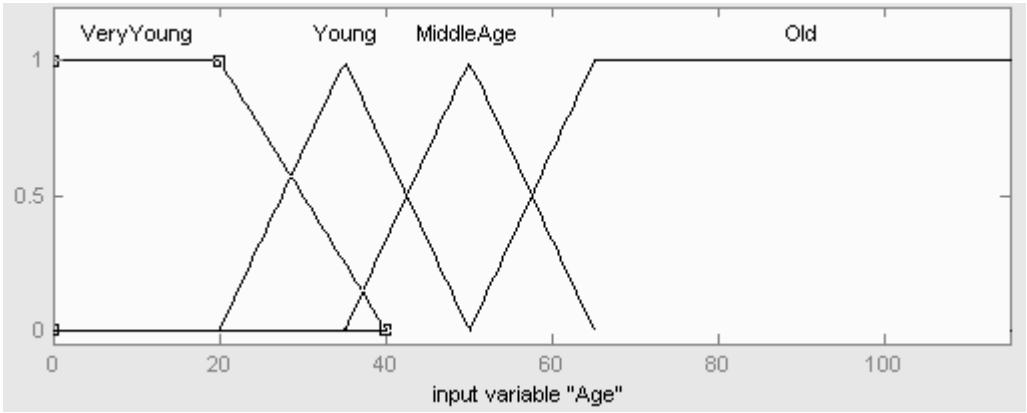

Fig. 3. The membership function of the Age

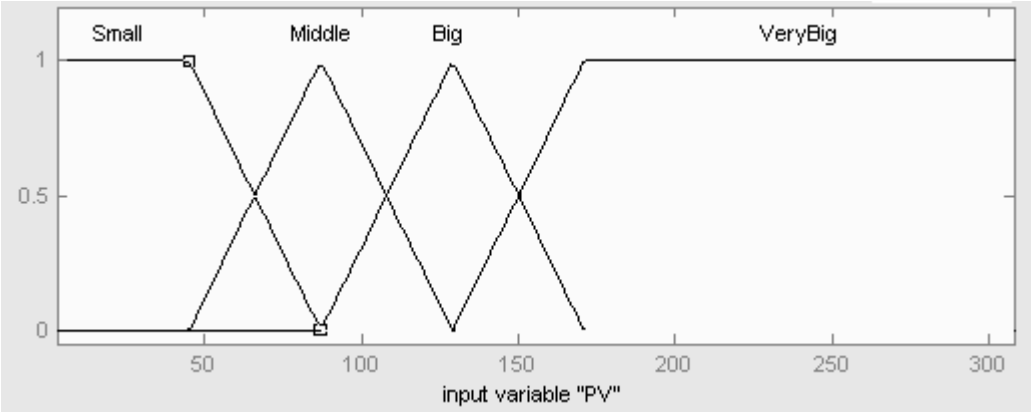

Fig. 4. The membership function of the PV

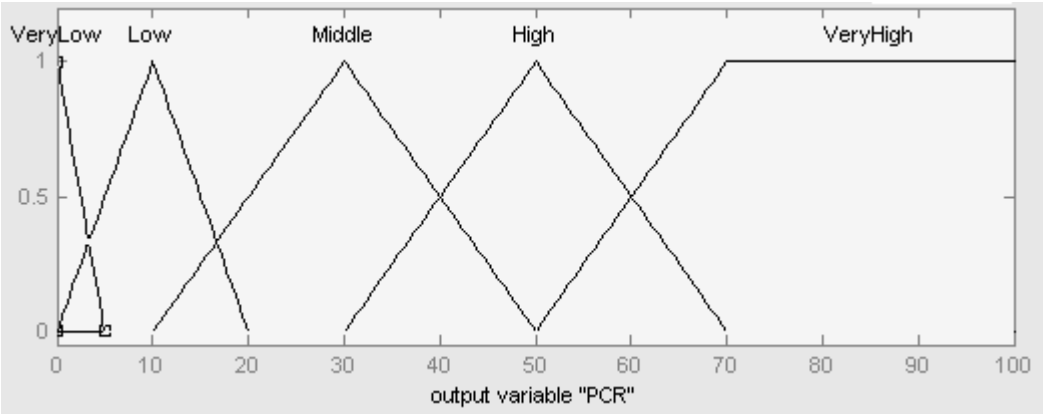

Fig. 5. The membership function of the PCR

From the developed rules and from the formulas (1) we obtained, for example, for PSA linguistic expressions as follows:

$$\mu_{Ver\,low}(A)=\begin{cases}\dfrac{4-a}{4}; & 0<a<4\\ 0; & Diğer\ durumlar\end{cases}$$

$$\mu_{Low}(A)=\begin{cases}\dfrac{a}{4}; & 0<a\le 4\\ \dfrac{8-a}{4}; & 4<a<8\\ 0; & a\ge 8\end{cases}$$

$$\mu_{Middle}(A)=\begin{cases}0; & a\le 4\\ \dfrac{a-4}{4}; & 4<a\le 8\\ \dfrac{12-a}{4} & 8<a<12\\ 0; & a\ge 12\end{cases}$$

$$\mu_{High}(A)=\begin{cases}0; & a\le 8\\ \dfrac{a-8}{4}; & 8<a\le 12\\ \dfrac{16-a}{4} & 12<a<16\\ 0; & a\ge 16\end{cases}$$

$$\mu_{Veryhigh}(A)=\begin{cases}0; & a\le 12\\ \dfrac{a-12}{4}; & 12<a<16\\ 1; & a\ge 16\end{cases} \qquad (2)$$

The other linguistic expressions (Very Young, Young, Middle Age and Older) are determined similarly. For the output factor PCR the linguistic expressions are Very low, Low, Middle, High and Very high, which can be expressed as Very small, Small, Middle, High and Very high respectively in the formulas (2). For example, for High PSA, Middle Age, and Very Big PV the membership functions will have forms respectively:

$$\mu_{high}(PSA) = \{0/8+0.25/9+0.5/10+0.75/11+ 1/12 +0.75/13+0.5/14+0.25/15+ 0/16\}.$$

$$\mu_{middle}(Age) = \{0/35+0.33/40+0.67/45+1/50+0.67/55+0.33/60+0/65\}.$$

$$\mu_{very\,high}(PV) = \{0/2129+0.1/133+0.2/137+...+1/171+1/175+...+1/308\}.$$

Defuzzification

In this stage, truth degrees (α) of the rules are determined for the each rule by aid of the min and then by taking max between working rules. For example, for PSA=40 ng/ml, Age=55 year, PV=230 ml the rules 60 and 80 will be fired and we will obtain:

α_{60} = min(Very High PSA, Middle Age, Very Big PV) = min(1, 0.67, 1) = 0.67.

α_{80} = min(Very High PSA, Old Age, Very Big PV) = min(1, 0.33, 1) = 0.33.

From Mamdani max-min inference we will obtain the membership function of our system as max(α_{60}, α_{80})=0.67, that means Very High PCR. Then we can calculate the crisp output. The crisp value of the PCR is calculated by the method center of gravity defuzzifier by the formula:

$$D^* = \frac{\int D \cdot \mu_{middle}(D)dD}{\int \mu_{middle}(D)dD}$$

As also seen from the Fig. 6, the value of PCR=78.4. This means that the patient has the prostate cancer with a possibility 78.4 %. Because this is a quite high percentage, doctor has to decide a biopsy.

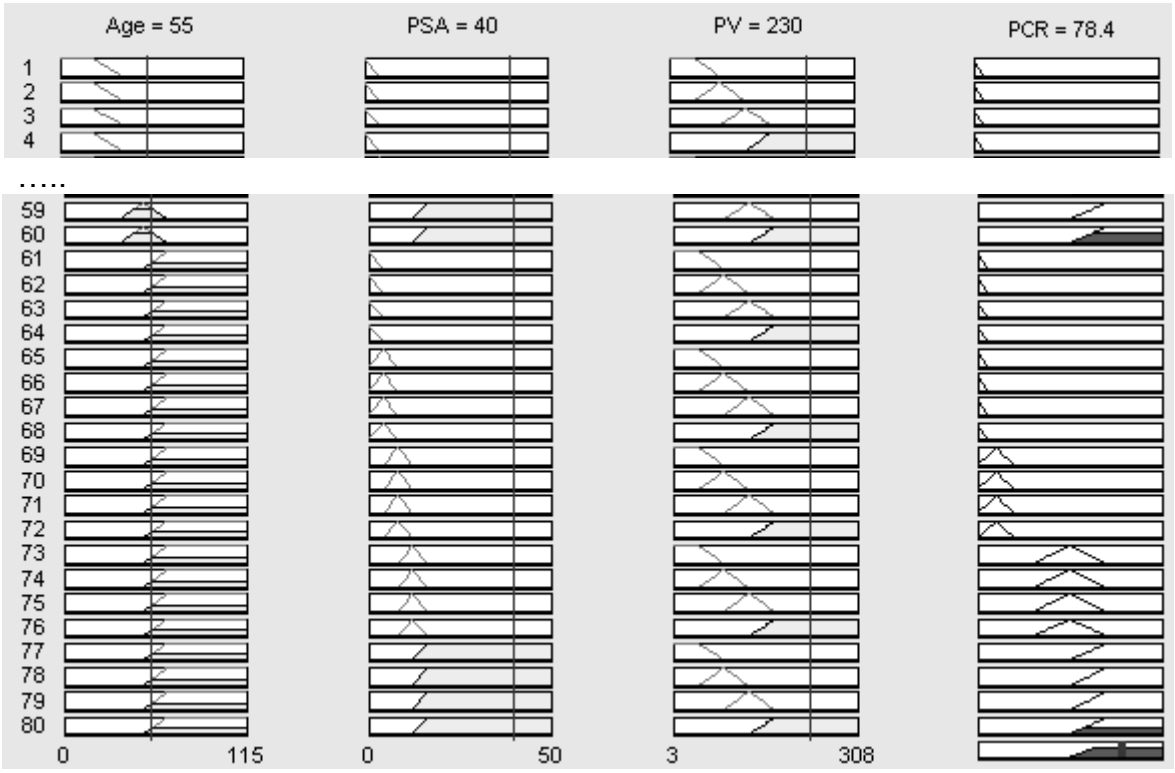

Fig. 6. Calculation of the value PCR for the values PSA=8ng/ml, Age=55, PV=300 ml

DISCUSSION AND CONCLUSION

The results of the developed FES were compared with the results in the literature [5] (Table 2). As seen from this Table the finding range of the risk of the prostate cancer diseases by FES is a few high then the data, given in the literature [5]. It may be the result of dividing of the linguistic variables to four areas. If one can be take more area for the linguistic variables, the results can be similar to the traditional results. But this system is very good for testing and learning process for the medicine students, specializing in the prostate cancer diseases. The system does not answer if there is a cancer disease in the patient, but it gives a percentage of the possibility of the prostate cancer and helps the doctor to decide a biopsy or not. The study also shows that PV is not a very important factor to diagnose the prostate cancer. Although high PV increases the PSA, it does not mean cancer.

Table 2. Comparison of the FES and literature

PSA (ng/ml)	Age	PV (ml)	Literature (%) [5, 11, 12]	FES (%)
2	20	35	0.2 – 2	1.67
3	45	90	1 - 4	1.53
4	20	44	0.2 - 3	1.33
12	55	200	48 - 55	50.00
15	60	250	68 - 75	73.20
40	65	211	72 - 85	79.80

The paper describes a design of a fuzzy expert system for determination of the possibility of the diagnosis of the prostate cancer, which can be used by the specialist-doctors for treatment and by the students for learning the scope. This system can be developed further with increasing the knowledge rules from one side and with adding the neural network to the system from the other side.

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