FESMI: A Fuzzy Expert System for Diagnosis and Treatment of Male Impotence

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Abstract. In this paper, we present the design, implementation and evaluation of FESMI, a fuzzy expert system that deals with diagnosis and treatment of male impotence. The diagnosis process, linguistic variables and their values were modeled based on expert's knowledge the statistical analysis of the records of 70 patients from a hospital database and existing literature. The expert system has been implemented in FuzzyCLIPS. The fuzzy rules are organized in groups to be able to simulate the diagnosis process. Experimental results showed that FESMI did quite better than non-expert urologists and about 79% as well as the expert did.

1 Introduction

Human sexual dysfunction (or impotence) is characterized by disturbances in sexual desire and in psychophysiological changes associated with the sexual response cycle in men and women. There are three types of sexual dysfunction found in men: erectile dysfunction, premature ejaculation and a low sexual desire. An estimated 10% of the male population experience chronic erectile dysfunction (ED), however as few as 5% seek treatment. ED may affect 50% of men between the ages of 40 and 70 [1]. Furthermore, transient lost or inadequate erection may affect men of all ages. Most men experience this inability at some stage in their lives, usually by the age of 40, but are not psychologically affected by it. It has many causes, most of which are treatable. It is not an inevitable consequence of aging.

Due to the experts on this field, more men have been seeking help and returning to normal sexual activity because of improved, successful treatments for ED. Causes of erectile dysfunction can be both physiological and/or organic [2], [3]. Manipulation of the dysfunction requires expertise and great experience. Doctors, even urologists, cannot provide a typical evaluation and treatment strategy. Different approaches according to medical as well as psychosocial and cultural characteristics of patients are usually followed. A number of parameters and their possible impacts on the diagnosis and treatment are still under consideration and vogue.

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So, the creation of an expert system to assist non-expert doctors in making an initial diagnosis would is very desirable. As it is known, real world medical knowledge is often characterized by inaccuracy. Medical terms do not usually have a clear-cut interpretation. Fuzzy logic makes it possible to define inexact medical entities via fuzzy sets. During last decade, a number of fuzzy techniques have appeared which, have been extensively applied to medical systems [4], [5]. One of the reasons is that fuzzy logic provides reasoning methods for approximate inference [6], that is inference with inaccurate (or fuzzy) terms.

In this paper, we present a Fuzzy Expert System for the diagnosis and treatment of Male Impotence (called FESMI). Although there are a few systems in the area of Urology that use intelligent techniques [7], [8], [9], according to our knowledge, there hasn't been another system like FESMI. The system primarily aims to help in the diagnosis and treatment of ED by urologists (but not andrologists). Also, it can be used by medical students for training purposes.

2 Medical Knowledge Modelling

Appropriate diagnosis of ED requires urology doctors with long experience in Andrology. One of the problems is that there is no a widely accepted approach yet. Therefore, except from the fact that we had a number of interviews with an expert in the field, we also used patient records and bibliographical sources. Our approach to knowledge modeling included three steps. First, we constructed a model of the basic diagnosis and treatment process. We relied on the expert and the literature at this step. Then, we specified the parameters that played a role in each entity of the process model. At this step, we relied on the expert and the patient records. Finally, we determined the fuzzy models for the values of the resulted linguistic variables. We had, however, to iterate a number of times on this last step to tune the model.

2.1 Process Model

We constructed the model of Fig. 1 for the diagnosis and treatment process. According to that, initially, a urologist-andrologist requires the following information: (a) medical history, (b) psychosocial history, (c) sexual history, (d) physical examination and (e) diagnostic tests. At this stage, based on the patient history information as well as physical examination and testing, an initial diagnosis is made, concerning the nature of the cause of the problem. There are two possible initial diagnoses: (a) psychogenic and (b) organic.

To confirm the initial diagnosis and be more concrete, the expert requires further information related to diagnostic laboratory tests. Once he gets them, can give the final diagnosis, which can be one of (a) psychogenic, (b) arteriopathy, (c) venooclusive insufficiency, (d) specific neuropathy and (e) endocrinopathy. The possible treatments corresponding to the final diagnoses are: (a) psychosexual consultation, (b) oral medications, (c) injectables (non-invasive) and (d) surgery treatment (invasive). In psychosexual consultation, qualified therapists (e.g., sex counselors, psychotherapists) use techniques that decrease the anxiety associated with intercourse. The most effective and famous oral medications are yohimbine, apomorphine and PDE-inhibitors. Many men achieve stronger erections by injecting drugs into the penis, causing it to become engorged with blood. Usually, after the failure of the previous treatments, surgical treatment is employed, which includes penile implants, vascular reconstructive surgery, etc.

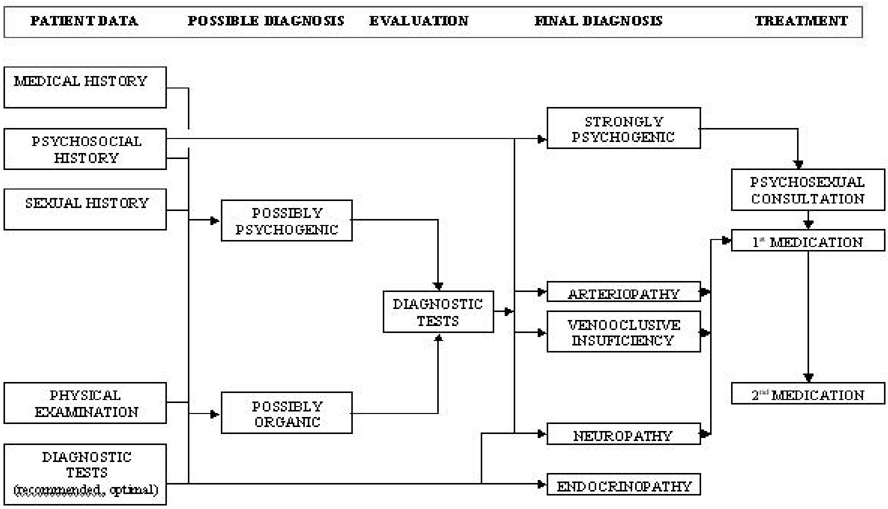

Fig. 1. ED Diagnosis and Treatment Process Model

2.2 Linguistic Variables and Values

Based on our expert urologist, we specified a set of parameters that play a role in diagnosis for each of the entities in the process model that represent patient data (Fig. 1). We also used a statistical analysis method (Pearson analysis) to evaluate which of the parameters recorded in the patient records are significant for the intermediate and final diagnosis. We analyzed 70 patient records from the patient database of the "Andrology Laboratory" of the Department of Urology of the University Hospital of Patras. We found that parameters like chronology, alcohol and weight are significant, although they were underestimated by the expert. Finally, we resulted in the following parameters (i.e. linguistic variables) for each entity in the process model. According to the model, we distinguish between *input*, *intermediate* and *final* parameters.

Input parameters: (a) medical history (onset, non-coital erection, onanism, diabetes mellitus, coronary artery, prostate, neuropathies), (b) sexual history (chronology), (c) psychosocial history (age, depression, smoking, alcohol), (d) physical examination (blood pressure, weight), (e) diagnostic tests (hormonal evaluation, cholesterol).

Intermediate output parameters: possible_diagnosis (psychogenic, organic).

Intermediate input parameters: (a) possible diagnosis, (b) diagnostic tests (NPT, PIP, Doppler, DICC, neurophysiological).

Final output parameters: final diagnosis. It is the only final output parameter with five possible values: psychogenic, arteriopathy, venooclusive insufficiency, neuropathy and Endocrinopathy.

Final treatment parameters: final treatment. It is the only treatment parameter with five possible values: psychosexual consultation, yohimbine-apomorphine, PDE-inhibitors, injections and surgery.

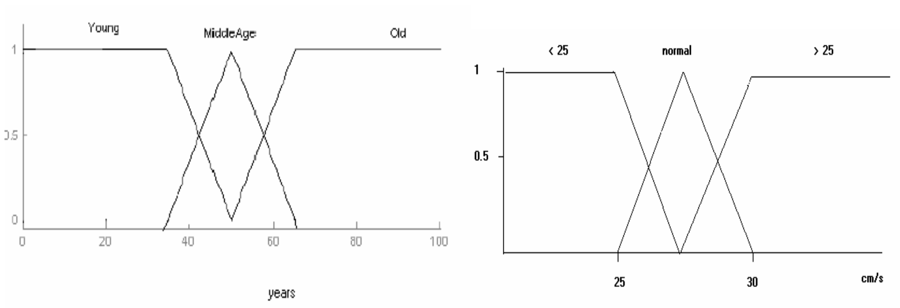

Fig. 2. Linguistic values and membership functions of 'Age' and 'Doppler_Test'

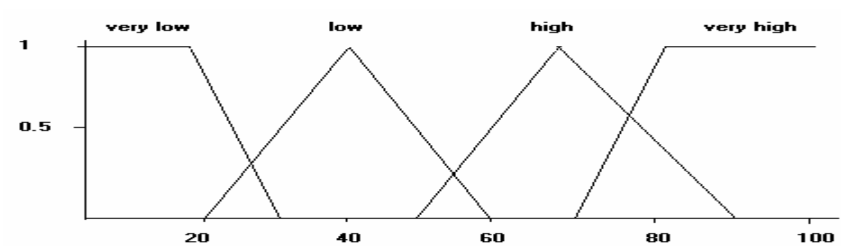

Fig. 3. Linguistic values and membership function of 'Psychogenic_Diagnosis'

Linguistic values and corresponding membership functions have been determined by the aid of the expert, the statistical analysis of patient data and the literature. Examples of values and corresponding membership functions are shown in Fig. 2 and Fig. 3.

3 FESMI Architecture and Design

The developed fuzzy expert system has the structure of Fig. 4, which is similar to the typical structure of such systems [6], [10]. The *knowledge base* of the expert system includes *fuzzy rules*, which are symbolic (if-then) rules with linguistic variables (e.g. age). Linguistic variables take linguistic values (e.g. young, middleaged, old). Each linguistic value is represented by a *fuzzy set*: a range of crisp (i.e. non-linguistic) values with different degrees of membership to the set. The degrees are specified via a *membership function*. The variables of the conditions (or antecedents) of a rule are inputs and the variable of its conclusion (or consequent) an output of the system.

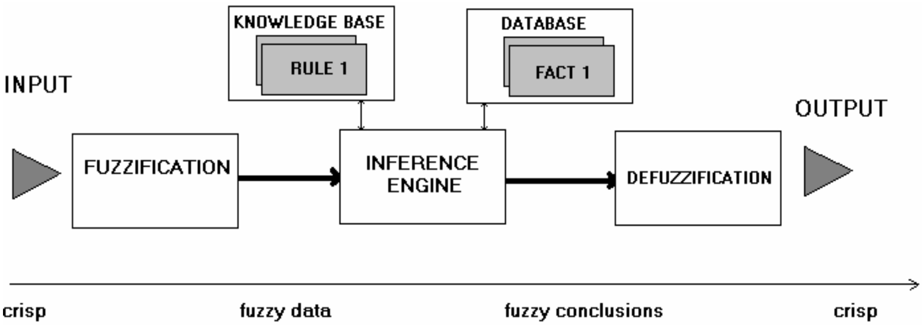

Fig. 4. The general structure of FESMI

Reasoning in such a system includes three stages: fuzzification, inference, defuzzification. In *fuzzification*, the crisp input values (from the fact database) are converted to membership degrees, by applying the corresponding membership functions, that become the truth degrees of the corresponding conditions of the fuzzy rules. In the *inference* stage, first, the degrees of the conditions of the fuzzy rules are combined to produce the degrees of truth of the conclusions. The MIN method is used here. According to that, the degree of truth of a conclusion is the minimum of the degrees of the conditions of the corresponding rule (AND fuzzy operation) and its membership function is clipped off at a height corresponding to that minimum. Afterwards, all the degrees assigned to same conclusions (i.e. rule outputs) are combined into a single degree using the MAX method. According to that, the combined output degree of truth is the maximum of the degrees (OR fuzzy operation) and its membership function is clipped off at a height corresponding to that maximum. Finally, the clipped off membership functions of all outputs are aggregated to form the combined fuzzy output. In *defuzzification*, the fuzzy output is converted to a crisp value. Here, the well-known centroid method is used. According to that method, the crisp output value is the x-coordinate value of the center of gravity of the aggregate membership function [10].

To represent the process model, we organized fuzzy rules in three groups: *classification rules*, *diagnostic rules* and *treatment rules*. The current patient data are stored in the Database, as *facts*. Each time that the reasoning process requires a value, it gets it from the database. In an interactive mode, it could be given by the user. Fig.5 presents how the rule groups and the facts/user are used/participates during the reasoning process to simulate the diagnosis process.

4 Implementation Issues

The system has been developed in FuzzyCLIPS 6.1b expert system shell. Finally, about 93 fuzzy rules have been constructed. Patient data in the Database are organized by using CLIPS templates. For example, the following rule:

Rule 3: If onset is acute and non-coital is yes and onanism is yes and chronology is recent and age is middleage and smoking is high then psychogenic is very high.

has been implemented in CLISP as follows:

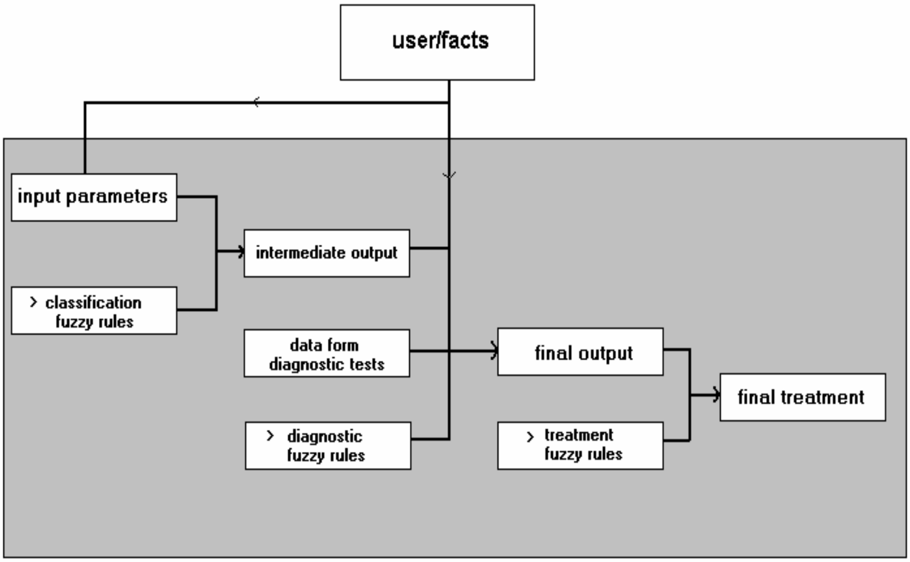

Fig. 5. Reasoning flow in FESMI

```
 (defrule psychogenic_very_high
       (possible_psychogenic (disfunction  ?n)
                        (onset acute)
                        (non-coital  yes)
                        (onanism yes)
                        (chronology recent)
                        (age middle)
                        (smoking high))
=>
                (printout   t ?n  "is very high"  crlf)
)
```

where the following fact template is used:

```
(deftemplate possible_psychogenic
       (slot   disfunction (type PSYCHOGENIC))
       (slot   onset (type FUZZY-VALUE fz-onset))
       (slot   non-coital (type FUZZY-VALUE fz-noncoital))
       (slot   onanism (type FUZZY-VALUE fz-onanism))
       (slot   chronology (type FUZZY-VALUE fz-chronology))
       (slot   age (type FUZZY-VALUE fz-age))
       (slot   smoking (type FUZZY-VALUE fz-smoking))
)
```

To implement reasoning flow, different priorities have been used for different rule groups.

5 Experimental results

FESMI was run for the 70 patient cases, whose records were in the hospital database, and its results were compared to the results of three urology residents and those of the expert doctor, who was the director of the "Andrology Lab" (see Tables 1a,b,c). As can be easily seen from the tables, the results of FESMI for each stage of the reasoning process is quite closer to the expert's than those of residents (i.e. three different non-expert doctors). For example, FESMI has a 79% success compared to the expert (e.g. see Table 1b, for Psychogenic).

Table 1a. Comparison of the FESI and the urology residents (possible diagnosis)

POSSIBLE DIAGNOSIS	RESIDENT %			F.E.S.I. %	EXPERT %
	1st	2nd	3rd		
Psychogenic	23	26	28	**35**	44
Organic	77	74	72	**65**	56

Table 1b. Comparison of the FESI and the urology residents (final diagnosis)

FINAL DIAGNOSIS	RESIDENT %			F.E.S.I. %	EXPERT %
	1st	2nd	3rd		
Psychogenic	23	26	25	**35**	44
Arteriopathy	46	44	51	**46**	35
Venooclusive	10	14	15	**19**	20
Neuropathy	21	16	9	**0**	1
Endocrinopahty	0	0	0	**0**	0

Table 1c. Comparison of the FESI and the urology residents (proposed treatment)

TREATMENT	RESIDENT %			FESI %	EXPERT %
	1st	2nd	3rd		
Psychosexual	21	20	19	**35**	50
Yohimbine-Apomorphine	0	0	0	**8**	3
PDE-ihnibitors	50	53	55	**37**	11
Injections	29	27	26	**20**	36
Surgery	0	0	0	**0**	0

6 Conclusions

In this paper, we present the design, implementation and evaluation of FESMI, a fuzzy expert system that deals with diagnosis and treatment of male impotence. The diagnosis process was modeled based on expert's knowledge and existing literature. Linguistic variables were specified based again on expert's knowledge and the statistical analysis of the records of 70 patients from a hospital database. Linguistic values were determined by the help of expert, the statistical analysis and bibliographical sources. Experimental results showed that FESMI did quite better than non-expert urologists, but worse than the expert. A possible reason for that may be the determination of the values (fuzzy sets) of the linguistic variables and their membership functions. Better choices may give better results. One the other hand, use of more advanced representation methods, like hybrid ones [11], may give better results.

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