FUZZY APPROACH IN PSYCHIATRY

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ABSTRACT: *The need for computer assistance in psychiatry is very great. Several authors have claimed that the existing computer programs, which are mainly based on statistical or decision-tree methods, are not satisfactory. The main reasons for this failure are the lack of standard medical definitions and the lack of a good data validation basis. The fuzzy approach is based on a linguistic description of the state of the psychiatric system and of the utilities of the relevant pathologies. In this way the computer diagnosis will use the same terminology as physicians.*

Key Words: medical diagnosis, fuzzy logic, psychiatry, expert system.

1. Introduction:

In medical diagnosis it is seldom possible to work with exact definitions, descriptions or assertions. There is very rarely a sharp boundary between diseases. Psychiatry is a good example of that, there is a large number of linguistic expressions which are vague and the relationship between diseases and symptoms, signs is very imprecise. Fuzzy set theory proposed by Zadeh in 1965, make it possible to define inexact medical entities as fuzzy sets. It offers a linguistic approach that represents an excellent approximation to medical texts and the fuzzy logic provides reasoning methods capable of making approximate inferences. In this paper we draw our attention to application above mentioned theory in psychiatry to design a computer assisted diagnostic system based on fuzzy logic inference mechanism. The activity of the system is based on the propagation of knowledge through a set of rules. The activity of the system consist of four steps:

1. Learning data of patient (observations).
2. Fuzzyfier observational data.

3. Conceptual classification and filtration of relevant observational data.

4. Decision-making process.

The block diagram (Fig. 1) shows above mentioned steps

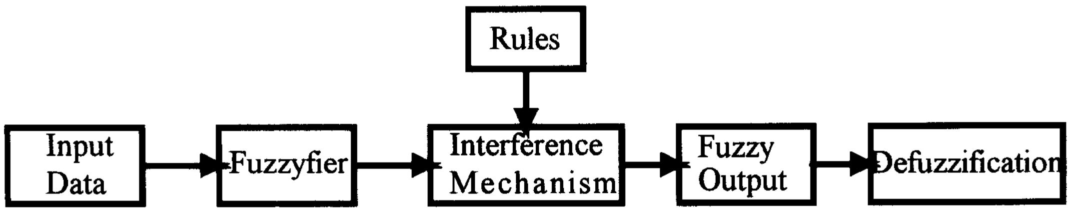

Fig. 1. Block Diagram

2. Medical Data and Membership Functions

In dealing with medical decisions and the development of medical expert systems, one is very dependent on the quality of data. It is, therefore, appropriate to consider the variability of medical data and to recognise the fact that medical data are more or less soft. It is also important to know how to describe the properties of the data both qualitatively and quantitatively [2]. Most databases should really be accompanied by such a description, possibly stored in an attached database. Another important carrier of medical information is the medical language and this is also made up, to a large extent of "fuzzy" expressions.

Firm Pfizer Roerig Pratt Pharmaceuticals published the Prime-MD (primary care evaluation of mental disorders) to help making the diagnosis of depression [5]. This short program is divided into five modules: MOOD, ANXIETY, ALCOHOL, EATING, SOMATOFORM, as example we take the module one which is dealing about the major depression and contains nine questions. The evaluation is based on classical logic (binary logic) i.e. **NO** or **YES.**

1- **Trouble** falling or **staying asleep**, or sleeping **too much**?

2- Feeling **tired** or having **little** energy?

3- **Poor** appetite or **overeating**?

4- **Little** interest or pleasure in doing things?

5- Feeling **down**, depressed, or hopeless?

6- Feeling **bad** about yourself - or that you are a **failure** - or have let yourself or your family **down**?

7- **Trouble** concentrating on things such as reading the newspaper or watching television?

8- Being so fidgety or restless that you were moving around **a lot more than usual**?

9- In the last two weeks have you had thoughts that you would be better off dead or of hurting yourself in some way?

Are answers to five or more of #1 to #9 Yes then Major Depressive Disorder.

It is extremely difficult to translate these expressions into a form that the computer can deal with, to combine them with harder data and yet not destroy the richness in the professional language that is so closely related to human behaviour and thinking.

At this point we were obviously faced with the big problem of asking the physician to evaluate the expression *trouble falling or staying asleep, or sleeping too much* in manner like Yes or No.

This was clearly inappropriate, hence we allowed them to express their opinion by means of linguistic values such as "Very Low," "Low", "Medium", "High", "Very High" (as basic weights) (figure 2).

The meaning of these terms is expressed by five fuzzy sets A_q, whose membership functions $\mu_{A_q}(x)$ are defined for interval [0, 1].

3. Qualifying a Fuzzy Set

Linguistic variables also can be modified by "hedges," which are set transformers that are either built into the analysis system or created by users. These hedges change the membership gradients by either intensifying or weakening the truth tables. (Table 1) contains a representative collection of conventional fuzzy hedges with their effects [4].

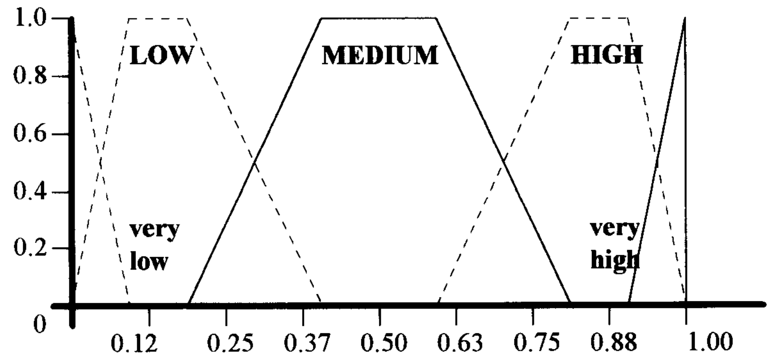

Figure 2. Basic weights.

Table 1. Fuzzy Linguistic Hedges and Their Approximate Meanings.

HEDGE	MEANING
about, around, near, roughly	Approximate a scalar
above, more than	Restrict a fuzzy region
almost, definitely, positively	Contrast intensification
below, less than	Restrict a fuzzy region
vicinity of	Approximate broadly
generally, usually	Contrast diffusion
neighbouring, close to	Approximate narrowly
not	Negation or complement
quite, rather, somewhat	Dilute a fuzzy region
very, extremely	Intensify a fuzzy region

The mechanics underlying a hedge operation are generally heuristic in nature. That is, the hedges to which a fuzzy surface is transformed and the nature of the transformation are not based on a mathematical theory of fuzzy surface topology operations, but is associated with the perceived "fit" of the transformation and the psychological "goodness" of the resulting fuzzy region.

Lotfi Zadeh's definition of the hedge "very", for instance, intensifies the fuzzy space by squaring the membership function at each point in the set ($\mu_A^2[x]$).

Zadeh's definition of the "somewhat" or "rather", on the other hand, dilutes the fuzzy space by taking the square root of the membership function at each point along the set ($\mu_A^{1/2}[x]$) [4]. (Figure 3) give as an overview how applying a hedges "very".

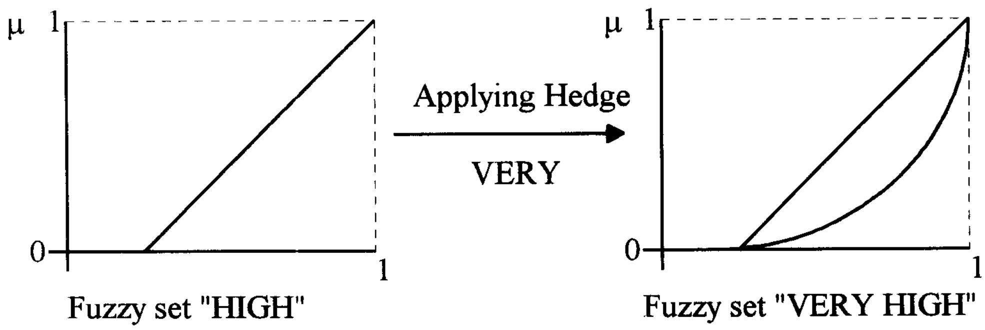

Figure 3. Applying hedge "very" to fuzzy set "high"

4. Knowledge Representation

It is obvious that much knowledge in the real-world is fuzzy rather than precise. The fuzziness occurs when the boundary of a piece of information is not clear cut. For example, the following is a piece of fuzzy knowledge: "IF the count of answers "YES" was more than five THEN the diagnosis of depression is confirmed. But these questions contain many linguistic variables which are vague and not clear enough (*e.g. trouble, too much, tired, little, poor, overeating, down, a lot more than usual, etc.*).

In order to make the real-world knowledge suitable for being processed by computers, fuzzy production rules have been used for knowledge representation. The fuzzy production rules allows the rule to contain some fuzzy quantifiers and operators (AND, OR) [3].

Let R be a set of fuzzy production rules

$$R = \{ R_1, R_2, ..., R_n \}.$$

The general formulation of the rule R_i, i =1, ..., n, is as follows:

$$R_i\text{: IF } D_i \text{ THEN } d_i \text{ with } (CF = \mu_i)$$

where

D_i: represents the antecedent portion of R_i which may contain some fuzzy quantifiers.

d_i: represents the consequence portion of R_i

μ_i : is the membership degree of Certainty Factor which indicates the certainty that R_i is believed in.

In medical diagnostic problems, a physician's knowledge can be represented as

IF symptom THEN concluded disease with ($CF = \mu_i$).

5. The Fuzzy Compositional Rules of Inference

There are two principal methods of inference in fuzzy systems: the min-max method and the fuzzy additive method. These methods differ in the way they update the solution variable's output fuzzy representation.

However, it is useful to be able to conduct the inference computation manually with a few rules to check computer programs or to verify the inference operations. To illustrated this idea, we consider a simple two-rule system where each rule comprises two antecedents and one consequent. This is analogous to a dual-input and single-output fuzzy system. The graphical procedures illustrated here can be easily extended and will hold for fuzzy rule-bases (or fuzzy systems) with any number of antecedents (inputs) and consequents (outputs).

A fuzzy system with two noninteractive inputs x_1 AND x_2 (antecedents) and a single output y (consequent) is described be a collection of r linguistic IF-THEN propositions:

IF x_1 is A_1^k and x_2 is A_2^k THEN y^k is B^k for $k = 1, 2, ..., r$

where A_1^k and A_2^k are the fuzzy sets (in our case are: very low, low, medium, high and very high) representing the kth-antecedent pairs, and B^k are the fuzzy sets representing the kth-consequent.

Example 1: Let inputs input(i) and input(j) are fuzzy variables described by fuzzy membership fuctions (very low, low, medium, high, very high), and the inference method is a correlation-product method defined as

$$\mu_R(x,y) = \mu_A(x).\mu_B(y)$$

The resulting expression for this inference for the r disjunctive rules would be

$$\mu_{B^k}(y) = \max_k \left[\max\left[\mu_{A_1^k}(x) \wedge \mu(x_1) \right] . \max\left[\mu_{A_2^k}(x) \wedge \mu(x_2) \right] \right]$$

This equation has a simple graphical interpretation, which is illustrated in (Fig. 4). In this figure the fuzzy inputs are represented by triangular membership functions (input (i) and input(j) in the figure). The intersection of these inputs and the stored membership functions for the antecedents (A_{11}, A_{12} for the first rule, and A_{21}, A_{22} for the second rule) results in other triangules. The maximum value of each of these intersection triangles results in a membership value, the minimum of which is propagated for each rule (because of the "and" connective between the antecedent of each rule. The crisp value y^* we get using defuzzification method.

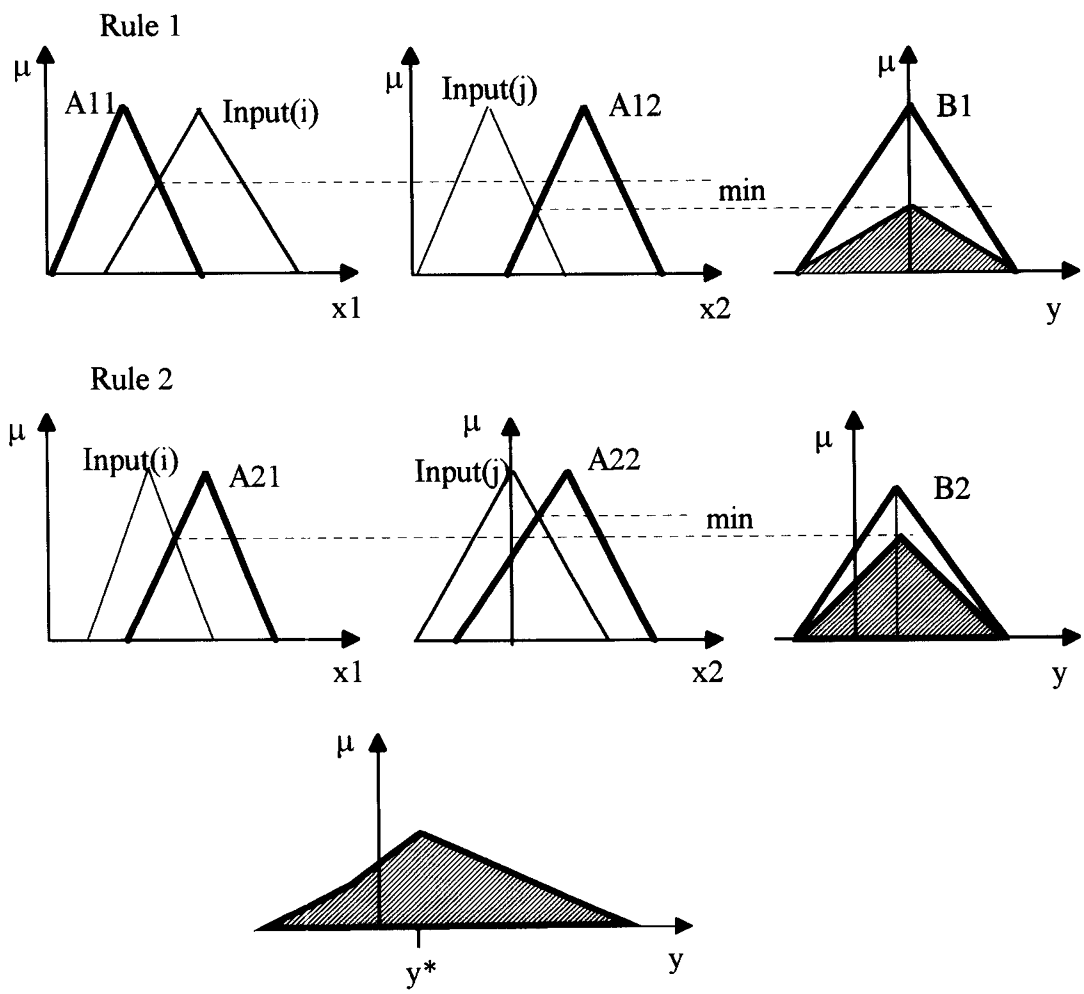

Fig. 4. Graphical correlation-product inference using fuzzy inputs.

6. Materials and Tools

Above mentioned method we examined in the daily sanatorium in Bratislava in colaboration with the chief of sanatorium Dr. Zdenka Gešová, where we will observe patients suffering depressions. We used the facilities of Fuzzy Modelling System developed by Earl COX i.e. like programs written in C++ language [4]. Table 2 shows the results given by our system which was developed for the first module.

When there are many ways for interpretation the fuzzy rules, for instance implication, correlation and defuzzification. After many experiments the best combination was min-max method for implication, correlation minimum for correlation and average support method for defuzzification, the results of this method are shown in table 2.

Table 2: Results

Serial Number	HIGH	MEDIUM	LOW	Result x 100 %
patient 1	1	6	2	0,527
patient 2	2	2	5	0,319
patient 3	2	6	1	0,569
patient 4	3	2	4	0,462
patient 5	4	2	3	0,599
patient 6	4	5	0	0,858
patient 7	5	1	3	0,637
patient 8	5	3	1	0,83
patient 9	6	1	2	0,779
patient 10	6	3	0	0,92
patient 11	7	1	1	0,879
patient 12	8	1	0	0,93
patient 13	9	0	0	0,985
patient 14	0	9	0	0,665
patient 15	0	0	9	0

The column 5 in the table 2 shows us the percent being or not being the patient desease, i.e. if the result is less than 0,5 then the patient is not ill. If the result is more than 0,5 then the patient is ill with some percents. For example, the patient number 9 had answered 6 times high, once medium and 2 times low, the percent of his depression is 77,9 %.

7. Conclusion

There are compelling reasons for predicting an increase in computer support for medical decisions in the future. In order to meet the need for user satisfaction, the following requirements are mandatory for any decision support or expert systems:

- The user must not lose knowledge but must gain new knowledge.
- The user must not become too dependent on the system.
- He/she must have a chance to practice "human processing".
- When using an expert system, the user should feel like an expert- not only like the consultant of an expert.

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