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Application of intuitionistic fuzzy logic in expert system for textile engineering

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Abstract. This paper presents an implementation of intuitionistic fuzzy linear system of equations in artificial intelligence. Comparison with the conventional fuzzy model is given.

1 Introduction

The aim of this work is to present an application of the intuitionistic fuzzy sets in expert systems. The fuzzy logic diagnostical models of the objects have one important disadvantage - the linguistic variables for describing one parameter are interdependent, but participate as independent variables. In some cases this produces contradictory results. Joining these variables in one intuitionistic variable eliminates this problem. Using fuzzy linear systems as inference engine is presented in section 2, with practical example from the sewing industry in section 3. Introducing intuinitionistic variables is given in section 4 and the application of intuitionistic fuzzy linear system as inference engine - in section 5. Finally, comparison between intuitionistic fuzzy logic and fuzzy logic is done.

2 Fuzzy linear systems as inference engine

The inference engine in fuzzy diagnosis system is based on the fuzzy linear system of equation:

$$A \bullet X = B, \tag{1}$$

where $A = (a_{ij})_{m\times n}$ with $a_{ij} \in [0,1]$, $B = (b_i)_m$ with $b_i \in [0,1]$, $X = (x_j)_n$, $x_j \in [0,1]$ and $\bullet$ is the $\max - \min$ composition. Detailed description of the theory of the problem and solution technics is given in [4], [6], the form of application and organization of the knowledge base in [7], [2] and [3].

It is supposed the matrix A to be given. Each element a_{ij} of this matrix shows how the $i-$th input influences the $j-$th output. We analyze situations, where the symptoms B

are known and we search the causes using proposed in [6] algorithm and simplification rules. This model works well if the linguistic variables for x_j and b_i are logical and correct given. In some cases, using independent linguistic variables for describing various state of one parameter will provoke contradictory answers. This problem can be solved very elegant using intuitionistic fuzzy linear systems instead of fuzzy logic.

3 Practical example

One of the most important problems in sewing industry is the quality of stitches. There are a lot of factors, which may influence over the stitches quality and not every person can operate within them. If is possible when troubles to ask the computer expert system, could be profitably for a lot of companies and housewives, instead to use the specialist. Here is introduced only the needed information from [3] for current paper presentation of such expert system.

Let we use short list of stitch defects, introducing the variables:

- b_1 - no defects found;
- b_2 - missing stitches;
- b_3 - the interweave of the threads visible on the upper (face) side;
- b_4 - the interweave of the threads visible on the bottom (back) side;
- b_5 - torn upper thread;
- b_6 - torn down thread.

The input "missing stitches" with degree of appearance 0.3 will be coded as

$$B = \begin{bmatrix} 0 & 0.3 & 0 & 0 & 0 & 0 \end{bmatrix}^T.$$

Used causes, presented with relevant linguistic variables are:

- upper thread tension - x_1- low ; x_2- normal ; x_3- high
- proportion upper / bottom thread tension - x_4-greater than 1, x_5-near to 1, x_6- less than 1
- upper thread tenacity - x_7-low; x_8-normal ; x_9-high
- bottom thread tenacity - x_{10}- low; x_{11}- normal; x_{12}- high
- hook to needle horizontal distance - x_{13}- near, x_{14}- normal, x_{15}- far

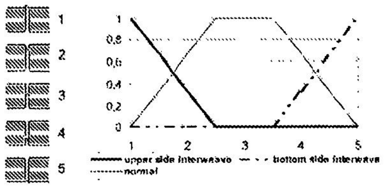

Figure 1: Membership functions for some used linguistic variables

- vertical position of the needle - x_{16}- low, x_{17}- normal, x_{18}- high.

The relational matrix between given defects and causes for selected type of sewing machine and membership functions for the parameters could be:

$$A = \begin{bmatrix} 0.0 & 1.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 1.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 1.0 & 0.0 & 1.0 \\ 0.0 & 0.0 & 1.0 & 1.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 1.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.7 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.7 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \end{bmatrix}$$

Let we analyze the result from solving the system (1), by the given A and B. The program output window is given in the Fig. 2

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Input
b 2 = 0.3 missing stitches
Max solution
x 9 = 1 high upper thread tenacity
x 12 = 1 high bottom thread tenacity
x 13 = 1 near hook to needle horizontal distance
x 15 = 0.3 far hook to needle horizontal distance
x 16 = 0.3 low vertical position of the needle
x 18 = 0.3 high vertical position of the needle
Min 1-st solution
x 15 = 0.3 far hook to needle horizontal distance
Min 2-th solution
x 16 = 0.3 low vertical position of the needle
Min 3-th solution
x 18 = 0.3 high vertical position of the needle
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Figure 2: Output from the simple diagnosis system to the given symptom "missing stitches"

The machine is skipping stitches as result of the following three reasons, separately or combined: the horizontal distance between the hook the needle, in moment of the stitch building is greater then normal x_{15}, the needle is lower positioned relevant to the hook x_{16} or the needle is high positioned x_{18}. The last two reasons x_{16} and x_{18} are contradictory. This is not a problem for the minimal solutions, because in each minimal solution appear only one of the reasons. But in the maximal solution both reasons appear together, because mathematically they are independent factors.

Using intuitionistic approach contradiction will be avoided, because each parameter will be described with three dependent variables.

4 Introducing intuinitionistic variables

If intuitionistic variable for position of the needle is used, the problem with contradictory positions of the needle as answer will be solved automatically, using the natural higher "intelligence" of the intuitionistic approach. Let we introduce the intuitionistic variable "high position of the needle". To this intuitionistic variable corresponded three linguistic variables, with relevant membership functions are: $\mu(x_1)$ - "the needle is too high", $\nu(x_1)$ - "the needle is too low" and $\pi(x_1)$ - "the needle is in normal state". Actually, the linguistic variable should be named "normal position of the needle", but then is difficult to make relation between membership and non-membership degrees and the application variables. Because of the rule for the membership degrees

$$\mu(x_1) + \nu(x_1) + \pi(x_1) = 1. \tag{2}$$

It will be no so possible to appear at the same time "very high position" and "very low position" of the needle. In this example the degree of non-uncertainty $\pi(x_1) = 1 - \mu(x_1) - \nu(x_1)$ has meaning of the normal state of the variable. In some other cases $\pi(x_1)$ becomes the natural meaning of degree of uncertainty. As normal state, or as degree of uncertainty,if we using intuitionistic variables, the system not operate with π directly and it is calculated as corollary of the degrees of membership and non-membership.

5 Intuitionistic fuzzy linear system as inference engine

Intuiotionistic fuzzi linear system is used as inference engine by analogy with the model, presented in section 2, but now according to the definistions in [1], [5]:

$$A \otimes X = B, \tag{3}$$

where

$$A = (a_{ij})_{m\times n}, a_{ij} = (\mu^A_{ij},\ \nu^A_{ij}), B = (b_i)_{m\times 1},\ b_i = (\mu^B_i,\ \nu^B_i),$$

$$X = (x_j)_{1\times n},\ x_j = (\mu_j^X,\ \nu_j^X)$$

and

$$0 \leq \mu_{ij}^A + \nu_{ij}^A \leq 1,\ \leq \mu_i^B + \nu_i^B \leq 1,\ \leq \mu_j^X + \nu_j^X \leq 1,$$

and $\otimes$ is the "standard - co-standard" composition. The solving of this system is presented in [5].

6 Intuitionistic fuzzy logic versus fuzzy logic

The intuitionistic model logically joins variables, that misses in the conventional fuzzy model. In both of the cases, we have to analyze the same number of variables. Because of the dependency (2) the intuitionistic model operate with $2/3$ from the variables, and the rest $1/3$ are calculated after solving the system. For this reason, the intuitionistic fuzzy logic will be 33.3% faster as computing time in comparison with the conventional fuzzy logic systems. The next advantage of the intuitionistic model more adequate presentation of the variables - the specialist will orient faster inside the matrices, which dimensions diminish with $1/3$ dimensions of the fuzzy model.

References

[1] K. Atanassov. *Intuitionistic Fuzzy Sets.* Heidelberg New York, Physica-Verlag, 1999.

[2] Y. Kyosev. A fuzzy logic expert system for sewing machines diagnostic. *Textile-clothing*, Sofia, ISSN 1310-912X:19-23, 2001.

[3] Y. Kyosev. Diagnostics of sewing process uding fuzzy linear systems. In J. Militky and M. Marsalkova, editors, *International Conference TEXSCI 2003,16-18 June, Liberec*, volume CD-Edition of *Section 7 – Clothing Science and Technology*. Technical University of Liberec 2003, 2003.

[4] K. Peeva. Fuzzy linear systems. *Fuzzy Sets and Systems*, 49:339-355, 1992.

[5] K. Peeva. *Methods and Algorithms for Solving Fuzzy Linear Systems - Applications in Artificial Intelligence Areas.* , DrSc Thesis, Sofia , 239p, 2002.

[6] K. Peeva. Inverse problem resolution. *Fuzzy Sets and Systems*, submited.

[7] K. Peeva, I. Gueorguieva, and Y. Kyosev. Fuzzy linear systems for adequate diagnosis and prediction, in 25th jubilee summer school applications of mathematics in engineering and economics. In *Jubilee Summer School Applications of Mathematics in Engineering and Economics*, pages 178-184, 1999.