Inference Technique Based on Precedents in Knowledge Bases of Intelligence Systems

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Abstract[1]

The inference technique based on the knowledge matrix, fuzzy inference and the a situational vector with quantitative coordinates.

Keywords: problem substitution, linguistic variables, knowledge matrix, inference.

1. Introduction

In intellectual system of the operative purpose, when current quantitative information about appeared problem (problem subsituations (PrS/S)) operative enters in intellectual system, is claimed a priori successful experience of the decision of the similar PrS/S. In work is described formalization of this experience and mechanism of the decision of the appeared problem on base this formalized experience.

2. Inference Technique Based on Precedents

Such inference methods are used in problem subsituations, whose complexity does not allow one to constructively formalize them, but for which there is some experience (precedents) of their successful resolution.

One of difficulties of this approach is the correct choice of the coordinates $(x_1,\dots,x_i,\dots, x_n)$ of the situational vector SV(PrS/S-solution), both in their number and in the form of representation of each coordinate. The completeness of the description of the situational vector and the connection of a particular vector with a particular precedent is established by long-term cooperation with experts, who are actual bearers of this knowledge [1].

As a rule, the coordinates of the situational vector are linguistic variables.

3. Linguistic Variable as a Coordinate of the Situational Vector

A linguistic variable is defined by Zadeh in [3] as a variable whose values belong to a specified set of terms or expressions of a natural language. The latter were also called terms.

To work with linguistic variables, one should represent each term via an appropriate fuzzy set [4]. The latter, in turn, is represented via a universal set (universe) and the membership function of the elements of the universal set to the considered fuzzy set.

The membership function takes the values in the interval [0, 1]. It quantitatively estimates the grade of membership of an element in a fuzzy set.

Note that both the universal sets and the membership functions on the set are specified on the basis of investigation results (together with experts) of the corresponding object domain.

For a large number of terms, their membership functions are usually specified in a unified form. Most often, this is a piecewise linear function.

4. Knowledge Matrices by Precedents

Let a state of a problem subsituation be described by a situational vector with coordinates $(x_1,\dots, x_i, \dots, x_n)$ and each coordinate x_i be a linguistic variable with a set of terms $A_i = \{a_i^1,\dots,a_i^j,\dots,a_i^{K_i}\}$. For certain realizations of the situational vector, where each linguistic variable takes one of its possible values (a concrete term), there is a precedent of successful resolution of this PrS/S.

Suppose that a set d_j, $j = 1, \dots, p$, of precedents is accumulated and each precedent is associated with a set of particular situational vectors, for which this precedent has been selected.

Let us construct the matrix of this correspondence (this matrix have the form of Table 1). We select the rows of the matrix corresponding to a precedent (the block of the

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precedent). Any row of the matrix is a concrete situational vector for which the corresponding precedent has been successfully realized in the past.

We enumerate the rows of the block of precedent d_j, with two indices: the first index is the number of the precedent (here, it is the number of the block), and the second index is the serial number of the situational vector in this block.

This matrix determines a system of logical propositions of the form *"if..., then..., else..."* For instance, the row j_1 of the matrix encodes the following proposition:

$$\underline{\text{if}}\ x_1 = a_1^{j1}\ \underline{\text{and}}\ x_2 = a_2^{j1}\ \underline{\text{and}} \dots \underline{\text{and}}\ x_i = a_i^{j1}\ \underline{\text{and}} \dots$$

$$\underline{\text{and}}\ x_n = a_n^{j1},\ \underline{\text{then}}\ d_j, \qquad (1)$$

else a similar proposition for the next row, etc.

The obtained system of logical propositions ordered in this way is called a fuzzy knowledge matrix or, simply, a knowledge matrix.

5. Algorithm for Calculating the Membership Function of Precedent d_t

First of all, we present an algorithm [5] for determining the membership function μ_{dj} (x_1, .. x_i, .. x_n) of the precedent d_j interpreted as a fuzzy set on a universal set $Ud = Ux_1 \times \dots \times Ux_i \times \dots \times Ux_n$, where Ux_i is a universal set on which the terms of the linguist! variable x_i are defined, and U_d is the Cartesian product of the universal sets Ux_i.

Any logical proposition of the type (1) or, equivalently, any row of the knowledge matrix is a fuzzy relation of the corresponding fuzzy sets. For instance, this is $a_1^{j1} \times a_2^{j2} \times \dots \times a_n^{jn}$.

Table 1

Nos.	Coordinates of the situational vector					min	max	d
	x_1		x_i		x_n			
:	:	:	:	:	:	:	:	:
j_1	$(a_1^{j1})^*$	....	$(a_i^{j1})^*$	....	$(a_n^{j1})^*$	$\min_i$		
:	:	:	:	:	:	...		
j_s	$(a_1^{js})^*$	....	$(a_i^{js})^*$	....	$(a_n^{js})^*$	$\min_i$	$\max_{js}$ $\min_i (a_i^{js})^*$	μ_{d_j}
:	:	:	:	:	:	...		
j_{K_j}	$(a_1^{jK_j})^*$	....	$(a_i^{jK_j})^*$	....	$(a_n^{jK_j})^*$	$\min_i$ $(a_i^{j1})^*$ ... $(a_i^{is})^*$ ... $(a_n^{jK_j})^*$		
:	:	....	:	....	:	....	....	:

The membership function of a fuzzy set generated by this fuzzy relation is $\mu_{a_1^{j1}}(x_1) \wedge \dots \wedge \mu_{a_i^{j1}}(x_i) \wedge \dots \wedge \mu_{a_n^{j1}}(x_n)$, where "$\wedge$" we denote the "min" operation.

Analyzing the whole block of logical propositions related with precedent d_j (the block of the corresponding rows of the knowledge matrix), note that they form the union of the corresponding fuzzy sets generated while considering the rows of the selected block. In accordance with [4, 5], the membership function of this union, which is identified with the membership function of the precedent *dj*, is

$$\mu_{d_j}(x_1,\dots,x_i,\dots,x_n) = (\mu_{a_1^{j1}}(x_1) \wedge \dots \wedge \mu_{a_i^{j1}}(x_i) \wedge \dots \wedge \mu_{a_n^{j1}}(x_n)) \vee \dots \vee (\mu_{a_1^{jK_j}}(x_1) \wedge \dots \wedge \mu_{a_i^{jK_j}}(x_i) \wedge \dots \wedge \mu_{a_i^{jK_j}}(x_n))$$

where by «$\vee$» we denote the "max" operation.

Formally, this algorithm for determining the membership function of the precedent *dj* can be written in the following form:

a. fix an arbitrary point

$$(x_1^*,\dots,x_i^*,\dots,x_n^*) \in U_{x_1} \times \dots \times U_{x_i} \times \dots \times U_{x_n};$$

Operation $\max_{jS} \min_{i} a_i^{js}$ selects the greatest of the row minima obtained for $1 \le j_s \le K_j$. This number is the value of the membership function μ_{dj} $(x_1, \dots, x_i, \dots, x_n)$ at the fixed point $(x_1^*, \dots, x_i^*, \dots, x_n^*)$. Performing this calculation for every point of the universal set, we obtain the membership functions that interest us.

6. Algorithm for Choosing a Precedent when Observing a Situational Vector with Quantitative Coordinates

When observing a situational vector [5] with quantitative coordinates (all coordinates of the vector are measured by numerical scales), in order to select the most preferable precedent, it is not necessary to completely determine the membership functions μd_j $(x_1, .. x_i, .. x_n)$ on the whole set of points of the universal set. It is sufficient to calculate their values only for fixed numerical values of the coordinates of the vector, which is obtained by us as a result of the observation (table 2). For this purpose, we should use the algorithm from Subsection 4 once, taking the coordinates of the observed situational vector as $(x_1^*, \dots, x_i^*, \dots, x_n^*)$.

As a result, for any precedent dj, we obtain a number dj $(x_1^*, \dots, x_i^*, \dots, x_n^*)$, which is the grade of membership of dj to the point $(x_1^*, \dots, x_i^*, \dots, x_n^*)$.

Starting from this interpretation, the most preferable precedent for resolving the observed PrS/S is the precedent dj* such that

$$d_j^*(x_1^*,\dots,x_i^*,\dots,x_n^*) = \max_{1\le j\le p} dj(x_1^*,\dots,x_i^*,\dots,x_n^*).$$

Table 2

Nos.	Coordinates of the situational vector					min	max	d
	x_1		x_i		x_n			
:	:	:	:	:	:	:	:	:
j_1	(a_1^{j1})	....	$(a_i^{j1})^*$	....	$(a_n^{j1})^*$	$\min_i (a_i^{j1})^*$		
:	:		:		:	... ...		
j_s	(a_1^{js})	....	(a_i^{js})	....	$(a_n^{js})^*$	$\min_i (a_i^{is})^*$	$\max_{js} \min_i (a_i^{js})^*$	μ_{d_j}
:	:		:		:	... ...		
j_{K_j}	$(a_1^{jK_j})$	....	$(a_i^{jK_j})$	....	$(a_n^{jK_j})^*$	$\min_i (a_n^{jK_j})^*$		
:	:	...	:	...	:	....	....	:

7. Conclusions

For decision operative appeared problems, referring to class of the problems, for which on-is accumulated positive experience of their decision (the precedents), is offered:

- fix this experience in form of the matrix of the knowledge with situational vector (vector coordinates are a linguistic variables),
- on the current quantitative description of the appeared problem by means of situational vector with quantitative coordinate using operations fuzzy relations and associations is chosen the most-favored precedent.

This inference technique has been studied only theoretically and has been tested on simple practical examples [6]. It is directed to be used in the inference technique of precedents and is based on the algorithms for choosing a solution on the basis of the knowledge matrix. These algorithms are successfully applied in diagnostic problems.

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