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SUPPORT SYSTEMS FOR DECISION AND NEGOTIATION PROCESSES

Preprints of the IFAC/IFORS/IIASA/TIMS Workshop

Warsaw, Poland

June 24-26, 1992

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VOLUME 1:

Names of first authors: **A-K**

SYSTEMS RESEARCH INSTITUTE, POLISH ACADEMY OF SCIENCES

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DECISION-MAKING BASED ON DISTRIBUTED KNOWLEDGE BASE WITH RELATIONAL STRUCTURE

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Abstracts: The problems of Decision-making based on distributed knowledge base with relational structure are considered in the paper. Fuzzy relation model of knowledge representation and processing, in accordance with it each object is described by triad: plurality of properties, plurality of time and spatial responses has been suggested. Designing of destributed knowledge base topology, fragmentation and reliability are described. Superposition principle of knowledge search process has been proved. In conclusion the different applications of method suggested are discussed.

Keywords: decision making, knowledge base, distributed processing, support system, fuzzy relation, expert system, network

When controlling large-scale systems which are difficult to formalize - such as social-economical, administrative-management, complex technological processes there often arises necessity of use of distributed decision-making systems (DDMS). Hence, it is necessary to consider geographical and functional distribution of knowledge and decision-making persons (DMP) within one subject sphere, difference between expert estimations on the same problem, collective decision-making in real time etc.

The first works which dealt with this problem were /1-3/. In /4/ attempt has been made to present conceptions of DDMS and some specific problems from military practice have been described which could be solved using DDMS principles.

It should be noted that whereas technology of distributed data processing has been known for a long time, various methods of control over distributed knowledge bases and specific control systems have been developed, works connected with distributed data processing for decision-making systems and knowledge bases only begin.

Thus, the present paper which deals with development of distributed knowledge bases in computer networks is of specific interest both from theoretical and engineering point of view.

The essence of DDMS consists in development and realization of distributed knowledge bases (DKB) in computer networks and development of special decision-making methods based thereon.

Distributed knowledge bases can be of two types: fragmentally distributed knowledge base (KB) and integrated KB. Fragmentally distributed KB assumes plurality of identically organized subbases arranged in various network nodes, which being combined will define DKB for functioning DDMS. Integrated KB could be defined as combination of local and independent KB organized in various network nodes. Such distributed KB differs from fragmentally distributed one in that local KB could be organized in different ways and each one will be closed-loop DDMS. Detailed description of integrated KB and problems on decision-making connected therewith are given in /5/.

Some specificities of DKB should be pointed out. In local systems of decision-making problems of knowledge representation and decision-making are often considered as identical. Thus, in case of knowledge representation using method of rules organization decision-making is often reduced to the choice of action corresponding to required rules. However, when passing to DDMS this problem becomes more complicated. DDMS may contain various knowledge (with various content) on one and the same subject and user or application program can encounter decision-making problem even with contradicting information. Such situation calls for discrimination of knowledge representation and decision-making process in DDMS. On the other hand, data representation in DDMS should be convenient for their fast retrieval and delivery to the user or to the application program; it should be also convenient to account for relative reliability of knowledge presentation by various experts.

Considering abovementioned specificities of DDMS and necessity of complete knowledge accounting the most suitable method of knowledge representation in DKB, in our opinion, will be fuzzy relation model wherein each object is represented by a triad $R = \{ S, T, P \}$. Here S - set of the the I object properties; T and P - respectively sets of time and spatial responses of the object. As objects specific notions, actions or semantic ideas can be used. Conformity of properties, time and spatial responses with the objects is represented by three - dimensional relation model of fuzzy relationship:

$$G[R]: M_Z(x) \longrightarrow [0,1], \quad Z \in \left\{ S,T,P \right\}$$

where $M_Z(x)$ is function of Z-elements accessory to R-objects. In case of distinct relationships $M_Z(x)$ may assume values "0" or "1" /6/.

It should be noted that fuzzy relation model is more universal and allows to accomplish simple self-mapping of other representation types which is especially important when developing integrated KB with heterogeneous structures of knowledge representation. Thus, the rule represented by scheme "condition-action", accounting for situation uncertainty, can be described by the following fuzzy functional relationship:

$$\overline{Y} = F[\ \overline{X}(x_{ik}),\ i=\overline{1,n};\ k=\overline{1,l}\ ]$$

wherein F defines ratio of $\overline{X}$ arguments to $\overline{Y}$ actions. Relationship F is represented by set of accessory functions:

$$M_Z(y_j, x_{ik}) \longrightarrow [0,1],\ j=\overline{1,m};\ i=\overline{1,n};\ k=\overline{1,l}$$

It should be noted that besides sluice functions fuzzy relation model has additional advantages, one of them being possibility of development of unified decision-making methods. If the latter is considered as choice of the best variants among possible ones then in terms of fuzzy sets decision-making process would be reduced to the choice of efficient alternatives or to the task of fuzzy mathematical programming.

In realization of DKB rational topological design of DKB is equally important; this is reduced to three basic problems: division of DKB into fragments; arrangement of these fragments in the network nodes; assignment of fragments to application programs. Main criteria for solution of these problems are: system response, uniform load distribution between application programs and fragments of DKB, total cost of DDMS etc., which are characteristic for DKB designing. Solutions of many problems in DKB limits are given in literature. Due to similarity of topological design problems of distributed knowledge bases and distributed databases description of formal problem statement and solving of such problems for DKB in our opinion makes no sense. But division of DKB into fragments besides topological design of DKB influences also logic of DKB construction and to a large extent defines the quality of decision-making.

Selection of desired knowledge from DKB represented by $R = \{S,T,P\}$ model is complicated and important multistage process. Multiplicity of stages is necessitated by the fact that fragments have been geographically distributed all over the network nodes, search and selection of desired knowledge throughout total DKB are very difficult and in most cases senseless. The last statement follows from superposition principle for the process of knowledge selection which could be formulated as follows: if the process of knowledge selection will be divided into sub-processes according to fragments then desired knowledge might be found from multiplicity chosen by fragments.

However, this statement is not always valid and depends on the fragmentation method. Analysis of reliability of superposition principle of knowledge search for different types of fragmentation is given below.

Let us assume that DKB is divided in accordance with horizontal fragmentation principle, without copies, i.e.

$$R = \bigcup_{i=1}^{n} R_i, \; R_i \cap R_j = \emptyset, \; i \neq j; \; Z_i \cap Z_j = Z_i = Z_j = Z, \; \forall \, i,j$$

Here $R_i \in R$ and $Z_i \in Z$ define i-th fragment of DKB. Degree of R_i fulfilment with characteristics (or criteria) Z is defined by set of accessory functions:

$$\mu_S(r_i), \; \mu_T(r_i), \; \mu_P(r_i) \rightarrow [0,1], \; i=\overline{1,n}; \; r_i \in R_i$$

Then for each i-th fragment the process of knowledge search is reduced to multicriteria problem of fuzzy mathematical programming which could be solved applying generalized Belman-Zade principle. Solution of the problem will be as follows:

$$\mu_Z(R_i^*) = \max \min \, [\mu_S(r_i), \mu_T(r_i), \mu_P(r_i)], \; r_i \in R_i$$

In accordance with abovegiven conditions of horizontal fragmentation the problem of global knowledge search throughout total DKB is solved by intersection of R_i^* , $i=1,n$, i.e.

$$M_z(r^*) = \min [M_s(r_i^*) \,|,\, i=\overline{1,n}]$$

Hence, it follows that for horizontal fragmentation without copies superposition principle is valid.

In case of vertical fragmentation of DKB without copies, i.e.

$$R_i \cap R_j = R_i = R_j = R, \; \forall \; i,j \;;\; R = \bigcup_{i=1}^{n} R_i \,,\; R_i \cap R_j = \emptyset, \; \forall \; i,j$$

failure of superposition principle of knowledge search process could be proved. To solve the problem one should act as follows. At the first stage set of minimum $M_{z_j}(r_i)$ by fragments $j=\overline{1,m}$ will be chosen, and new matrix of ratios R x z', z'$\in$ Z will be obtained; we can apply Belman-zade maximization principle to this matrix and obtain desired solution:

$$M_z(r^*) = \max \min [M_{z_j}(r_i) \,|,\, i=\overline{1,n} \,,\, j=\overline{1,m}]$$

Now let us consider the case when DKB is divided into fragments and they have copies. The process of knowledge search in this case differs from the case without copies, as copies of one and the same fragment can differ by degree of compliance with reality. This fact might be called contradiction of knowledge in DKB.

This allows to make conclusion about failure of superposition principle for considered case. To find a way out one could use coefficients of relative importance of fragments $\mathcal{L}_i$, $i=\overline{1,n'}$, where $\sum_{i=1}^{n'} \mathcal{L}_i = 1$.

Here n' - number of all fragments of DKB taking copies into account. Consequently, $n' - n > 0$ - number of fragment copies additionally fromed in DKB. TO obtain final decisions one could use abovedescribed methods.

It should be noted that formation of DKB is not end in itself, as it is an important component of decision-making system realized in computer networks. Final objective of this work is formation of distributed expert systems in various spheres of control including real time systems as described arahitecture and methods of knowledge handling allow to increase in the first place speed of access and knowledge search. It should be noted that suggested method is not unique and unambiguous.

However, while is no accepted conception of formation of distributed expert systems suggested in the present work methods could favour the development of theory.

At present alongside with theoretical works distributed system of decision-making is beeing developed for Azerbaijan Academy of Sciences using suggested methods.

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