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Global decision-making in multi-agent decision-making system with dynamically generated disjoint clusters

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ABSTRACT

This paper discusses the issues related to the process of global decision-making on the basis of knowledge which is stored in several local knowledge bases. The approach considered in this paper is very general because we do not assume any additional conditions on the sets of objects or the sets of conditional attributes of local knowledge bases.

The paper proposes a new approach to the organization of the structure of multi-agent decision-making system, which operates on the basis of dispersed knowledge. In the presented system, the local knowledge bases will be combined into groups in a dynamic way. We will seek to designate groups of local bases on which the test object is classified to the decision classes in a similar manner. Then, a process of the elimination inconsistencies in the knowledge will be implemented in the created groups. Global decisions will be made by using one of the methods for analysis of conflicts.

The paper includes the definition of a multi-agent decision-making system with dynamically generated clusters and a description of a global decision-making process. In addition, the paper presents the results of experiments carried out on data from the UCI repository.

1. Introduction

In this paper, the problem of making decisions on the basis of dispersed knowledge stored in many local knowledge bases is examined. In the approach considered, very general assumptions have been adopted. There are several knowledge bases that contain information on the same subject, but that is defined on different sets of attributes. The sets of conditional attributes and the sets of objects in knowledge bases are not necessarily equal, or disjoint. However, the same decision attributes must be present in all of the knowledge bases.

In this paper a new approach to the organization of a system structure that uses dispersed knowledge is proposed. The method for creating a coalition of local knowledge bases is the main difference between the previous and the current proposed approach. In earlier papers [33–37,25], the system in which local knowledge bases that had common conditional attributes formed a group was considered, which means that a system with a static structure was previously analyzed. Groups of local knowledge bases that were created once were used in the decision-making process for all of the test objects. Thus, the structure of groups that were created was completely independent of decisions that were made for the test object based on local knowledge bases. The structure only depends on the conditional attributes of the local knowledge bases. Such an approach is quite rigid. In the approach that is proposed in this paper, an attempt was made to simulate the natural process of creating coalitions. Each time a different test object is considered, new groups of knowledge bases are created that reflect their compatibility in decision making. The new approach is based on the assumption that one group should contain the knowledge bases on the basis of which a similar classification for the test object will be made. As a result, for each test object, the reorganization of local knowledge bases into groups (coalitions) is performed. Such an approach seems to be more natural and obvious. In this paper, it is shown that the proposed dynamic approach provides better results than the static approach. This is also proven using a statistical test that shows that the difference between the classification errors of both approaches is significant. After coalitions are created, the knowledge bases that remain in such a coalition are aggregated. An important problem that occurs when this process is performed is the elimination of inconsistencies in the knowledge that is stored in different knowledge bases. In this paper, the method for the elimination of inconsistencies in the knowledge that was proposed

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in earlier papers [34,35] is used. Local decisions are taken within group based on this aggregated knowledge. Due to the fact that the inference is carried out in groups of knowledge bases, there is a problem of conflict analysis in the proposed system. Two methods of conflict analysis that were proposed in earlier papers [33,34,37] are used in this paper. In the final stage of the global decision-making process, a set of global decisions is generated using the method of conflict analysis.

From a more technical point of view, the classification problem is under consideration, although not in the classical sense, because we are considering dispersed knowledge. A simple classifier is constructed based on each local knowledge base, which is modeled on the k nearest neighbors method. Local databases are combined into clusters with respect to similarities in the decisions taken. A modified hierarchical agglomeration clustering algorithm is used to build clusters. However, the paper does not focus on the clustering problem. The clustering issue is used in the process of the decisions taken; in other words, in the classification process. Local decisions are taken within the clusters and inconsistencies in the knowledge are eliminated. Then, local decisions are aggregated into global decisions.

In order to justify the need for this study, we analyzed an example of a real application of the considered approach. For example, consider four different medical centers that have different apparatuses and diagnostic methods to detect heart problems. Each medical center has different patients, but some patients may be treated at several of the medical centers. Suppose that one of the medical centers in the database stores information about echocardiograms and EKGs. A different medical center only examines the level of cholesterol and performs Doppler tests. Another medical center investigates cholesterol and performs CT Heart Scans and yet another medical center performs echocardiograms, myocardial biopsies and stress tests. Thus, we have the knowledge about the same topic being stored in four different databases. There are different objects in these databases, which can sometimes be shared and there are different attributes that can also be shared. In the previously considered approach, when we used the knowledge from the four medical centers to make a decision for a new patient the following two coalitions always occurred – the first coalition was formed by the first and fourth centers, while the second coalition was formed by the second and third centers. That was because the first and fourth medical centers had the common attribute echocardiograms and the second and third medical centers had the common attribute cholesterol. For each new patient, a coalition tries to reach a common local decision. In this case, compatibility of the decisions within the coalition may not be present, but the members of the coalition must come to an agreement. This approach meant that the voices of some members within the coalition were ignored; those members would perhaps find support among the members of other coalitions. In the new approach, each of the medical centers will first vote on the decision for a new patient. Then the centers that made the same decisions will form a coalition. Different coalitions can be formed for each new patient. In this approach, each member of the coalition can count on the support of the group to which it belongs.

The article is organized as follows. In the second section of this paper an overview of papers that are related to the subjects being discussed in this article is included. In the third section a new approach to the structure of a multi-agent decision-making system is proposed. In this section, the definition of a multi-agent decision-making system with dynamically generated clusters is given. The fourth section describes the method used for the elimination of inconsistencies in the knowledge. The fifth section describes the methods of conflict analysis. The sixth section gives a description and the results of experiments carried out using some data sets from the UCI repository.

2. Related work

It is difficult to find a solution to the exact same problem that is considered in this paper in the literature, which is a situation in which we have knowledge about the same topic being stored in several different databases. There are different objects in databases being considered, which can sometimes be shared and there are also different attributes that also can be shared. Certainly, a decision attribute is a common element that is present in all of these databases. A similar approach is the multiple model approach [13]. In a multiple classifier system, an ensemble is constructed based on base classifiers, which usually permits more precise predictions than any of the individual base classifiers. The accuracy of an ensemble depends on both the quality of the problem decomposition and the individual accuracies in the base classifiers. One of the methods for decomposition is to use the domain knowledge to decompose the nature of the decisions into a hierarchy of layers [18]. In the papers [19,31,38], an ensemble of feature subsets is considered. In the paper [9], a random subspace technique for building an ensemble is considered. A very important issue is that some form of diversity among the base classifiers must exist in order to improve accuracy [29,32]. The method for generating the final decision also has a significant impact on the efficiency of the ensemble [8]. Examples of the application of this approach can be found in the literature [1,30]. This article describes an approach that is different from all of those mentioned above. The main difference is that we assume that a set of local knowledge bases (base classifiers) that contain information from one domain is determined prior to the process of inference – it is set up in advance.

The main aim of this paper is to propose a system in which knowledge bases will be combined into groups (coalitions) in a dynamic way. The negotiations for and the formation of coalitions is an important form of social interaction and it is studied in various branches of the social sciences as well as in computer science. Artificial intelligence researchers have investigated the design of agents with negotiation competence from two main perspectives: a theoretical or formal mathematical perspective and a practical or system-building perspective. The various negotiation models that have been proposed in the literature exhibit different features. A brief overview of various negotiation models that have been proposed in the literature can be found in the paper [15]. Zeng and Sycara [40] proposed a sequential decision-making model, called Bazaar, which is able to learn. The model formalizes the issues of negotiation and incorporates a set of negotiation strategies. Faratin et al. [7] presented a model for bilateral service-oriented negotiation that defines a range of strategies and three groups of concession tactics. Lopes et al. [14] presented a negotiation model that formalizes various problem-solving and concession strategies. Nguyen and Jennings [17] presented a model that handles one-to-many negotiations in service-oriented contexts. A buyer engages in multiple concurrent bilateral negotiations with a set of sellers who are capable of providing a specific service. All of these approaches to the issue of coalition formation that were mentioned above are different from the approach considered in this paper. In the approach considered in the paper, the goal of each agent is a classification based on the knowledge accumulated in the local knowledge base to which the agent has access, whereas in the approaches discussed in the literature, the goals of agents have an extremely diversified nature.

In the papers of Zdzisław Pawlak [20,21,23], a different approach to the issue of coalition formation was considered. This model describes a conflict situation in which the agents have decided to analyze the conflict by using a peaceful method. In such a situation the relations of conflict, friendship and neutrality were defined and the method of formulating the coalition as well as the method of calculating the intensity of the conflict were proposed. In this paper,