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A dispersed decision-making system – The use of negotiations during the dynamic generation of a system's structure

Małgorzata Przybyła-Kasperek *, Alicja Wakulicz-Deja

University of Silesia, Institute of Computer Science, Będzińska 39, 41-200 Sosnowiec, Poland

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ABSTRACT

The issues that are related to the process of global decision-making on the basis of knowledge which is stored in a dispersed form (several local knowledge bases or classifiers) are discussed in this paper. In a decision-making system, which is described in the paper, the classification process of the test object starts with an investigation of how particular classifiers classify a test object. We describe the views of classifiers by using probability vectors over decision classes. In the system, the process of combining classifiers in coalitions is very important. Negotiation is used in the clustering process. We define three types of relations between classifiers: friendship, conflict and neutrality. The clustering process consists of two stages. In the first step, the initial groups are created. These groups contain classifiers that are in a friendship relation. In the second stage, classifiers which are in neutrality relation are attached to the existing groups. In this paper, a formal description of the clustering process is presented and mathematical properties of functions, which are used, are described. For every cluster, we find a kind of combined information. Finally, we classify the given test object by voting among clusters, using the combined information from each of the clusters.

In the paper a new way of creating clusters (with a negotiation stage) is compared to the approach presented in the paper (Przybyła-Kasperek and Wakulicz-Deja, 2014) [23] (without negotiations). There are significant differences between the clusters that are generated using these two approaches, which are shown in the paper. In the new approach, the clusters are more complex and better reconstruct and illustrate the views of the classifiers on the classification.

1. Introduction

Nowadays, knowledge is stored in huge databases, the analysis of which requires a great deal of time and computing power. In addition, very often many different centers accumulate knowledge on the same subject, but it is stored in separate sets in various forms. Supporting the decision-making process in such situations is a great challenge and a difficult task. Traditional methods of data analysis are not sufficient in this situation. Therefore, it is necessary to develop new methods of dealing with the dispersed knowledge that is available in the form of many different knowledge bases.

Issues concerning the use of dispersed knowledge were considered by authors in earlier papers [22,23,32–34]. In those papers decision-making systems using dispersed knowledge and some methods to deal with inconsistencies in the

* Corresponding author.
E-mail address: malgorzata.przybyla-kasperek@us.edu.pl (M. Przybyła-Kasperek).

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knowledge and the analysis of conflicts were proposed. In this paper, we develop and modify the concepts discussed earlier. The new idea of creating a system structure and formulating coalitions of agents is proposed. In previous papers [23,34], only two relationships between agents have been used – friendship and conflict relation. These relationships were defined by the function of the distance between agents. A pair of agents was in a friendship relation if the value of this function was less than 0.5. Otherwise, the pair was in a conflict relationship. As is quite clear, there was a fine line between those two relationships (a pair with a value of the distance function of 0.49 is in a friendship relation, while a pair with the value 0.5 is in a conflict relation). This situation seems to be adverse. Therefore, in this paper, a third relationship is proposed – a neutrality relation. The process of creating coalitions has also been changed. Now the process consists of two stages. In the first stage – the agents in a friendship relation are connected into groups. The second stage is the negotiation stage, in which the neutral agents play a crucial role. A more detailed description of the proposed approach is presented below.

We assume that in the system knowledge is available in the form of many local knowledge bases. A test object is given, for which we want to determine the global decision based on all of the available knowledge. A vector, which describes the classification of a test object that is made on the basis of the local base, is generated for each local knowledge base. Between local knowledge bases three types of relations – friendship, conflict and neutrality – are defined. Then a two-stage process of connecting the local knowledge bases in coalitions, groups of bases that agree on the classification of the test object, is implemented. In the first step of this process, the local knowledge bases that remain in a friendship relation are combined into groups. The second step consists of re-examining the relations between the initial coalitions that were created. A negotiation process is implemented, in which in addition to the initial coalitions, the local knowledge bases that remain in a neutrality relation are included. Then the local bases that have been included in the coalition are aggregated. Decisions within a coalition are determined based on the aggregated knowledge. In the next step conflict analysis methods are used to permit the designation of a global decision.

The article is organized as follows. In the second part of this paper an overview of papers related to the subjects considered in this article is included. In the third chapter, a new approach to the creation of a system's structure is described. In this chapter we define the relations, friendship, conflict and neutrality and describe a two-step process of creating a coalition of local knowledge bases. It also gives the definition of a dispersed decision-making system. The third chapter describes an example showing the proposed approach being used. The fourth chapter describes a method for the elimination of inconsistencies in knowledge which is used in this study. The fifth section describes the method of conflict analysis. The sixth section contains a description and the results of experiments carried out using some data sets from the UCI repository. The article concludes with a short summary in the seventh section.

2. Related work

The issue of making decisions based on dispersed knowledge is widely considered in the literature. For example, this issue is considered in the multiple model approach [7,12,21]. In a multiple classifier system, an ensemble is constructed on the basis of base classifiers. The aim of this approach is to reduce the misclassification at the cost of increased computational complexity. Ensemble accuracy depends on both the quality of the problem decomposition and individual accuracies in the base classifiers. One of the methods for decomposition is to use of domain knowledge to decompose the nature of the decisions into a hierarchy of layers [15]. In the papers [17,30,35] an ensemble of feature subsets is considered. In the paper [16] a random subspace technique for building an ensemble is considered. A very important matter is that some form of diversity among the base classifiers must exist in order to improve accuracy [28,31]. The method of generating the final decision also has a significant impact on the efficiency of the ensemble [6].

In the papers [1,2,10], another approach to the problem of classification on the basis of several different decision tables, which is different from that which is considered in this paper, can be found. In Distributed Data Mining (DDM) methods, it is assumed that the data are collected and stored in different decision tables representing either horizontally or vertically partitioned.

The concept of distributed decision-making is widely discussed in the paper [26]. In addition, the problem of using distributed knowledge is considered in many other papers [3,27,29]. In the paper [36], an approach was proposed in which many classifying agents are generated by using fast approximation heuristics, after which a classification system is constructed by selecting the optimal subset of agents.

This paper describes a different approach to the process of global decision-making. We assume that a set of local knowledge bases that contain information from one domain is determined prior to the process of inference – set up in advance. The only condition that must be satisfied is the occurrence of the same decision attributes in all of the local knowledge bases.

A very important issue that is discussed in this paper is formulating the coalition and the process of negotiations. The theory of negotiations and the formation of coalitions is an important issue of social interaction and it is studied in various branches of the social sciences as well as in computer science. A brief overview of the various negotiation models that have been proposed in the literature can be found in the paper [14]. Several ways of classifying the existing models of negotiation exist. One of them is to distinguish between two kinds of negotiations models – theoretical and computational models. Theoretical models are proposed for describing, specifying, and reasoning about the key features of negotiating agents [5,13,25]. Computational models are suggested for specifying the key data structures of negotiating agents and the processes operating on these structures [9,11,24].