Knowledge-Based Systems 106 (2016) 206–219

Contents lists available at ScienceDirect

Knowledge-Based Systems

journal homepage: www.elsevier.com/locate/knosys

Consensus reaching model in the complex and dynamic MAGDM problem

Yucheng Dong[a,*], Hengjie Zhang[a], Enrique Herrera-Viedma[b,c]

[a] Business School, Sichuan University, Chengdu, 610065, China
[b] Department of Computer Science and Artificial Intelligence, University of Granada, Granada, 18071, Spain
[c] Department of Electrical and Computer Engineering, Faculty of Engineering, King Abdulaziz University, Jeddah, 21589, Saudi Arabia

ARTICLE INFO

Article history:
Received 10 September 2015
Revised 17 May 2016
Accepted 23 May 2016
Available online 24 May 2016

Keywords:
Multiple attribute decision making
Group decision making
Dynamic context
Individual attributes
Individual alternatives
Consensus

ABSTRACT

In classical multiple attribute group decision making (MAGDM), decision makers evaluate predefined alternatives based on predefined attributes. In other words, the set of alternatives and the set of attributes are fixed throughout the decision process. However, real-world MAGDM problems (e.g., the decision processes of the United Nations Security Council) frequently have the following features. (1) Decision makers have different interests, and they thus use individual sets of attributes to evaluate the individual alternatives. In some situations, the individual sets of attributes may be heterogeneous. (2) In the decision process, decision makers do not have to reach a consensus regarding the use of the set of attributes. Instead, decision makers hope to find an alternative that is approved by all or most of them. (3) Finally, both the individual sets of attributes and the individual sets of alternatives can change dynamically in the decision process. By incorporating the above practical features into MAGDM, this study defines a complex and dynamic MAGDM problem, and proposes its resolution framework. In the resolution framework, a selection process in the context of heterogeneous attributes is proposed that obtains the ranking of individual alternatives and a collective solution. In addition, a consensus process is developed that generates adjustment suggestions for individual sets of attributes, individual sets of alternatives and individual preferences, thus helping decision makers reach consensus. Compared with existing MAGDM models, this study provides a flexible framework to form an approximate decision model to real-world MAGDM problems.

1. Introduction

Multiple attribute decision making refers to the problem of ranking the alternatives based on the evaluation information of alternatives associated with multiple attributes [14,41,42,49]. The increasing complexity of decision environments makes it difficult for a single decision maker to consider all of the relevant aspects of a decision problem. Thus, multiple attribute group decision making (MAGDM) is widely used to integrate the knowledge and experiences contained in a group of decision makers. MAGDM can be understood as a task to find a collective solution to a decision problem in a situation in which multiple decision makers express their preferences regarding multiple attributes and alternatives [46,54].

In an ideal MAGDM situation, all of the attributes are evaluated under the same information format. This type of MAGDM with the same information format of attribute values is called a homogeneous MAGDM problem. However, in many cases, all of the attributes involved in the decision problem cannot be evaluated using the same information format because of the complexity of decision objects, and different attributes are thus suited for evaluation using different information formats (e.g., real numbers, intervals, fuzzy numbers, and linguistic variables, etc.). These types of MAGDM problems with different forms of attribute values are called heterogeneous MAGDM problems, and several approaches to handle such heterogeneous MAGDM problems have been presented (see Espinilla et al. [15], Martínez et al. [32], Yang and Sen [48], and Zhang et al. [55]).

Usually, at the beginning of the group decision making (GDM) problem, decision makers' opinions may differ substantially. The consensus reaching process is often a necessity in GDM to achieve a general consensus regarding the selected alternatives [20,23,30,36,38]. Classically, consensus is defined as the full and

* Corresponding author.
E-mail addresses: ycdong@scu.edu.cn (Y. Dong), hjzhang@stu.scu.edu.cn (H. Zhang), viedma@decsai.ugr.es (E. Herrera-Viedma).

http://dx.doi.org/10.1016/j.knosys.2016.05.046
0950-7051/

unanimous agreement of all the decision makers regarding all the feasible alternatives. However, this definition is inconvenient, and a complete agreement is not always necessary in practice. This belief has led to the use of a “soft” consensus level (i.e., consensus measure) [5,7,21,26,28,40]. A variety of consensus models have been proposed based on soft consensus. (1) There are consensus models under different preference representation structures. Cabrerizo et al. [3] investigated consensus model using linguistic preference relations. Further, Dong and Zhang [11] and Herrera-Viedma et al. [22] presented consensus models that address heterogeneous preference information. (2) Some consensus models feature minimum adjustments or cost. Ben-Ariech et al. [2] presented consensus model with minimum cost. In addition, Dong et al. [6,10] proposed linguistic consensus models with minimum adjustments, and Zhang et al. [54] devised consensus model with minimum cost by taking aggregation operators into account. (3) Other consensus models are based on consistency and consensus measures. Dong et al. [9] and Zhang et al. [53] developed consensus frameworks that simultaneously manage individual consistency and consensus. (4) Other consensus models consider the behaviors/attitudes of decision makers. Palomares et al. [35] presented a consensus model for addressing non-cooperative behaviors, in which the weights of the decision makers who have the non-cooperative behaviors are compulsively penalized by a moderator. Further, Dong et al. [12] proposed a novel consensus framework based on a self-management mechanism to manage non-cooperative behaviors. In the work of Dong et al. [12], the weights of decision makers are generated dynamically from multi-attribute mutual evaluation matrices. Besides, Wu and Chiclana [44] proposed a trust-based consensus model. (5) Finally, there are consensus models developed for dynamic/Web contexts. Pérez et al. [37] proposed the dynamic consensus model to manage decision situations in which the set of alternatives changes dynamically. Moreover, Alonso et al. [1], Kacprzyk and Zadrozny [27], and Zadrozny and Kacprzyk [51] investigated web-based consensus support systems.

The consensus rules and frameworks that are used in the above soft consensus models are also exported to MAGDM problems. Thus, Guha and Chakraborty [16] investigated consensus in MAGDM by taking the degrees of confidence of decision makers’ preferences into account. Moreover, Xu [45] and Xu and Wu [46] develop consensus models for MAGDM that autocratically guide decision makers to reach a consensus. Recently, Xu et al. [47] proposed a consensus approach for eliminating conflicts in emergency MAGDM problems.

In the homogeneous MAGDM and heterogeneous MAGDM problems referred to above, decision makers express their preferences over the same set of predefined attributes. However, in certain real decision situations, decision makers may come from different places and have different interests. As a result, decision makers may use different sets of attributes, which we call individual sets of attributes, to evaluate separate alternatives. Recently, Lourenzutti and Krohling [31] discussed heterogeneous MAGDMs with individual sets of attributes. In the work of [31], authors argue that the decision problem is discussed in a dynamic environment because some attributes are evaluated as random variables. Meanwhile, in the decision-making process, it may not be necessary to reach consensus over the use of a set of attributes and the set of alternatives. Instead, decision makers hope to find an alternative that is approved by all or most of the decision makers. For example, when the United Nations Security Council decides which action(s) it should take, the five permanent members frequently evaluate alternatives using different criteria based on their individual interests. However, the United Nations Security Council must decide upon an action that is approved by all of the permanent members. To address this type of MAGDM problem, this study defines a novel MAGDM, which is called a complex and dynamic MAGDM, and proposes a novel consensus-reaching model. Specifically, the following three features are considered in the complex and dynamic MAGDM problem:

1) Decision makers have different interests and thus use individual sets of attributes to evaluate the individual alternatives. Meanwhile, the individual sets of attributes may be heterogeneous.
2) In the decision process, decision makers do not have to reach a consensus regarding the use of the set of attributes. Instead, decision makers hope to find an alternative that is approved by all or most of the decision makers.
3) Both the individual sets of attributes and the individual sets of alternatives can change dynamically in the decision process.

The rest of this study is organized as follows. Section 2 introduces the background and proposes MAGDM problem. Section 3 then proposes a resolution framework for the proposed MAGDM. Next, Section 4 presents a selection process, and Section 5 proposes a consensus process. Following this, Section 6 provides a practical example. Subsequently, Section 7 compares the complex and dynamic MAGDM with existing MAGDM. Finally, Section 8 presents the concluding remarks.

2. Background and proposed MAGDM problem

This section introduces the classical MAGDM problem, and then defines a novel MAGDM, which is called the complex and dynamic MAGDM in this study.

2.1. Classical MAGDM problem

A classical MAGDM problem can be described as follows:

Let $X = \{x_1, x_2, ..., x_n\}$ $(n \geq 2)$ be a set of predefined alternatives. Let $A = \{a_1, a_2, ..., a_l\}$ $(l \geq 1)$ be a set of predefined attributes and $w = (w_1, w_2, ..., w_l)^T$ be the associated weights over attributes, where $w_i \geq 0$ $(i = 1, 2, ..., l)$ denotes the weight of the attribute a_i, and $\sum_{i=1}^{l} w_i = 1$. Let $E = \{e_1, e_2, ..., e_m\}$ $(m \geq 2)$ be a set of decision makers and $\lambda = (\lambda_1, \lambda_2, ..., \lambda_m)^T$ be the associated weight vector over the decision makers, where $\lambda_k \geq 0$ $(k = 1, 2, ..., m)$ is the weight of the decision maker e_k, and $\sum_{k=1}^{m} \lambda_k = 1$. Let $V^{(k)} = [v_{ij}^{(k)}]_{n \times l}$ $(k = 1, 2, ..., m)$ be the evaluation matrix given by the decision maker e_k, where $v_{ij}^{(k)}$ represents the preference value for the alternative $x_i \in X$ with respect to attribute $a_j \in A$.

The decision question is how to rank the alternatives from best to worst based on the evaluation matrices $V^{(k)} = [v_{ij}^{(k)}]_{n \times l}$ $(k = 1, 2, ..., m)$.

If all of the attributes in A are evaluated using the same information format, then the evaluation matrix $V^{(k)} = [v_{ij}^{(k)}]_{n \times l}$ is called a homogeneous evaluation matrix. This type of MAGDM problem is called a homogeneous MAGDM problem. Specifically, when all of the attributes in A are evaluated using fuzzy numbers, the MAGDM problem is called a fuzzy MAGDM problem [16]. In addition, when all of the attributes in A are evaluated using linguistic values, the MAGDM problem is called a linguistic MAGDM problem.

However, in some situations, the attributes in A cannot all be evaluated using the same information format. Some attributes may be suitable to be evaluated by numerical values, whereas other attributes may be suitable to be evaluated by other information formats (e.g., intervals, fuzzy numbers, and linguistic variables, etc.). In this situation, the evaluation matrix $V^{(k)} = [v_{ij}^{(k)}]_{n \times l}$ is called a heterogeneous evaluation matrix. This type of MAGDM problem is called a heterogeneous MAGDM problem [4,15,31,48,55].