Knowledge-Based Systems 000 (2017) 1–14

Contents lists available at ScienceDirect

Knowledge-Based Systems

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

A consensus reaching model for hesitant information with different preference structures

Yue He[a], Zeshui Xu[a,b,*]

[a] Business School, Sichuan University, Chengdu 610064, China
[b] School of Computer and Software, Nanjing University of Information Science and Technology, Nanjing 210044, China

ARTICLE INFO

Article history:
Received 19 October 2016
Revised 26 July 2017
Accepted 6 August 2017
Available online xxx

Keywords:
Consensus reaching model
Hesitant fuzzy preference relation
Hesitant multiplicative preference relation
Nonlinear programming model

ABSTRACT

Since the decision makers' experience, cognitions and knowledge background are quite different from each other, sometimes the preference information they provided may be various and different. In order to help the decision makers share information and make more reliable decisions, we design a consensus reaching model which consists of two parts: 1) selection process; 2) consensus process. In this paper, we apply the hesitant fuzzy preference relations, the hesitant multiplicative preference relations and the hesitant preference orderings to express and integrate these complex preference information in a simple and convenient way. In the selection process, we propose a hybrid nonlinear programming model to process the information with different preference structures. This model overcomes the shortcomings of the traditional decision methods for hesitant information and obtains the decision results in a more accurate and reasonable way. In the consensus process, the consensus measure is put forward to judge whether the decision results are acceptable and identify which decision maker needs to modify his/her provided information. Then, an interaction mechanism is also proposed to help the decision makers exchange information and adjust the evaluation values. In the last, we apply the consensus reaching model to solve the hospital's trust evaluation problem and verify the stability of the model.

1. Introduction

Group decision making (GDM) is a basic way to obtain the decision results in modern society. The more complex the decision environment and the decision problem, the more need for wisdom of the decision group. However, since the decision makers' experience, cognitions and knowledge background are quite different from each other, the preference information they provided may also be different. In order to express the decision group's provided information in a reasonable and convenient way, Torra [1] proposed the concept of hesitant fuzzy set (HFS). Among all the tools for expressing the decision makers' opinions, preference relation [2-4] is one of the most common and useful tools for the decision makers to express their preference information. Hesitant fuzzy preference relations (HFPRs) and hesitant multiplicative preference relations (HMPRs) [5] are two important tools to express the preference information provided by the decision makers, and have been widely used in practical situations, such as water conservancy [6], enterprises investment [7], and supply chain risk evaluation [8], etc. Another useful tool to indicate the decision makers' preference information is the preference orderings (POs) [9], which are a collection of positive integers $(1, 2, \ldots, n)$ used by the decision makers for showing the order positions of set of alternatives in sequence. As the extended forms of POs, the uncertain POs, such as the interval preference orderings [10] (IPOs) and the hesitant preference orderings (HPOs), can also be used to solve the decision making problems.

Since the preference information obtained from the decision makers are complex and various, there are two important problems with respect to the GDM: 1) how to obtain the decision results from the complex and various information; 2) how to affirm that the decision makers will accept the decision results.

For GDM, there have existed lots of decision making methods for the HFPRs, the HMPRs and the uncertain preference orderings to obtain the priority weights of alternatives, which is the basis to get the decision results. Zhu and Xu [11] developed a new hesitant goal programming model to derive priorities from the HFPRs. Zhang [12] established a goal programming model for deriving the priority weights from the incomplete HFPRs based on the α-normalization and developed a method for complementing the acceptable incomplete HFPRs based on the β-normalization. Zhu and Xu [6] proposed a hesitant multiplicative programming method as a new priority method to derive the ratio-scale priority from the HMPRs. For IPOs, Fan and Liu [10] gave the possibility

* Corresponding author.
E-mail addresses: yuehe_scu@sina.com (Y. He), xuzeshui@263.net (Z. Xu).

http://dx.doi.org/10.1016/j.knosys.2017.08.007
0950-7051/

degree on comparing two interval ordering numbers and built the optimization model based on the collective expectation possibility degree matrix to rank alternatives. From these existing researches, the programming method is a common way to obtain the priority weights for the HFPRs, the HMPRs and the IPOs.

Due to the different cognitions, experiences and knowledge background of the decision makers, the provided evaluation values based on the decision makers' preferences may be various. Therefore, obtaining the decision results which can be accepted by most of decision makers is another important issue in the GDM problems. In order to do that, the consensus reaching models are designed to help the decision makers share their knowledge and information, exchange their opinions and modify their evaluation values. Xu and Cai [13] developed a number of goal programming models and quadratic programming models by maximizing group consensus based on preference relations. With the prospect theory Wu and Xu [14] developed a consensus reaching process to solve the consensus problems of hesitant fuzzy linguistic preference relations. Dong and Zhang [15] proposed a direct consensus framework for multi-person decision making with different preference representation structures, i.e. preference orderings, utility functions, multiplicative preference relations and fuzzy preference relations. Herrera [16] et al. presented a consensus model under linguistic assessments for GDM, which allows to incorporate more human consistency in the decision support systems. Mata et al. [17] proposed an adaptive consensus support system model which can adapt its behavior to the agreement achieved.

Since hesitant preference structures are convenient and useful in expressing the opinions of the members in decision group and it is important to make the decision results acceptable for the decision group, the decision making methods with hesitant preference structures and the consensus frameworks should be combined to develop a new consensus reaching model for GDM. Moreover, the traditional decision making methods for hesitant information are based on singe hesitant preference structure. Considering the fact that different decision makers have different habits to express their preferences, how to deal with the hesitant information with difference hesitant preference structures and obtain a reasonable result is also an essential issue. Therefore, in this paper, a consensus reaching model is developed to solve the GDM problem with different hesitant preference structures. Normally, the consensus reaching model consists of two parts: 1) selection process; 2) consensus process. In the selection process, the hybrid nonlinear programming model is developed by combining the nonlinear programming models for the HFPRs, the HMPRs and the HPOs based on the distance measures. After the selection process, we can obtain a decision result which can be seen as the standard of the decision group's preferences. In the consensus process, the similarity measures are used to calculate the consensus degrees of the decision group. Then, the decision makers can share the information and modify their evaluation values by the interaction process, which will make the decision makers reach a consensus. In this model, the preferences information of decision makers can be well expressed and processed. Moreover, since we combine the nonlinear programming model in the selection process and the consensus process, the decision results can be accepted by most of the decision makers. The consensus reaching model of this paper has two important characteristics:

1) The hybrid nonlinear programming model in the selection process can use the preference information provided by the decision makers accurately. Hesitant information is difficult to calculate and process since it contains more than one dimension. Some of the decision making methods delete or add some information in order to make the dimension of the hesitant information consistent [4], which may cause some errors in the decision results. The hybrid nonlinear programming model can make full use of the provided information and obtain the decision results in a more reasonable way.
2) The consensus reaching model in this paper is relatively stable. The decision results are barely affected by the parameters in the selection process and the consensus process.

The rest of the paper is organized as follows: Section 2 introduces some basic concepts of the different hesitant preference structures, the distance measures and the basic consensus reaching model. In Section 3, we propose several nonlinear programming models for obtaining the priority vectors of the different hesitant preference structures. Then, based on these models, we develop a hybrid nonlinear programming model to get the priority vectors of the decision group. Section 4 introduces the consensus process, which consists of the consensus measure, the identification and modification of the preference information. Section 5 illustrates the consensus reaching model in this paper with a trust degree evaluation of hospitals and verify the stability of the model. The paper ends with the concluding remarks in Section 6.

2. Basic concepts and notations

In this section, we introduce some concepts of the hesitant fuzzy sets, the hesitant preference structures and basic distance measures which are commonly used in group decision making process. Then, we briefly introduce the procedure of the consensus reaching model.

2.1. Different hesitant preference structures

Since the cognitions, experiences and knowledge backgrounds of the decision makers are different, the decision makers may provide different evaluation values. In this case, the hesitant fuzzy set (HFS) and the hesitant multiplicative set (HMS) can express the decision group's opinion in a simple and convenient way, shown as follows:

Torra [1] first proposed the concept of hesitant fuzzy sets as follows:

Definition 1 [1]**.** Let X be a fixed set, a hesitant fuzzy set (HFS) on X is in terms of a function that when applied to X returns a subset of [0, 1].

To be easily understood, Xia and Xu [18] expressed the HFS by a mathematical symbol which can be represented as: $E = \{< x, h(x) > |x \in X\}$, where $h(x)$ is a set of some values in [0,1], denoting the possible membership degrees of the element $x \in X$ to the set E, and $h(x)$ is called a hesitant fuzzy element (HFE).

Based on 1–9 scale, Zhu and Xu [6] defined the hesitant multiplicative set (HMS):

Definition 2 [6]**.** Let X be a fixed set, a HMS is defined as $Z = \{\langle x, z(x)\rangle | x \in X\}$, where $z(x)$ is a subset of [1/9, 9] following the 1–9 ratio scale.

For convenience, $z = z(x)$ can be called a hesitant multiplicative element (HME). Since a HME may consist of several possible values, it can be considered as a hesitant judgment in the decision making environment.

In decision making process, preference relations and preference orderings are two most commonly used tools to express the decision makers' preference information. When dealing with the GDM problems, the preference information provided by the decision makers is usually complex and multifarious, which can be easily expressed in the forms of HFPRs, HMPRs and HPOs, whose definitions are shown as follows:

Please cite this article as: Y. He, Z. Xu, A consensus reaching model for hesitant information with different preference structures, Knowledge-Based Systems (2017), http://dx.doi.org/10.1016/j.knosys.2017.08.007