Information Sciences xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Information Sciences

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

ELSEVIER

INFORMATION SCIENCES

An enhanced consensus reaching process in group decision making with intuitionistic fuzzy preference relations

Q1 Huchang Liao [a], Zeshui Xu [a,*], Xiao-Jun Zeng [b], Dong-Ling Xu [c]

Q2 [a] Business School, Sichuan University, Chengdu, Sichuan 610065, China
[b] School of Computer Science, University of Manchester, Manchester M13 9PL, United Kingdom
[c] Manchester Business School, University of Manchester, Manchester M15 6 PB, United Kingdom

A R T I C L E I N F O

Article history:
Received 12 February 2015
Revised 16 August 2015
Accepted 11 September 2015
Available online xxx

Keywords:
Group decision making
Intuitionistic fuzzy preference relation
Consensus reaching process
Multiplicative consistency

A B S T R A C T

Group decision making (GDM) with intuitionistic fuzzy preference relations (IFPRs) has been an important and active research topic recently, in which one of the most challenging issues is how to reach the group consensus so as to get the best decision. As the uniform consensus is often unachievable in practice, in order to achieve the consensus, the existing method needs to remove the experts with the most different opinions from the decision group. It has two drawbacks: the first is the loss of the valuable judgments and opinions of the removed experts. This is especially harmful in practice where most experts or decision makers often have the biased knowledge in the sense of in-depth expertise in some aspects and naive views in other aspects. The second is demotivating the experts in GDM. To overcome these weaknesses in the existing method, this paper presents an enhanced consensus reaching process for GDM with IFPRs, which only removes some opinions of an expert for alternative(s) instead of removing the expert from the decision group. A numerical example concerning the selection of outstanding PhD students for China Scholarship Council is given to show the feasibility and effectiveness of the enhanced consensus reaching process.

1. Introduction

Group decision making (GDM) has attracted the attention of researchers and practitioners in a wide range of disparate areas from engineering, operations research, economic and management. Sometimes the GDM problem is very simple, such as a group of people choosing a candidate restaurant to have their dinner; sometimes it is very complicated, such as selecting the global supplier for Lenovo Group. A GDM problem can be simplified as a group of individuals/experts $E = \{e_1, e_2, \ldots, e_s\}$ to make a choice from a set of alternatives $A = \{A_1, A_2, \ldots, A_n\}$ for action in accordance with the opinions provided by the group members. Therefore, how to describe the group members' opinions is very important and it influences the final result directly as the experts often are only able to express their opinions roughly and subjectively.

Generally speaking, there are four ways in which the experts can express their opinions: preference orderings, utility values, fuzzy preference relations, and multiplicative preference relations. Preference orderings are a collection of natural numbers which are a permutation of $(1, 2, \ldots, n)$ used by the experts for showing the order positions of a set of alternatives in sequence [40]. For instance, considering four candidate alternatives $\{A_1, A_2, A_3, A_4\}$, a preference ordering $O = \{A_3, A_1, A_2, A_4\}$ given by an expert represents that A_3 is the best alternative, A_1 is in the second place, A_2 is in the third place, and A_4 is the worst one. Utility

* Corresponding author.
E-mail addresses: liaohuchang@163.com (H. Liao), xuzeshui@263.net (Z. Xu), x.zeng@manchester.ac.uk (X.-J. Zeng), ling.xu@mbs.ac.uk (D.-L. Xu).

http://dx.doi.org/10.1016/j.ins.2015.09.024
0020-0255/

values are a series of exact real numbers taken from a closed unit interval [0, 1] to indicate the preferences of an expert towards different outcomes. For example, the utility values of the four alternatives could be $U = \{0.7, 0.5, 0.8, 0.2\}$ which means that A_3 is the best choice, and A_4 is the worst one. The fuzzy preference relation describes the preference information of an expert over each pair of objects by a matrix $P = (p_{ij})_{n\times n}$, where $0 \le p_{ij} \le 1$ and $p_{ij} + p_{ji} = 1$. p_{ij} indicates the preference degree or the intensity of the alternative A_i over A_j. More specifically, $p_{ij} = 0.5$ indicates that there is indifference between the alternatives A_i and A_j; $p_{ij} > 0.5$ indicates that the alternative A_i is preferred to A_j; $p_{ij} < 0.5$ indicates that the alternative A_j is preferred to A_i. A multiplicative preference relation $Q = (q_{ij})_{n\times n}$ is also a $n \times n$ matrix in which each element q_{ij} represents a ratio of the preference intensity of the alternative A_i over A_j (i.e., A_i is q_{ij} times as good as A_j). The multiplicative preference relation uses the 1–9 scale to describe the preferences of one alternative over the other, where $q_{ij} > 1$ indicates that alternative A_i is preferred to A_j; $q_{ij} = 1$ indicates indifference between A_i and A_j; $q_{ij} < 1$ indicates that alternative A_j is preferred to A_i.

Among these four types of preference representation methods, the preference ordering is oversimplified because it contains little information about the experts' preferences, which makes it inconvenient or impossible for further investigation especially when a group of experts cannot reach a mutually agreeable result. The utility values of the alternatives are sometimes very difficult to be determined. In addition, Winkler [38] pointed out that utility theory is descriptive and lack of how people actually behave if they leave their own devices. Such a descriptive theory will never be prescriptively appealing [35]. Preference relations (no matter they are fuzzy or multiplicative) are constructed via pairwise comparisons over the alternatives, and thus can express the preferences of the experts easily. With the preference relations, there is no need for the experts to determine the crisp utility values of alternatives over each criterion. They can express their judgments subjectively according to their cognitions. For these reasons, the preference relations have attracted significant attention of many scholars.

However, there are still some weaknesses on fuzzy preference relation and multiplicative preference relation. Both of them consider only the preference degrees or intensities of the alternative A_i over A_j. In many cases, it might be very difficult for the experts to determine such preference degrees especially when some of the experts are not very familiar with the GDM problem or there exists some incomplete information about some of the alternatives. In such situations, motivated by the idea of intuitionistic fuzzy sets (IFSs) [2,3], the experts would prefer to express their inaccurate cognitions from the positive, negative and hesitative points of view and thus construct an intuitionistic fuzzy preference relation (IFPR) [41]. An IFPR $\tilde{R}^{(l)}$ provided by the expert E_l is a structure whose elements are intuitionistic fuzzy numbers (IFNs), denoted as $\tilde{r}_{ij}^{(l)} = (\mu_{ij}^{(l)}, \nu_{ij}^{(l)}, \pi_{ij}^{(l)})$ with $\mu_{ij}^{(l)}, \nu_{ij}^{(l)} \in [0, 1]$, $\mu_{ij}^{(l)} + \nu_{ij}^{(l)} \le 1$, $\mu_{ij}^{(l)} = \nu_{ji}^{(l)}$, $\mu_{ii}^{(l)} = \nu_{ii}^{(l)} = 0.5$, for all $i, j = 1, 2, \ldots, n$, $l = 1, 2, \ldots, s$. $\mu_{ij}^{(l)}$ means the preference degree of the alternative A_i to A_j; $\nu_{ij}^{(l)}$ indicates the non-preference degree of the alternative A_i to A_j, and $\pi_{ij} = 1 - \mu_{ij}^{(l)} - \nu_{ij}^{(l)}$ is interpreted as an indeterminacy degree or a hesitancy degree. As the IFPR can express the opinions of an expert in terms of "preferred", "not preferred", and "indeterminate" aspects, it is more comprehensive and flexible than the fuzzy preference relation and the multiplicative preference relation in expressing an expert's preferences. It is worthy noticing that the IFPR is isomorphic to the interval-valued fuzzy preference relation even if their interpretive settings and motivations are quite different: the latter captures the idea of ill-known membership grade while the former starts from the idea of evaluating the degrees of membership, non-membership and indetermination independently [8].

Up to now, many scholars and practitioners have investigated GDM with IFPRs. Generally, GDM with IFPRs involves three processes (for more details, please refer to Section 2):

(1) Consistency checking and improving process. The consistency checking and improving process is to make sure that the expert's preferences have no self-contradiction [16,17]. As perfect consistent IFPRs are very hard to be determined by the experts due to their limited cognitions, especially when the number of alternatives is very large, based on the consistency conditions, some inconsistency improving procedures, including the automatic iterative procedure and the interactive procedure [11,18,44], were proposed to make the IFPRs of acceptable consistency [12].
(2) Consensus reaching process. The consensus reaching process is to find a solution that is supported by all the group members despite their different opinions. Here consensus means that most members of a team agree on a clear option and the few who oppose it think that they have a reasonable opportunity to influence that choice [26].
(3) Selecting process. The selection process is to find the final result which is accepted by most individuals via some aggregation and ranking procedures.

Although there are many attractive achievements related to GDM with IFPRs, we can still find some drawbacks in the literature:

- Szmidt and Kacprzyk [29] investigated the consensus of IFPR by extending the idea of fuzzy analysis of consensus using the concept of distance. Later, they [31] introduced another consensus measure based on the similarity measure to calculate the degree of agreement of a group. Afterwards, Xu and Yager [45] also proposed a consensus measure for consensus analysis in GDM with IFPRs. However, all of these studies only pay attention to consensus measurements, but do not consider the processes (1) and (3); even for the process (2), how to reach a group consensus has not been discussed.
- Xu and Xia [44] proposed some iterative procedures to improve the consistency of IFPRs; recently. Liao and Xu [11] also introduced some automatic procedures to repair the inconsistent IFPRs. However, both of them only focus on the process (1) and do not pay much attention to the consensus process. In addition, the multiplicative consistency conditions they used are somewhat unreasonable [14].

Please cite this article as: H. Liao et al., An enhanced consensus reaching process in group decision making with intuitionistic fuzzy preference relations, Information Sciences (2015), http://dx.doi.org/10.1016/j.ins.2015.09.024