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Abstract

This paper presents a fuzzy group decision support system (GDSS) approach to group multiple criteria decision making. It includes a fuzzy group decision making method and a fuzzy GDSS framework. Six different preference formats are supported by the fuzzy group decision making method. The fuzzy GDSS framework integrates multiple criteria decision making methods, fuzzy multiple criteria decision making methods, and the proposed fuzzy group decision making method. It not only supports the whole group decision making processes, but also provides flexibility for decision makers to elicit and present their individual preferences in their chosen formats. A Web-based GDSS prototype has been developed based on the proposed fuzzy group decision making method and the fuzzy GDSS framework.

Keywords: Group decision making, Web-GDSS, fuzzy theory, MCDM, preference format

Introduction

Group multiple criteria *decision making* refers to making preference decisions (e.g., evaluation, prioritization, selection) by a group of decision makers over the discrete alternatives that are characterized by multiple criteria (also called attributes) (Hwang and Lin 1987). It is an important task in business organizations since groups make more and more decisions in fast changing environments. The most commonly used methods for group decision making under multiple criteria are social choice theory (Fishburn 1990), fuzzy group decision making (Blin and Winston 1974, Orlovsky 1978), multiple criteria decision making (MCDM) methods (Hwang and Lin 1987, Zeleny 1982), and fuzzy MCDM methods (Chen and Hwang 1992, Carlsson and Fuller 1996, Zimmermann 1987). Correspondingly, current GDSSs for group decision making under multiple criteria can be classified into three categories: GDSSs with social choice theory and fuzzy group decision making (Jessup and Valacich 1993), GDSSs with MCDM and fuzzy MCDM methods (Bose et al. 1997), and integrated GDSSs which combine MCDM methods with social choice theory (Bui 1987).

GDSSs with social choice theory and fuzzy group decision making have a strong theoretical ground for aggregation of individual preferences, but they do not support individual preference elicitation. GDSSs with MCDM and fuzzy MCDM methods support individual preference elicitation, but they only provide one decision method in each group decision making round. Integrated GDSSs take advantages of MCDM methods and social choice theory, but they can not deal with fuzzy decision data. Furthermore, the current GDSSs for group multiple criteria decision making do not allow different decision makers to give their individual preferences in different formats.

This paper aims to propose a fuzzy GDSS approach to group decision making under multiple criteria. It includes a fuzzy group decision making method and a GDSS framework. The fuzzy group decision making method supports six different preference formats. The fuzzy GDSS framework integrates MCDM methods, fuzzy MCDM methods, and the proposed fuzzy group decision making method. The proposed approach provides decision makers with a flexible way to elicit and present their individual preferences which takes into consideration fuzzy decision data and decision makers' different attitudes, motivation, and personalities.

The rest of the paper is organized as follows: Section 2 presents a fuzzy group decision making method. Section 3 describes a fuzzy GDSS, and a summary is given in Section 4.

Fuzzy Group Decision Making Method

This section briefly presents a fuzzy group decision making method to support different formats of individual preferences in group decision making, which extends the work of Chiclana et al. (1998). The method consists of three parts: preference formats, preference uniformity, and preference aggregation.

Preference Formats

In group multiple criteria decision making, there are a set of alternatives, a set of criteria and a set of decision makers. The decision task is to choose the best alternative(s) from alternative set according to decision makers' comprehensive consideration of the involved multiple criteria. It is assumed that decision makers can give their individual preferences directly at this stage. As each decision maker comes from a different background and has his/her own ideas, attitudes, motivation and personality, different decision makers may provide their individual preferences on alternatives in different formats (Chiclana et al. 1998).

Ordinal preference and cardinal preference are commonly used formats of individual preferences (Fodor and Roubens 1994, Tanino 1990). Ordinal preference can be expressed as ordered vector. The alternatives are ordered from the best to the worst. Cardinal preference can be expressed as numerical utility vector. Each alternative is assigned a numerical value in [0, 1].

Selected subset is one of the individual preference formats (Tanino 1990). Alternatives selected from basic alternative set compose a subset and there is no difference among the alternatives in the subset. This preference expression method allows decision makers easily to express their individual preferences.

As decision makers use their subjective judgments to choose alternatives, situations may often arise where it is difficult for them to simply choose or reject the alternatives. In such uncertain case, the yes/no method could not be sufficient. One alternative method is for decision makers to give belief levels to the selected alternatives to express this kind of uncertainty (Ma and Zhou 2000). The belief levels belong to a set of fuzzy linguistic terms that contains various degrees of preference required by decision makers. This kind of preference is called fuzzy selected subset in which each selected alternative is associated with a belief level (fuzzy linguistic term). It is an extension of selected subset. Fuzzy preference relation is an extension of normal preference relation (binary relation on alternatives) (Orlovsky 1978, Kacprzyk 1986, Nurmi 1981). It is the basic preference of fuzzy group decision making.

According to the above discussion, the following preference formats are provided to decision makers in the fuzzy group decision making method: 1) ordered vector: the alternatives are ordered from the best to the worst; 2) utility vector: each alternative is assigned a numerical value in [0, 1]; 3) selected subset: alternatives selected from basic alternative set compose a subset and there is no difference among the alternatives in the subset; 4) fuzzy selected subset: assign belief levels (fuzzy linguistic terms) to selected alternatives, it is an extension of selected subset; 5) normal preference relation; 6) fuzzy preference relation.

Preference Uniformity and Aggregation

In order to aggregate the different individual preferences to reach a group decision, different format preferences must be transformed to unique format preferences. Compared to other preference formats, fuzzy preference relation has its merits in aggregation and generality. This fuzzy group decision making method makes use of fuzzy preference relation as the base element of the uniform representation.

Once the decision information is uniformed, a set of individual fuzzy preference relations is obtained. *Fuzzy quantifier* (Kacprzyk 1986, Zadeh 1983) and *ordered weighted averaging operator* (OWA) (Yager 1988, 1998) are applied to aggregate individual fuzzy preference relations to the group solutions.

The detailed description about preference uniformity and aggregation can be found in (Kwok et al. 2002).

A Fuzzy GDSS for Group Decision Making under Multiple Criteria

The fuzzy group decision making method discussed in Section 2 provides a mechanism for decision makers to present their individual preferences in different formats. This section presents a fuzzy GDSS which integrates the fuzzy group decision making

method, MCDM methods, and fuzzy MCDM methods. The fuzzy GDSS supports individual preference elicitation, individual preference presentation, and the whole process of group decision making under multiple criteria.

The Conceptual Framework of the Fuzzy GDSS

Alternative generation, individual preference elicitation, individual preference presentation and aggregation, and alternative selection are the general processes of group multiple criteria decision making. A conceptual framework of the fuzzy GDSS is proposed (Figure 1) to support the whole process of group multiple criteria decision making. The foundation for this framework is:

- *Idea generation*. Idea generation for alternatives and the relevant criteria is an important process of group multiple criteria decision making. "Electronic brainstorming" is one of the major functions of GDSSs (Nunamaker et al. 1987, Nunamaker et al. 1991, Vogel et al. 1990). With "Electronic brainstorming" support, decision makers can not only make use of anonymity to express their ideas freely without fear of confronting other group members, but can also make use of parallel processing to express their opinions, ideas, or comments without having to wait for other members to finish their submission. This establishes an environment which lets decision makers participate in group discussions more equally and actively. The proposed GDSS should include "Electronic brainstorming" tool for idea generation.

- *Individual preference elicitation*. After getting alternatives and the relevant criteria, decision makers need to give their individual preferences to reach a group decision. Since alternatives involve multiple criteria, individual preference elicitation is a MCDM problem. MCDM methods and fuzzy MCDM methods, which make criteria become operational, can be used for individual preference elicitation. In addition, as each decision maker has his/her own background, decision makers may be familiar with different decision methods. One important issue concerning the decision methods is that decision makers be willing and able to use them (Lewis 1993). decision makers also prefer to use decision methods that they understand (Olson et al. 1995). So it is quite natural to think that different decision makers will use different MCDM or fuzzy MCDM methods to elicit their preferences on alternatives involving multiple criteria. On the other hand, for the reason of comparison, a decision maker may also use different decision methods to elicit individual preferences. The proposed GDSS should include MCDM and fuzzy MCDM methods (in model base) to provide decision makers with different MCDM methods and fuzzy MCDM methods to elicit their individual preferences.

- *Individual preference presentation and aggregation*. Different MCDM and fuzzy MCDM methods have different format preferences as outputs. After the initial preferences are elicited by MCDM and fuzzy MCDM methods, decision makers may adjust the initial preferences according to their judgments, and then present their individual preferences for group decision. It is also quite natural to think that different decision makers will present their preferences in different formats due to their familiarity with different preference formats. As true reflection of decision makers' individual preferences is essential to ensure the quality of group decision making (Olson et al. 1995), the proposed GDSS should provide a mechanism to group decision makers to express their individual preferences in different formats. The GDSS would then transform the different format preferences and make aggregation.

System Implementation

A Web-based GDSS prototype has been developed which is based on the fuzzy GDSS framework and fuzzy GDSS process discussed in previous sub-sections. Model base is the main focus of the fuzzy GDSS. The components of the system include:

(a) ***Electronic brainstorming***. This function allows group members to share ideas on a specific question or issue anonymously. decision makers are encouraged to be creative when giving ideas, suggestion and comments. The anonymity helps decision makers to focus on the merits of the contributed ideas rather than their source, enhances decision makers' participation and generates more information. The parallel process or the process of different space and time helps to improve the productivity, efficiency and effectiveness of group decision making.

(b) ***MCDM and fuzzy MCDM toolkit***. This is a toolkit of MCDM and fuzzy MCDM methods, such as Sample Additive Weighting Method, Weighted Product Method, etc. This function allows decision makers to select their familiar MCDM and fuzzy MCDM methods to elicit their individual preferences.

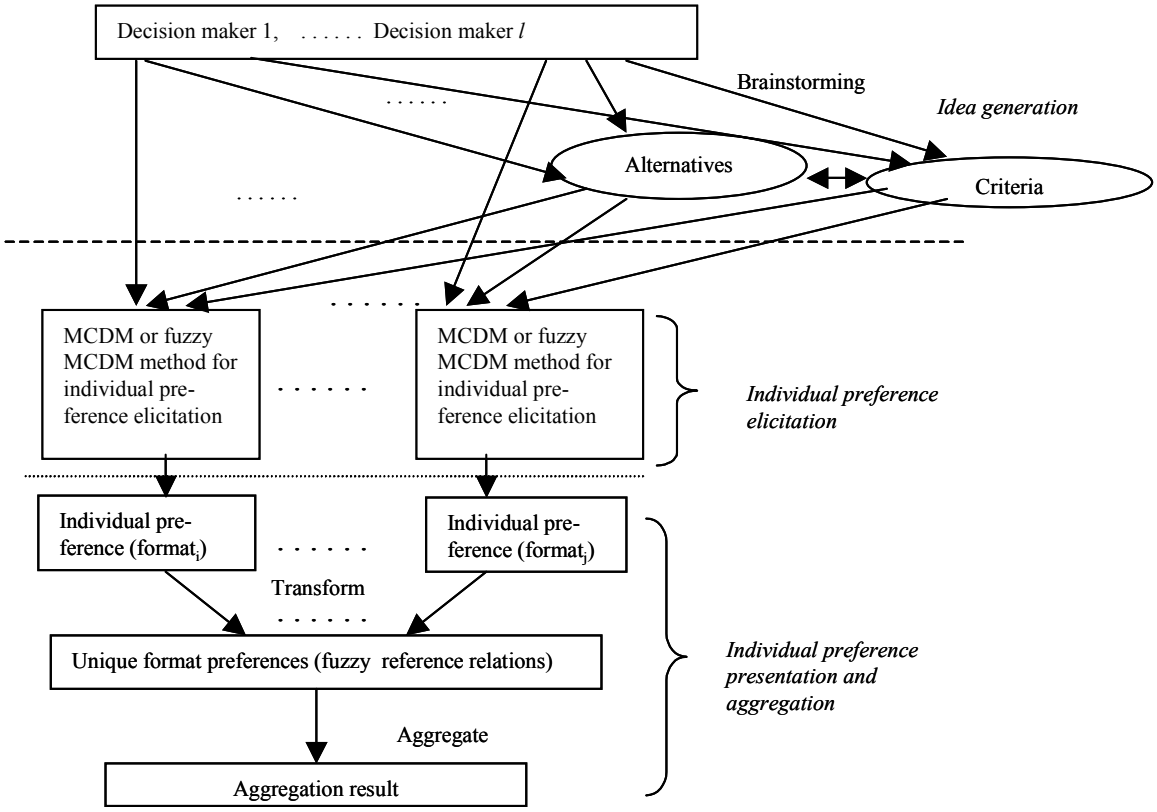

Figure 1. The Conceptual Framework of the Fuzzy GDSS for Group Multiple Criteria Decision Making

(c) ***Preference presentation tool.*** This function allows decision makers to present their preferences in different formats which include ordered vector, utility vector, selected subset, fuzzy selected subset, normal preference relation and fuzzy preference relation.

(d) ***Preference transformation***. This function transforms different format preferences to unique fuzzy preference relations. The transformation algorithm is based on the proposed fuzzy group decision making method.

(e) ***Preference aggregation.*** This function aggregates the unique format individual fuzzy preference relations, using ordered weighted averaging (OWA) operators with fuzzy quantifiers. The aggregation algorithm is also based on the proposed fuzzy group decision making method.

(f) ***Facilitator function tool***. This tool provides the facilitator or group leader with a set of functions for system management. It includes system initialization, parameter setting, user management, etc. For example, user management manages users' login user names, passwords, and the weights for aggregation.

Summary

This research presents a fuzzy GDSS approach to group decision making under multiple criteria. This approach consists of a fuzzy group decision making method and a fuzzy GDSS framework. The fuzzy group decision making method includes preference formats, preference uniformity, and preference aggregation. Six different individual preference formats, including ordered vector, utility vector, selected subset, fuzzy selected subset, normal preference relation, and fuzzy preference relation, are supported by the fuzzy group decision making method. The fuzzy GDSS framework integrates MCDM methods, fuzzy MCDM methods, and the proposed fuzzy group decision making method. Based on the proposed fuzzy group decision making method and the fuzzy GDSS framework, a Web-based GDSS prototype has been developed for further study. This approach makes use of fuzzy set theory to deal with incomplete, imprecise, and uncertain information in group decision making. It not only provides support to

the whole process of group decision making under multiple criteria, but also gives decision makers a flexible way to elicit and present their individual preferences in consideration of their different attitudes, motivation, and personalities. While flexibility is an important source of the value of decision support systems (Archer and Ghasemzadeh 1999, Kumar 1999).

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