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Decision Support

A new group ranking approach for ordinal preferences based on group maximum consensus sequences

Li-Ching Ma*

Department of Information Management, National United University, 1, Lienda, Miaoli 36003, Taiwan, R.O.C.

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ABSTRACT

Group ranking problems involve aggregating individual rankings to generate group ranking which represents consolidated group preference. Group ranking problems are commonly applied in real-world decision-making problems; however, supporting a group decision-making process is difficult due to the existence of multiple decision-makers, each with his/her own opinions. Hence, determining how to best aid the group ranking process is an important consideration. This study aims to determine a total ranking list which meets group consensus preferences for group ranking problems. A new group consensus mining approach based on the concept of tournament matrices and directed graphs is first developed; an optimization model involving maximum consensus sequences is then constructed to achieve a total ranking list. Compared to previous methods, the proposed approach can generate a total ranking list involving group consensus preferences. It can also determine maximum consensus sequences without the need for tedious candidate generation processes, while also providing flexibility in solving ranking problems using different input preferences that vary in format and completeness. In addition, consensus levels are adjustable.

1. Introduction

Group ranking problems involve aggregating individual rankings to generate group ranking which represents consolidated group preferences. Group ranking problems are commonly applied in decisions involving real world problems, such as ranking proposals from several reviewers (Cook, Golany, Penn, & Raviv, 2007), rank aggregation on the web (Beg & Ahmad, 2003) and ranking of advertising models based on customer surveys (Chen, Cheng, & Huang, 2013). However, supporting a group decision-making process is intensely difficult due to the existence of multiple decision-makers, each with his/her own perceptions about the way a decision should be made (Matsatsinis, Grigoroudis, & Samaras, 2005; Morais & Almeida, 2012). Therefore, in recent decades, determining how to best support the group ranking process has remained an important challenge.

There are various types of group ranking problems. According to Chen et al. (2013), group ranking problems can be classified according to the format of input preferences, as well as the completeness of input and output preferences. Users express input preferences in three major formats: weighting models, ranking lists (Chen & Cheng, 2009) and pairwise comparisons. The completeness of user-specified preferences can be divided into two types: total ranking preference and partial ranking preference (where only a subset of items is evaluated) (Chen & Cheng, 2010). The completeness of the final output results can be classified as constituting a total ranking list (Cook et al., 2007; Ma, 2010) or maximum consensus sequences (Chen & Cheng, 2009). A maximum consensus sequence is the longest ranking list of items that the majority agrees with and the minority disagrees with. The proposed approach can deal with the following types of ranking problems: (1) the format of input preferences: ranking lists and ordinal pairwise comparisons, (2) completeness of input preferences: total ranking and partial ranking preferences, (3) completeness of output results: maximum consensus as well as a total ranking list. The pairwise comparison matrix adopted in this study differs from that in the Analytical Hierarchy Process (AHP) (Saaty, 1980). In the conventional AHP, precise preferences are required in a ratio-scale pairwise comparison matrix. However, in this study, only dominance relationships between two alternatives need to be specified by users in an ordinal pairwise comparison matrix. In addition, decision makers are usually only able to provide incomplete information because of time pressure, lack of data, and their limited knowledge related to the specific problem domain (Kim & Byeong, 1999). Therefore, this study provides the flexibility whereby users can input incomplete preferences.

Most previous studies minimize the total disagreements among multiple input preferences in order to achieve an overall ranking list; however, the fact that users might achieve little or no consensus on the final results is often overlooked. Chen and Cheng (2009) proposed a method to mine maximum consensus sequences from

* Tel.: +886 37 381510; fax: +886 37 371462.
E-mail address: lcma@nuu.edu.tw

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multiple users' ranking preferences, based on the concept of the Apriori algorithm (Agrawal & Srikant, 1994). Instead of achieving an overall ranking list by minimizing total disagreements among multiple input preferences, their study generates only maximum consensus sequences. The group consensus preference can be realized by the maximum consensus sequence, and items of conflict can be detected. However, their method suffers from some major limitations. First, like many Apriori-based algorithms, candidate generation generates large numbers of subsets, resulting in the tedious workload of scanning, filtering and counting. In addition, maximum consensus sequences are usually fragmented; in practice, a complete total ranking list is generally of more help in making decisions. Finally, only input preferences with a ranking list format can be treated. This study aims to improve on these limitations by first determining maximum consensus sequences without a candidate generation process, and then developing an optimization model to obtain a final total ranking list.

This study aims to generate a total ranking list involving group consensus preferences for group ranking problems. A new group consensus mining approach based on the concept of tournament matrices and directed graphs is first developed, and then an optimization model involving maximum consensus sequences is constructed. The major advantages of the proposed approach are listed as follows.

(1) The proposed approach can obtain a total ranking list of alternatives based on maximum consensus sequences.
(2) Compared to Apriori-based consensus mining methods, the proposed approach can determine maximum consensus sequences without the need for tedious candidate generation processes.
(3) The proposed approach can provide flexibility in solving ranking problems with different formats and with varying degrees of completeness in the input preferences, including ranking lists and ordinal pairwise comparison formats, as well as partial and total completeness of input preferences.
(4) Minimum consensus levels and maximum disagreement levels are adjustable.

2. Related work for group ranking problems

In regard to solving group ranking problems, many methods have been proposed to generate a collective preference by aggregating different individual preferences. For instance, a value function approach for group ranking problems derives the final ranking lists using scores or value functions. Practice usually uses an additive form because it is more understandable for decision makers (Belton & Stewart, 2002; Ma & Li, 2011). For example, Ma (2010) adopted an additive score function and employed decision balls to visualize group ranking problems. Greco et al. (2008) presented a UTA^{GMS} approach for ranking problems using a set of additive value functions resulting from ordinal regression. In addition to additive functions, the Cobb–Douglas (1928) form with constant return to scale is a commonly used nonlinear score function for ranking problems (Ma & Li, 2008). Brugha (2000) pointed out that relative measured weights and scores should be synthesized using a power function, a kind of Cobb-Douglas function. The major limitation of the value function approaches is that most score or value functions have to be assumed in advance and users may have no consensus on the final ranking results.

A distance-based approach for group ranking problems uses a distance measurement to minimize total disagreement among multiple input preferences (Fernandez & Olmedo, 2005; Ma, 2012). Cook (2006) reviewed various distance-based models in ordinal preference ranking and demonstrated their levels of complexity by mathematical programming formulations. A distance-based approach has been widely applied in practice. For instance, Cook et al. (2007) proposed a branch-and-bound model based on a distance-based approach to support construction of an aggregate ranking of proposals from reviewers' partial ordinal rankings. By minimizing total distance, distance-based methods can obtain a complete total ranking list. However, like most value function approaches, users may have no consensus or only a slight consensus concerning the final total ranking lists.

In a multiple criteria environment, the concept of AHP (Saaty, 1980) has been widely applied in solving group decision problems (Lai, Wong, & Cheung, 2002; Altuzarra, Moreno-Jimenez, & Salvador, 2007; Dong, Zhang, Hong, & Xu, 2010). Group priorities can be identified through ratio-scaled judgments of pairwise preferences between alternatives specified by decision makers. The two most commonly used methods in AHP group decision-making are the aggregation of individual judgments (AIJ) and the aggregation of individual priorities (AIP) (Altuzarra et al., 2007). In AIJ, a new group judgment matrix is constructed by aggregating individual judgment matrices; priority methods are then employed to obtain the final group ranking (Dong et al., 2010). In AIP, the group's priorities are derived from individual priorities, using an aggregation method. The most popularly-adopted aggregation method acts as the weighted geometric mean for both the AIJ and AIP methods. After that, aggregation of individual preference structures (AIPS) (Escobar & Moreno-Jiménez, 2007) was proposed, which combined AHP and Borda count (Borda, 1981) to capture the perception of decision makers, as well as the uncertainty of the individuals. However, AHP has been shown to lack a rigorous theoretical basis (Barzilai, 2005). Recently, a robust ordinal regression method, called the UTA^{GMS}-GROUP, was proposed for multiple criteria group ranking problems (Greco, Kadzinski, Mousseau, & Slowinski, 2012; Kadzinski, Greco, & Slowinski, 2013). This method considers all compatible instances of a preference model, computes the necessary and the possible results, and then searches for consensus and disagreement between decision makers. However, a final total ranking list may not be obtained by this method.

The vote-counting approach for group ranking problems is based on ways of counting votes regarding group decision makers' preferences. Condorcet (1785) proposed a method based on vote-counting, known as the simple majority rule method, in which a relationship preferred by more voters is declared the winner. Borda (1981) developed an approach, called the Borda count, to obtain final ranking lists by counting the total of the ranks for each alternative evaluated by the voters. Morais and Almeida (2012) developed a position-based analysis of individual rankings composed of filtering, vetoing and choosing phases to solve group decision-making involving water resources. Recently, some counting-based data mining approaches have been applied in solving group ranking problems. For instance, Chen and Cheng (2009, 2010) employ the concept of an Apriori algorithm to mine maximum consensus sequences through repetitive candidate generation as well as counting and filtering processes. This approach can treat incomplete input preferences, and no score functions have to be assumed in advance; however, like most Apriori-based approaches, Chen and Cheng's approach (Chen & Cheng, 2009) has the following disadvantages: multiple scans of database and large numbers of candidates to be processed. In addition, maximum consensus sequences, rather than a total ranking list, can be achieved; however, the former are usually fragmented. This study aims to improve on these limitations.

3. The proposed group ranking approach

The proposed approach aims to find maximum consensus among users, and then construct an optimization model involving maximum consensus to achieve a total ranking list. Given a group ranking problem, denote $U = \{u_1, u_2, \ldots, u_m\}$ as m users in the group where users can be reviewers, managers, agents, individual decision makers, etc. Denote $A = \{a_1, a_2, \ldots, a_n\}$ as n distinct alternatives for evaluation. In this study, the preference of user u_k for n alternatives can be