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A social ties-based approach for group decision-making problems with incomplete additive preference relations

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ABSTRACT

With the rapid growth of Web 2.0 technology, a new paradigm has been developed that allows many users to participate in decision-making processes within online social networks. The social information (i.e., social ties and social influence) of the members that is stored in online social networks provides a new perspective for investigating group decision-making (GDM) problems. In this paper, a new interactive GDM approach, based on online social networks, is proposed to address a ranking problem with incomplete additive preference relations (IAPRs). This approach incorporates the strength of social ties and social influence calculated by social network analysis methods regarding the decision-making process. After decision makers (DMs) provide IAPRs, a searching algorithm is developed to identify the optimal preference information transfer path from DMs to the decision supporters who can provide the corresponding preference information. Next, a linear programming model is constructed to complete the missing preference values of the IAPRs. The main features of the linear programming model include its ability to account for other DMs' preference information and to maintain consistency. To help the group reach an agreement on the ranking of alternatives, a consensus reaching process is proposed. The strength of social ties and social influence are used to calculate the acceptable adjustment coefficients for DMs in the feedback mechanism. Finally, an illustrative example and further discussion demonstrate the validity of the proposed approach.

1. Introduction

Because the socioeconomic environment has grown progressively complex, the consideration of all of the relevant aspects of a problem by a single decision maker (DM) has become increasingly less feasible. Therefore, many organizations employ multiple members in decision-making processes [8], which is known as group decision-making (GDM). GDM is a type of participatory procedure in which multiple DMs collectively evaluate and select the available alternatives as a solution or solutions [50]. To help DMs to express preference, several preference representation formats, such as utility values [6,26], preference orderings [17,61] and preference relations [24,25,60] have often been used. Preference relations are popular and powerful techniques to model the preference intensities between alternatives and can be represented by preference matrices. Three most commonly used preference relations are multiplicative preference relations [14,57], linguistic preference relations [7,9] and additive preference relations (APRs) [10,56]. In some real decision-making problems, for various reasons, such as time pressure, lack of knowledge or data and limited expertise related to the problem domain [27], DMs might provide preference matrices with some missing values. Some approaches for addressing such incomplete preference relations have been proposed in the literature. For example, Herrera-Viedma et al. [23] propose a sequential iterative process to estimate the missing preference values using known preference information according to the consistency rules. Meng and Chen [36] present a goal programming model to estimate the missing preference values. Wu et al. [55] develop a preference estimation method based on the trust relationships between DMs. These approaches can be roughly classified into the following three categories: (1) methods iteratively estimating missing preference values and completing incomplete preference relations [1,3,23,29,49,59], (2) methods motivated by optimization techniques to estimate the unknown preference values of incomplete preference relations [34,36,52], and (3) methods estimating missing preference values using all of other DMs' known preference information [55]. Note that the approaches of the former two categories use consistency properties to estimate missing preferences values (i.e., the estimation of the unknown preference values relies on the known preference

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information provided in advance by DMs). The main advantage of using consistency rules is that the estimated preference values will be compatible with the known preference information provided by DMs. However, few methods driven by consistency rules suit total ignorance situations [2] in which DMs might not give any preference information about some alternatives. One of the exceptions is the study developed by Meng and Chen [36] in which the authors build a nonlinear programming model to estimate missing preference values in the case of total ignorance. The third approach uses trust relationships between DMs to estimate missing preference values in individual decision matrices. However, this method suffers from some limitations. On the one hand, it requires much cognition from DMs to specify the degree to which they trust others, which is cumbersome and DMs might refuse to do. On the other hand, it estimates DM's missing preference values using preference information for the remainder of DMs, contradicting mainstream studies [37,45,62,66], which indicates that only strong ties can exert influence on members' opinions.

In the context of GDM, due to DMs' different knowledge and experience levels, there may be a diversity of opinions among DMs. Thus, one critical issue is how to help DMs reach an agreement on a final solution. The consensus-reaching process (CRP) is usually employed to achieve a general consensus regarding the selected alternative [15]. Different types of CRPs have been proposed in the literature. For example, Herrera-Viedma et al. [22] propose a consensus model using consistency as a control in the CRP. Gong et al. [19] develop two types of minimum cost models with regard to all the DMs and one particular DM, respectively. Wu and Chiclana [54] present a trust-consensus-based GDM model, in which the consistency index and similarity index are combined to support DMs in changing their opinions. These approaches can be roughly classified into the following three categories: (1) consensus models based on consistency and consensus measures [14,22,57], (2) consensus models with minimum adjustments [5,13,19], and (3) consensus models based on trust relationships between DMs [54,55]. Although these works have made significant contributions to solving GDM problems, most CRP methods tend to assume that DMs are completely independent and therefore ignore social ties and social influence among DMs. However, there are always some links between the DMs [39]. DMs usually interact and influence each other, and thus each DM cannot be considered as an isolated entity when making a decision.

With the rapid development of Web 2.0 technology, online social networks have played a vital role in individuals' daily lives because of their effectiveness and efficiency in communication. Currently, the decision-making problems embedded in online social networks have increasingly attracted scholars from different fields [4,31,32,41,42,44]. Alonso et al. [4] first demonstrate the new characteristics of Web 2.0 communities in GDM contexts. For example, Web 2.0 technologies support real-time communication and users are heterogeneous. Li and Lai [32] propose a social appraisal mechanism to support individuals' decision-making through online social networks. Quijano-Sánchez et al. [41] employ users' social interaction information extracted from online social networks to develop a group recommendation application. Historical interaction information among users within online social networks provides a new way to infer individuals' preferences and aid individuals in decision-making. Based on these studies, we can conclude that the social information (i.e., social ties and social influence) of the members stored in online social networks is useful for solving real-life decision-making problems. Therefore, it is worthwhile to investigate and design a novel GDM framework for supporting decision-making within online social networks.

Social network analysis (SNA) has become one of the most popular methodologies for investigating social ties among members. It provides a way to describe and analyze the interconnections among individuals. According to SNA, strong social ties between two members indicate that the members could be more willing to share opinions with each other openly; at the same time, a member with more connections (e.g., friendships or interactions) is more important and influential than another member with fewer connections [32]. Duong et al. [16] design a consensus-based SNA method to investigate collaborative video annotation for social TV. Grady et al. [20] employ the SNA method to measure organizational relationships and integrated social relationships into an analytic network process to form a multi-criteria ANP project selection model. Pérez et al. [40] use an SNA method to investigate the social influence of DMs. In this study, SNA is used to estimate the strength of the social ties between DMs within online social networks. The commonly used modeling techniques for SNA such as graph theoretical, sociomatrix models, algebraic models, statistical models and agent-based models, are reviewed in [28]. The former two modeling methods have been widely used because they are able to show how actors are linked in a straightforward way. Algebraic model is used to analyze the structure of social roles by emphasizing multiple relations rather than actors [28]. Statistical and agent-based models are more useful for link predictions or investigating the evolution of networks. In this study, we adopt graph theoretical and sociomatrix models to progress SNA because we focus on the characteristics of individual actors (e.g., social ties and social influence) within online social networks rather than designing networks or analyzing the evolution of networks.

In this paper, we propose a social ties-based approach for the GDM problem with IAPRs. First, the SNA methodology is used to calculate the ties strength and the social influence of DMs within online social networks. Then, the social influence of DMs is used as a reliable source to determine DMs' weights. Second, to estimate IAPRs, social ties between DMs are employed to estimate DMs' unknown preference values. In reality, when a DM has strong tie strength with another member, he/she is more willing to seek decision support from that member. Based on such an idea, a linear programming is established to estimate the missing preference values. Third, to improve the group consensus level, the social ties and social influence of DMs are incorporated into the CRP. When group consensus level is lower than a predefined threshold, DMs with the minimum individual consensus level is advised to modify their incompatible preferences. To accelerate the reaching of consensus, another DM who has a minimum preference similarity with the identified DM is found to generate feedback. The acceptable adjustment coefficient of the DM for modifying preference is derived either from the ties strength or social influence. Finally, when the group consensus level is satisfactory, group preference is acquired by solving a linear programming model.

The approach proposed in this paper is distinguished from previous methods by the following features. (1) Compared to consistency-based preference estimation methods, our approach considers social ties between DMs and uses other DMs' preferences to estimate missing preference values in preference matrices. Meanwhile, the consistency level of completed preference relation is controlled within an acceptable range. (2) A searching algorithm is developed to identify the set of decision supporters for each missing preference value of IAPR. Using the algorithm, DMs who have available preference information and strong social ties with DMs who provide IAPR will be identified to aid in estimating unknown preference values. (3) To improve group consensus, we develop a social ties-based CRP to support interaction among DMs. The strength of social ties and social influence is used to calculate the acceptable adjustment coefficients for DMs in the feedback mechanism. Compared to existing consensus models [22,54,55,57,64], the acceptable adjustment coefficients for adjusting individual preference is personalized.