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A Survey of Group Decision Making Methods and Evaluation Techniques

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Abstract

This survey paper updates the literature with the various technologies associated with group decision making (GDM) processes including concepts, decision technology support, and evaluation metrics. We are concerned about quantitative and qualitative criteria for GDM results' success measurements. Further, we discuss the factors that contribute to enhance information presentation and user interfaces' usability. We also discuss how the eye tracking method is used to record users' eye movements for users' interfaces effectiveness evaluation. The Analytic Hierarchy Process (AHP) standard method and how it is adapted to GDM are covered. Related GDM voting mechanisms are reviewed. Examples of the key remarks on group decision quality found in the literature include the following. The quality of group decisions has been historically linked to the quality of the information available to decision makers as well as to the number of decision-makers contributing their observations and opinions as research reveals. Domain knowledge expertise is shown to affect group decision quality positively. Besides, users' satisfaction is commonly used in literature to judge on the GDM results.

Keywords: Collaborative group decision making (GDM), group decision support systems (GDSSs), GDM techniques, GDM evaluation metrics, GDM quality, the Analytic Hierarchy Process (AHP), GDM voting techniques, eye-movement tracking.

1 Group Decision Making

Group decision making (GDM) is not a new phenomena. Yet, in today's world, collaborative group decision-making can impact people's significant choices in different ways. GDM refers to processes where the decision made can no longer be associated with a single person, but with the entire group since many group members contributed to its adoption. The focus of this research is on evaluating GDM technical methods and decisions' outcome rather than judging on other aspects such as group formation or group dynamics. These assessments lead to suggestions on improvements to GDM processes and presentation methods. Enhancing the usability of GDM interfaces highly motivates the evaluation of the design and GDM results. Such evaluation suggests better ways to adequately presenting relevant information to decision makers. Various factors determine successful decisions including the ability of group members to communicate effectively and reach efficient decisions.

In the following sections, we introduce concepts relevant to group decision making processes, the Analytic Hierarchy Process (AHP), group decision voting methods, commonly used group decision making evaluation mechanisms, and finally a summary of the paper's contribution.

Group Decision Making Processes Humans cognitive tasks involve solving problems and making decisions (Aberg and Chang 2005). Decision making is a multi-disciplinary term (Kahneman and Tversky 1984), corresponding to the cognitive process that includes exploring several alternatives and selecting one choice (Harris 2016). The selection of the choice requires information gathering and processing (O'Connell and Cuthbertson 2009), as well as a criteria. Decision-making activities have been categorized into six practical components: *"information, representation, visualization, communication, reasoning*, and *intuition"* (Pohl 2008). Decision making input comprises alternatives that decision makers have to evaluate and a goal or a set of goals that have to be satisfied, while the output is an action or a choice of opinions (Bohanec 2009). Decision making can be made by individuals or groups for personal or public issues. A co-decision refers to a decision made by a collaborative group of people (De Michelis 1996) where a group consists of two or more individuals (Forsyth 2009).

Decision Making Models Decision making falls into two main categories: *descriptive* and *prescriptive* (also called *normative*). The descriptive approach, which is representative of cognitive sciences, studies how people actually make decisions, rather than how they are supposed to. On the other hand, normative reasoning, which studies the rationality essence, is concerned with finding the optimal choice under the assumption that the decision maker is aware of all available options and their consequences (Zhang, Fujiwara, and Kuwano 2007; Bohanec 2009; Kahneman and Tversky 1984). However, research shows that humans in reality tend to not be well informed about all decision alternatives (Bohanec 2009).

Global Rationality vs. Bounded Rationality In global rationality and based on a constant *utility function*, Simon (Simon 1997) presumes that the decision maker is

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aware of all available choices along with the corresponding anticipated worth of utility to be able to select the alternative that expands the assumed utility. Contrastingly, *bounded rationality*, supposes that the decision maker has a limited knowledge of available options and their consequences. Thus, he has to decide on alternatives that meet goals and fulfill restrictions. An example of applying the utility function in a household travel group decision making is found in (Zhang, Fujiwara, and Kuwano 2007).

Human vs. Computer-based Decision Making Compared to computers, humans have superior methods in making decisions by using natural cognitive, emotional, and computational circumventing activities (Antos 2011). While, humans can manage both quantitative and qualitative data efficiently, machines can support humans with fast computational matters that adhere to predefined rules, but they are inherently inflexible (Cummings and Bruni 2005).

Decision Support Systems Artificial intelligence techniques are frequently studied to emulate human reasoning actions, in order to assist with suggestions in computer-based human decision making (Dutta 1996). Preferable results come up when humans collaborate effectively with computers offering decision support systems (Cummings and Bruni 2005).

2 The Analytic Hierarchy Process (AHP)

Standard approaches to solve complex decision making problems include the Analytic Hierarchy Process (AHP). AHP is one of the widely used mathematical techniques for dealing with complex decision-making cases having multiple criteria (Saaty 1990; Alghamdi and Alfurhood 2007). In order to make rational decisions, AHP serves as a logical technique to resolve complex problems using a hierarchal structure decomposition (Lee, Yeom, and Park 2007). AHP integrates decision factors with a pairwise analysis of alternatives based on priorities given by a decision maker to each alternative. Specifically, priorities are allocated as weights to options concerning criteria in regard to the goal (Lee, Yeom, and Park 2007). Further, AHP allows decision makers to assign measures to abstract alternatives according to a relative priority ratio (Saaty 2008). The AHP was also shown to help organizations in determining rationales behind needs for change or no change in critical decisions (Chatterjee and Patra 2014).

AHP Critiques and Responses Although AHP is mathematically verified, there exist various critiques and responses. For example, AHP is challenged as to how one can perform comparisons between varying choices and to which degree the obtained results are applicable in practice. Besides, AHP does not come with useful instructions on how to construct the structure for problems hierarchically because results may vary accordingly (Hartwich 1999). Moreover, in AHP, priority scales are obtained via expert judgments by making relative pairwise comparisons between alternatives. Experts are humans and, therefore, there is a concern about inconsistencies in experts' judgments (Saaty 2008).

AHP for Group Decision Making A model to come to a consensus in group decision making by means of AHP is suggested by Dong and Saaty (Dong and Saaty 2014). A detailed example of using the AHP techniques for GDM to decide on the proper penalties for the common Internet crimes in Saudi Arabia is found in (Alfurhood 2007). Moreover, an AHP-based web tool was developed to achieve a unified English-Arabic dictionary for the field of information technology by a group of field's experts (Alghamdi and Alfurhood 2007).

The use of AHP in constructing analytic hierarchies is useful for group decisions as productive discussions along with justifications from distinct individuals help to form the final results even if their independent choices were not eventually selected (Hartwich 1999). In his paper (Saaty 2008), the developer of AHP brings to attention two matters related to group decision making with AHP, namely the aggregation of each member's judgment into a form that reflects the judgments of the whole group and the selection of the group choice based on individual group members' preferences. Correspondingly, Saaty discusses some current solutions to the above mentioned issues.

3 Group Decision Voting Techniques

Voting theory is a solution used by democratic societies to resolve conflicts among group members' various preferences into a single alternative. A vote represents the choice of a voter (Bowen 2016). There exist many different preferential voting mechanisms that are based on stated preferences. The main mechanisms are unanimity, consensus, majority, and plurality.

Unanimity vs. Consensus There is a key difference between unanimity and consensus in which the former requires all decision making participants to prefer taking the action, while the later is used by different sources to mean either consent, solidarity, or a large majority that is close to unanimity (Ford 2012).

Majority vs. Plurality Furthermore, majority differs from plurality in which the former works in the case of two candidates, while the later works in the case of more than two candidates to select from. To demonstrate, when a group has to select between two alternatives, the majority can be accomplished for the choice that exceeds 50% of the votes. However, when there are more alternatives to vote for, plurality makes the alternative that receives the highest number of votes wins even though if it does not pass the 50% threshold of the votes (Risse 2005; Bowen 2016).

Borda Count vs. Condorcet Methods Other voting mechanisms, including Borda count and Condorcet methods, have been used to overcome some of the problems associated with majority and plurality methods (Risse 2005; Erdmann 2011). Borda count is not a majority system, but a single winner consensus-based voting method. In Borda count, if N is the number of candidates and there are several candidates, then voters rank candidates according to their preferences. After that, one point is given to the last in the rank candidate, two points to the next in rank candidate, and so on up to the first ranked candidate which receives N points. After summing all the points given to the candidates by all voters, the candidate that receives the highest sum of points is the winner (Bowen 2016).

A Fair Voting Method To achieve fairness criteria in selecting a candidate, the pairwise comparison method must satisfy the Condorcet criterion by making sure that the candidate who wins all possible head-to-head match-ups wins the election (Bowen 2016). After all, Arrow's theorem shows that there exists no stable technique to select a fair option from a set of alternatives by deploying a preferential voting procedure (based on ranking candidates) (Bowen 2016).

4 Group Decision Making Evaluation: Qualitative and Quantitative Measures

Cummings' research (Cummings and Bruni 2005) aims at developing tools that represent quantitative and qualitative information visually so that humans take into account all limitations and consequences on local and global mission objectives when making their decisions. A goal in computer-mediated groups (Lemus et al. 2004) is expressed in the amount of *generated ideas*, *task information exchange*, *general participation levels*, and *consideration of alternatives*. Decision-making accomplishments in time, precision, and usability depend on the field of the task, the way images are presented, interactivity approaches, and the user's familiarity with the system (Gonzalez 1996). Further, quantitative or qualitative measures such as: *flexibility, emotions, control, politeness, homogeneity*, and *polarization* can be used as well.

Group Decision Quality Evaluation The quality of group decision making can be evaluated based on the satisfaction of the group members with respect to the selected choice (Kattan 2009). Decision quality can be subjective as it can be based on the views of the judge who is evaluating the decision quality and it relies on the circumstance (Kattan 2009). Besides, the quality of a judgment can be about the decision made or the group members who made the decision to which extent they achieve objectives and fulfill the criteria. This is relevant especially when the rationality of a decision cannot be evaluated mathematically.

The quality of the information participants provide could be an indicator of the quality of a decision support system (Bohanec 2009). Besides, the quality of the GDM is related to the differences between individuals' and the groups' decisions (De Michelis 1996).

Domain Knowledge Expertise Effects The probability of high-quality decision output increases when participants exchange more domain knowledge information (Felfernig, Stettinger, and Leitner 2015). Moreover, the authors in (Klein and Sprenger 2015) have developed a group decision model that under certain circumstances shows that individual expertise impacts the quality of group decision positively. This can be expressed statistically by computing differential weighting instead of the general averaging mechanism.

Visual Gaze Fixation and Eye-Movement Tracking One of the main mechanisms for understanding the impact that computer-based decision-making systems have on humans is to analyze their gaze. It helps verify whether the information is fairly provided to the user, and essential instructions have a chance to be observed and understood. When accomplishing a task, every moment users decide deliberately on what to gaze at. Preserving eye gaze in one position is visual fixation. Eye tracking technology is used to extract the gaze of the users (Poole and Ball 2006). Therefore, eye tracking is a reliable method to record indications of what users looked at momentary (Lynch 2009). The effect of human gaze is exploited by (Bahr and Ford 2011) to evaluate pop-up alerts in user interfaces, showing the lack of efficiency of such pop-ups.

Decision Quality Measurement: Choicla Application Evaluation of decision quality in Choicla (Stettinger and Felfernig 2014) uses functions such as Group Distance (GD), or Ensemble Voting (ENS). For a solution s with a set of values d for the given set of dimensions H, where each user u from the set U has a different preference value for a feature given by a function $eval$, are:

$$GD(s) = \underset{d}{\operatorname{argmin}} \left(\sum_{u \in U} |eval(u, s) - d| \right)$$

$$ENS(s) = \underset{d}{\operatorname{argmax}} \left(\# \left(\bigcup_{h \in H} eval(h, s) = d \right) \right)$$

"ENS" looks for the solution that maximizing the number of people preferring it or in other words, the number of people at a small distance of it. "GD" minimizes the sum of distances from the solution to preferences of all users.

5 Conclusions & Key Observations

Collaborative group decision making is an emergent area which has proven tremendous influence on society by its intended or unintended occurrence in social media. In this survey paper, we present concepts relevant to GDM processes and decision technology support. Most importantly, group decision quality evaluation mechanisms are discussed based on several factors. Research on the Analytic Hierarchy Process, AHP, and how it can be adjusted to reach a group decision is reviewed. Voting methods related to collaborative GDM are introduced. Among several quality indicators, users' happiness is chosen to judge on the group decision quality (Kattan 2009). Increasing domain knowledge information exchange proves to be effective to enhance decision quality (Felfernig, Stettinger, and Leitner 2015). There is no voting mechanisms that ensures complete fairness according to Arrow's theorem (Bowen 2016). However, there should be a compromise to use a voting mechanism that produces a good decision. Eye tracking is a reliable technique to record indications of what users looked at momentary (Lynch 2009). Finally, we believe that more solid evaluation and measurement criteria for group decision-making processes and decisions' quality are necessary. Structuring group decision information is an active research area.

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