

Voting Methods and Information Exchange in Group Support Systems

Kung-E Cheng

Information Systems Department
New Jersey Institute of Technology
kc37@njit.edu

Fadi P. Deek

College of Science and Liberal Arts
New Jersey Institute of Technology
fadi.deek@njit.edu

ABSTRACT

Voting tools in Group Support Systems (GSS) have been considered valuable assets in groups' decision processes. One important aspect of voting is the method of conducting the vote. Research in Social Choice Theory (SCT) has shown that different voting methods can lead to different voting outcomes. However, SCT seldom addresses how a voting method affects decision making processes. Voting methods interacting with the computation power and communication capability in GSS can also affect decision processes and outcomes. This paper reviews theories about voting methods and their implications to GSS. A classification of voting methods based on information exchange is proposed to examine the effect of voting methods on groups' decision processes.

Keywords

Voting, group support systems (GSS), decision support.

INTRODUCTION

Computerized voting has gained attention in research. However, the attention is focused on large-scale elections with topics such as security and integrity of voting protocols and usability of voting machines (Hoffman and Cranor, 2001; Mercuri and Camp, 2004). There is another side of computerized voting, voting tools in Group Support Systems (GSS) that support group decision making. Voting tools have been recognized by GSS researchers as valuable assets to aiding groups in making decisions. For example, Kraemer and King (1988, p. 131) suggest that voting systems have a pronounced effect on group decision making, that is, voting systems allow groups to identify the variance in issues being considered rapidly, and the anonymous voting in such systems can reduce the bias of dominant individuals. Nunamaker and his colleagues (Nunamaker, Briggs, Mittleman, Vogel and Balthazard, 1997) have pointed out that voting in GSS plays a different role than paper-balloting. Electronic voting encourages members to "vote early, vote often," because it is fast, preserves anonymity, helps achieve equality among members, and minimizes irrelevant influences.

Although voting tools provide great potential for group making decisions, theories and studies of voting in GSS remain sparse (Cheng, Li and Van de Walle, 2001). In order to fully utilize voting tools, there is a need to develop theories for voting in GSS. The theories can direct GSS researchers in formulating experiments, guide GSS system builders in designing sophisticated voting tools, and help GSS users better utilize voting tools. Many aspects of voting have been studied in fields such as Social Choice Theory (SCT) and Public Choice. However, those studies usually do not consider the voting process in group decision making with enhancements provided by computer systems. In this paper, we will propose a theory about possible effects of voting in GSS.

SOCIAL CHOICE THEORY

There are many factors related to GSS voting tools (Cheng et al., 2001; Gavish and Gerdes, 1997). One factor, the voting method, may have a very profound effect. The central theme of SCT is to investigate the features of various methods used in aggregating individual preferences into collective decisions (Nurmi, 1987). SCT can offer some insights in studying the effects of voting methods in GSS.

Preference

A brief explanation of key concepts in SCT is necessary before the analysis of attributes of various voting methods is presented. SCT is about combining individual preferences. Preference can be seen as the relative degree of desirability over a set of alternatives. Scholars in SCT have developed a set of notations to express preferences. Let's assume there are n individuals (voters) in a social choice system (a group, a committee, or a society). Each individual holds a preference (R)

over a set of alternatives (T). We can define relations P and I to express the preference. The relation P denotes that the alternative on the left-hand side is strictly preferred to the alternative on the right-hand side. The relation I denotes that the individual is indifferent to these two alternatives. Usually a subscript index is used to indicate which person in the social choice system holds this preference. For example, given two alternatives a and b , the i^{th} person in the social choice system may prefer a to b (stated as $aP_i b$), prefer b to a ($bP_i a$), or be indifferent to these two ($aI_i b$). Another relation R is also commonly used in SCT to express that the alternative on the left-hand side is at least as preferable as the alternative on the right-hand side. We can think of R as a union of P and I . The expression $aR_i b$ means that the i^{th} individual either prefers a to b or is indifferent to a and b ($aP_i b$ or $aI_i b$). We can see that this notation of preference only considers the order but not the magnitude of desirability. It is also possible to express the magnitude of preference by using the utility of each alternative for each individual. Because it is difficult to ensure the numerical values of voters' utilities are compatible, SCT studies usually concentrate on the order of preference.

Aggregation of Preferences

The procedure used to aggregate individual preferences into collective choices is called a choice rule or choice scheme or choice function (C) in SCT. We will use the term "voting method" in the context of GSS voting. There may be an infinite number of choice rules because it is possible to construct special mapping functions in numerous ways. However, a useful choice rule should satisfy some reasonable properties. Here we present a brief introduction about some desired properties and choice rules. For more in depth discussion, please refer to SCT literature, such as (Craven, 1992; McLean and Urken, 1995; Nurmi, 1987).

A choice rule should be able to aggregate any preference profile to a collective choice. The social choice scheme satisfies that the universal criterion will produce a choice (with the possibility of ties) no matter what the preference profile may be. The usefulness a social choice scheme is doubtful, if it fails to produce an outcome under certain situation. Conversely, there should not be any restriction on an individual's preference imposed by the choice scheme. Everyone in the choice system should have the freedom to hold and express any kind of preference.

Condorcet, one of the pioneers in SCT, argued that a good choice scheme should select the alternative that beats every other alternative in pairwise comparisons. This alternative, called the Condorcet winner, is superior to any other alternative in one to one competitions. However, there may be no Condorcet winner in some situations. This is known as Condorcet Paradox. For example, with voters holding preferences as shown in table 1, alternative a will beat alternative b in a pairwise comparison with a score of 70% to 30%. Alternative b will defeat alternative c because 70% of the voters prefer b to c . Yet alternative c will top alternative a because 60% of the voters prefer c to a while only 40% of the voters prefer a to c . There is no Condorcet winner in this case. The Condorcet winning criterion argues that a choice rule should pick the Condorcet winner if there is one. Conversely, we can also build a Condorcet loser criterion, an alternative that loses to every other alternative in pairwise comparisons should never be chosen by a choice scheme.

Percentage of Voters	Preference	
40%	$aPbPc$	a vs. b 70%:30%
30%	$bPcPa$	b vs. c 70%:30%
30%	$cPaPb$	c vs. a 60%:40%

Table 1 Example of Condorcet Paradox

The monotonicity criterion maintains that an alternative should not be harmed by having more support. If an alternative already won under a choice scheme, it should remain the winner if some people change their preferences in favor of this alternative and nothing else has changed.

An ideal choice scheme should be stable. Independence of Irrelevant Alternatives (IIA) states that out of a set of alternatives, a is preferred to b under a choice scheme, then if any other alternative c is added to or removed from the set, a should still be preferred to b because c is irrelevant to the pair a and b . With this stability, if the first choice becomes unavailable, the second choice will become the new winner without the need for another round of voting because the order between the original second choice and all the other alternatives will not change in the absence of the original winner.

The Pareto condition deals with unanimity in individual preference. The weak form of the Pareto condition asserts that if every voter ranks alternative a above b , b should never become the winner if a is available. The strong form of the Pareto condition argues that if everyone believes alternative a is at least as good as b and at least one member regards a as better than b , then b should not be chosen when a is available for choice.

For a fair choice scheme, we would like that no individual or a small group of individuals can dictate the outcome of a social choice, regardless of the preferences of other people. A choice scheme is said to have a dictator if under that choice scheme, a certain individual prefers x to y , then the group prefers x to y , regardless of other individuals' preferences. In other words, the social choice is based on the preference of one person. There could be a hierarchy of dictators in the choice system. When the upper dictators are indifferent about alternatives, then the next dictator's preference would decide the system's choice.

COMMONLY USED VOTING METHODS

There are numerous voting methods that are used in elections, legislative processes, and group decision making. Here are descriptions of some commonly used voting methods.

Simple Majority Voting Method

Simple majority voting, or plurality method, is a widely used voting method because it is straightforward and intuitive. Every person in the choice system has one vote. Each will endorse the most preferred alternative in the choice set. The alternative that has the most votes wins. If there is a tie for more than one alternative in the first place, an additional procedure will be taken to determine the winner. While it is uncomplicated, the simple majority voting method does not always pick the Condorcet winner, if there is one. In extreme cases, it will even pick the Condorcet loser as the winner. A well known problem is the "majority split." Two popular candidates can split the support of voters thus allowing a third candidate with only minority support to become the winner. It also fails to meet the IIA criterion.

Many voting methods are variations of the plurality method. Some methods require that the winning alternative must pass certain threshold to become the winner. The threshold can range from half of the votes to total support of the voters (unanimous support). Voters have to vote repetitively until one alternative surpasses the threshold. Like the plurality method, majority rule does not always pick the Condorcet winner and fails to meet the IIA criterion.

Another variation of the simple majority voting method is "run-off," that is eliminating alternatives from the next round of voting before there is a final winner. One version of run-off vote is to allow the two alternatives with the highest number of support to enter the second round of voting. Another run-off variation eliminates the alternative with the lowest number of vote in each round. The process is repeated until there is one final winning alternative.

Approval Voting

Approval voting was conceived to overcome the problem that only the topmost alternative in an individual's preference list is considered in the plurality method. In the approval voting procedure, every voter in the choice system can cast one vote for all the alternative(s) he/she approves. The alternative with the most votes is declared as the winner. Approval voting fails the Condorcet winning criterion and Pareto condition but satisfies IIA.

Borda Count

The Borda count considers the entire ranking of individual preferences when making the choice. Each alternative is given a count based on its ranking in individual's preferences. For n alternatives, the most frequently used way to assign counts to alternatives is $n-1$ points for each ballot on which it is ranked first, $n-2$ for second, etc., down to 0 for last place. The alternative with the highest total count wins. Variations of the Borda count method may assign different weights to different ranks. The Borda count method chooses a Borda winner which does not always coincide with the Condorcet winner. Although it has been debated by scholars for centuries, there is no consensus on which winner is the "better" one.

Average Score Method

Average score method can be seen as a variation of Borda count. Instead of assigning scores based on the alternatives' ranking in the voter's preferences, voters assign the scores themselves. Each voter has a fixed amount of points that can be assigned to alternatives. Each alternative is given some number of points by each voter. The alternative with the highest total points wins. Neither the average score method nor the Borda count method meet the IIA and Pareto condition.

IMPLICATIONS OF SCT IN GSS VOTING

For almost two centuries, scholars have tried to find a perfect social choice scheme that could meet all the desirable properties but could not find any. Arrow (1951) proved that it is impossible for a social choice rule to satisfy all the five reasonable conditions (universality, monotonicity, IIA, no imposed preference, and no dictatorship) when making a choice among three or more alternatives. The Impossibility Theorem has had a profound impact on SCT, as it demonstrates that

there is no single social choice rule that can always fairly decide an outcome that involves more than two alternatives. After Arrow published his Impossibility Theorem, researchers have discovered other impossibilities in social choice. This does not mean that people should abandon voting because there is no perfect choice scheme. If we allow some properties to be relaxed, there are still good choice schemes for making choice. In the GSS context, researchers should consider these two implications of Impossibility Theorem on voting: A GSS should not have only one voting method for all the situations and GSS facilitators should be aware of the limitation of available voting methods and choose a suitable method for the circumstance.

The discussion above is based on the voters vote sincerely. The problem of voting becomes more complicated when some of the voters try to manipulate the outcome by expressing false preferences. Voters might cast bogus votes to help a preferred alternative win or to avoid an undesired alternative being chosen. Unfortunately, the Gibbard-Satterthwaite theorem (Gibbard, 1973; Satterthwaite, 1975) proves that any choice rule satisfy no dictatorship and universal criterion will be susceptible to manipulation when there are three or more alternatives. We propose two approaches to alleviate the problem of manipulation in GSS voting. One is to use some method such as the Clarke tax mechanism (Wang and Leung, 2004) to reduce the incentive for a voter to manipulate the voting outcome. The other one is to use voting as a mean to promote discussion rather than forming the final decision.

TWO VIEWS OF VOTING: AGGREGATION AND COMMUNICATION

Traditional research on voting, such as SCT, focus on how the final decision is formed by aggregating members' preferences. The aggregation view is especially true if voting is used only once at the end of the decision process. We will argue that voting is also a concise form of communicating members' views about alternatives and personal choices. This kind of communication is very formal and lean. Nevertheless, this communication process can affect group members. Voters will have to prepare, express, and understand the communication. There will be information exchange with this communication. The communication effect on voting will be more apparent in a GSS environment that enables a group to use multiple rounds of voting to reach the final decision.

Individual Effort for Voting Communication

The efforts imposed on an individual to cast a vote can be divided into mental and physical efforts. Some voting methods are straightforward and require very little effort from the voter. Yet some other voting methods are very complex and require much more effort from the voter to communicate a person's preference. There is also the effort to understand the voting communication. Here we focus on the effort of expressing one's preference.

Mental Efforts

The act of voting requires mental effort for an individual to make one's preference explicitly regardless of whether the internal decision process is consciously or subconsciously. It is difficult to determine the real mental effort needed by an individual to cast a vote. We can consider an approximate index of mental effort. One way to estimate the mental effort is to estimate the order of number of comparisons between alternatives needed for an individual to be able to vote. Studies on sorting and searching algorithms (Knuth, 1973) can be used to calculate this mental effort index. However, it is impossible to know the exact way an individual does the mental comparison because humans use heuristics in judgments, and so the number of comparisons computed by sorting and searching algorithms can only give us a theoretical index. It is also difficult to compute an index for voting methods that ask voters to assign scores to alternatives. It is safe to assume that assigning scores requires more effort than simply comparing alternatives. Below is a table of the number of comparisons for some voting methods based on an n -alternatives voting scenario.

Voting Method	Order	Note
Plurality Method	$O(n)$	Assumes a simple search for maximum among alternatives
Approval Voting	$O(n)$	Assumes comparing each alternative to an approval threshold
Borda Count	$O(n^2)$	Assumes using a straight sorting algorithm
Average Score Method	-	Assigning a score to each alternative requires more effort than comparisons

Table 2 Order of Numbers of Comparisons for Voting Methods

Physical Efforts

Physical efforts are about the amount of data that a member has to enter into the system to cast a vote. A more complex voting method usually would require more data input from the voter. The voter may only have to click on the alternative in simple majority voting; on the other hand, one has to assign ranks to all the alternatives in Borda count. A member may lose interest if there were a lot of data needed to be entered for a single round of voting. This will discourage members from another round of voting, thus nullify the advantage of using multiple rounds of voting. It is difficult to analyze the physical efforts of voting method alone because it also relates to the user interface design of voting tools.

Gavish and Gerdes (1997) have suggested a five-level classification of ballot complexity that can be seen as a combination of the mental and physical efforts at the individual level. The first level is simply marking the highest valued alternative. The second level is to partition the alternatives into two sets and mark all alternatives in the acceptable set. The third level is to rank alternatives in the acceptable set and allocate limited votes. The fourth level requires the voter to rank the entire alternative set. The voter has to quantify the whole preference profile in the fifth level. Table 3 is a summary of the ballot complexity.

Ballot Complexity Level	Description of Efforts	Example
1	Mark highest valued alternative	Plurality Method
2	Separate alternatives into two sets, mark all alternatives in acceptable set	Approval Voting
3	Rank alternatives in acceptable set to allocate limited votes	Multiple Vote
4	Rank whole preference profile	Borda Count
5	Quantify whole preference profile	Average Score Method

Table 3 Ballot Complexity (Gavish and Gerdes, 1997, p. 70)

If the voter can choose the voting method to use, the easiness of a simple voting method and the expressive power of a complex voting method are the two forces that pull the members toward either ends in the ballot complexity scale of the voting methods. Gavish and Gerdes (1997) have observed that people choose complex voting methods more often than simpler ones. They assume that the benefit of increased information exchange and more precise expression of preferences outweigh the increase in mental and physical effort. Nonetheless, members should note that there might be a limitation of the number of rounds one can use complex voting methods in a row. Since complex voting methods demand more effort, members may feel burdened after fewer rounds of voting than simple voting methods.

An individual will process more information to make comparisons and judgments in a voting method with higher complexity. The increase in information processing by an individual may lead to better decision quality because an individual has to integrate more information into his/her decision framework (Hilmer and Dennis, 1999). On the other hand, Information overload might become more severe with a complex voting method when a person has to deal with a large number of alternatives. It would be an interesting topic to investigate the relation between ballot complexity and number of alternatives. Ballot complexity might also affect post decision regret. There are two types of post decision regret “action” (action should not have been taken but in fact was taken) or “inaction” (action should have been taken but in fact was not taken) (Gilovich, Medvec and Kahneman, 1998). A complex voting method usually allows an individual to vote for more than one alternative, so this should reduce the “inaction” type of regret. On the other hand, an individual might have a higher chance to experience the “action” type of regret with a complex voting method because one might feel his/her vote makes the alternative being chosen. Nevertheless, because an individual has to process more information to vote in a complex voting method, the individual should be able to justify the action of voting for an alternative more easily and reduce the “action” type of regret. The net effect of a complex voting method should reduce post decision regret.

Information Exchange in Voting Communication

Coombs (1964) proposed a “Searchingness structure,” which arranges data collection procedures on two general dimensions: the number of items presented at a time (from 1 to n) and whether the respondent has the task of choosing some items (pick k), or rank ordering two or more of the items (order k). The data collection procedures in the searchingness structure vary in “channel capacity” and “redundancy.” Channel capacity reflects how much information a procedure yields and provides a measure of the relative power of the method. Redundancy indicates how much of the capacity is used in measuring and

controlling inconsistency in the procedure. Voting methods, like data collection procedures, ask the voters to either pick some alternatives or rank order them. Thus it is possible to apply techniques in the searchingness structure to analyze voting methods. The channel capacity will indicate information contributed by the voter.

The channel capacity is based on information theory (Shannon, 1948). The information value of a vote can be estimated from all possible presentations of votes. We start with the formula for entropy (in bits) $H = -\sum_i p_i \log_2 p_i$, where p_i is the probability for the i^{th} presentation. To calculate the maximum theoretical channel capacity for a voting method, we assume that all combinations have equal probability of occurring, and then probability for a presentation becomes $1/k$, where k is the number of all possible combinations. The channel capacity C for a voting method is $C = -\sum_{i=1}^k \frac{1}{k} \log_2 \frac{1}{k}$, or, after simplification, $\log_2 k$.

Based on an n -alternatives voting scenario, we compute the channel capacity for several voting methods. For plurality method, because the voter can only pick one from all the alternatives, the possible number of combinations is $P_1^n = n$ (Pick 1 from n). There are 2^n possible combinations for approval voting as a voter can either vote for or not vote for each alternative. In Borda count, the voter has $n!$ ways of ordering all the alternatives. A voter has $H_n^m = C_{n-1}^{m+n-1}$ different ways to allocate m points to n alternatives in average score method. Table 4 is a summary and sample calculation of the channel capacity for several voting methods.

Voting Method	Possible Number Of Combinations	Channel Capacity	Channel Capacity for a 10-alternative Case
Plurality Method	n	$\log_2 n$	3.32
Approval Voting	2^n	n	10
Borda Count	$n!$	$\log_2 n!$	21.79
Average Score Method with m points	$H_n^m = C_{n-1}^{m+n-1}$	$\log_2 C_{n-1}^{m+n-1}$	With 50 points: 33.55 With 100 points: 41.96

Table 4 Channel Capacity and Redundancy of Voting Methods

Difference in channel capacity does not only mean members express, more or less, preference in voting but also concerns the group's exchanging different amount of information in the discussion. In a study of rank-order effects on hidden profile task, Hollingshead (1996) compares groups in which members had to rank order alternatives with groups in which members only needed to choose the best alternative. Groups where members ranked alternatives exchanged more information than groups that only chose the best alternative. More information in voting and more information exchange in discussion may lead the members to discover things they have overlooked in decision-making tasks and to find common ground for compromise in preference tasks. A high channel capacity voting method allows more information exchange and/or more precise expression of members' preferences. The group may also pay more attention to uncommon information by noticing that some members are holding very different preferences. A group is more likely to find similarities and disparities in members' preference profiles in a high channel capacity voting method and then explore the underlying reasons more deeply. The exploration will lead the group exchange more information. A complex voting method can also improve the information exchange among group members. This may lead to better decision quality.

The expressive power of a high channel capacity voting method should enable a group to use less rounds of voting to reach a decision. Thus a high channel capacity voting method might reduce the time for a group to reach a decision. However, the individual has to put in more efforts and there is more information to be discussed in a high channel capacity voting method. Each round of voting may take longer to complete. Thus, it is difficult to speculate the net effect of voting method's channel capacity on time to decision.

CONCLUSION

Although voting tools are regarded as important in GSS, there is very little theory to guide the study and application of voting in GSS. Organizations and groups can benefit from better understanding of voting in GSS by using voting tools more effectively and efficiently. This paper focuses on voting methods, one crucial aspect of voting. Traditional studies of voting emphasize the aggregation side of voting, but GSS provide additional capability that makes the communication side of voting

significant. We examined some basic concepts of voting in SCT, which can provide insights to the use of voting tools in GSS. In addition, we also analyzed the communication effects of voting methods by reviewing related research and proposing a classification of voting methods based on information exchange. Because of the scarcity of empirical data, experiments to validate those hypotheses are needed. The next step of our research will consider other factors of voting and the interplay of those factors within an experimental setting. This could be a rich area in GSS research because there are many unanswered questions about the use of voting in GSS.

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