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1995-01-01

Can Declared Strategy Voting be an Effective Instrument for Group Decision-Making?

Lorrie Faith Cranor

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Department of Computer Science & Engineering - Washington University in St. Louis
Campus Box 1045 - St. Louis, MO - 63130 - ph: (314) 935-6160.

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Lorrie Faith Cranor

WUCS-95-04

February 8, 1995

Department of Computer Science
Campus Box 1045
Washington University
One Brookings Drive
St. Louis, MO 63130-4899

Abstract

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Lorrie Faith Cranor
lorracks@cs.wustl.edu
+1 314 935 5095

1. Specific Aims

The goal of this research is to determine whether *declared strategy voting* can be an effective tool for group decision-making. Declared strategy voting is a novel group decision-making procedure in which preference is specified using voting strategies — first-order mathematical functions that specify a choice in terms of zero or more parameters.

In a traditional election with three or more alternatives, some voters develop personal strategies to determine which alternative to select [7]. These strategies may take into account the voter's preferences for each candidate and the voter's estimate of the likelihood that each candidate will win the election. For example, voters may develop a strategy in which they vote for their most preferred alternative only if they believe that candidate has a "good chance" of winning. These voters may consider the results of pre-election polls to determine which alternatives meet their good chance criteria before mentally evaluating their strategies. They express the result of this personal decision-making process in the form of a vote. However, traditional election results cannot distinguish between voters who vote for their sincerely preferred alternative regardless of other factors and those who base their votes on a strategy such as the one described above; this dilemma frustrates attempts at analyzing election results.

In declared strategy voting, each voter submits a strategy that a computer resolves into a simple choice by substituting actual values for parameters. Parameters may include the percentage of counted ballots that select a particular candidate and the percentage of ballots already counted.

When a decision must be made between three or more alternatives, the outcome can depend on the voting method used. For example, plurality voting¹ selects the alternative most preferred by the most people, while Borda count voting² tends to select a good compromise alternative. But every

¹Plurality voting is a procedure in which each voter votes for his or her single most preferred alternative. The alternative that receives the most votes wins [33].

²Borda count voting, proposed in 1770 by the French mathematician Jean-Charles Borda, is a procedure in which each voter forms a preference ranking for all alternatives. Given n alternatives, each voter casts n votes for his or her most preferred alternative, $n - 1$ votes for his or her second most preferred alternative, etc. The alternative that receives the most votes wins [33].

voting method is subject to manipulation by voters who develop mental voting strategies and cast votes that misrepresent their *sincere* preferences. Declared strategy voting may be a useful method for selecting a good compromise alternative, especially in large committees or geographically distributed organizations in which it may not be practical for members to personally negotiate a compromise.

This research will focus on refining the declared strategy voting concept, developing an accessible implementation of declared strategy voting that can be used for mock elections, assessing the potential impacts of declared strategy voting, and evaluating the effectiveness of declared strategy voting for group decision-making. This proposal describes the significance of this research, preliminary studies, and proposed methodology for the remainder of this project.

2. Significance

With the advent of accessible and affordable high-speed computers and interconnection networks, elections and surveys are starting to move from the voting booth, postal mail, and telephone into the computer. Voting over computer networks is likely to appeal to geographically distributed organizations such as professional societies. Existing methods of conducting surveys and elections electronically are focused on emulating (to the greatest extent possible) the feel, look, and mechanics of traditional surveys and elections, while taking advantage of the speed, accuracy, and computational power offered by the electronic system. Such approaches are quite reasonably founded on placing the computer and its associated technology in the background, so that participants suffer little shock in moving to electronic means of expressing choice. These methods thus improve on traditional voting systems, by allowing voters to cast secret ballots without being physically present at an official polling place and by introducing new ways to verify the accuracy of the election results [28]. However, these systems do nothing to improve the vote aggregation procedure itself.

The goal of this research is to explore a new method of expressing choice that is only now made feasible by advances in computing and communications technology. Rather than simply transferring extant paradigms to the computer, I seek to develop more beneficial and meaningful ways of conducting surveys and elections using computers.

The next three subsections detail the declared strategy voting paradigm, describe how it relates to the political science concept of strategic voting, and outline the potential impacts of declared strategy voting on the populations that might choose to use it.

2.1. The Declared Strategy Voting Paradigm

In a democratic society, the purpose of an election is to determine the preferences of the public. Determining a single most popular choice is usually the primary objective; however, the margin of victory or the distribution of votes among alternatives can be useful for assaying public opinion.

Analysts have shown that the distribution of votes does not necessarily reflect actual public opinion: situations often arise in which voters—perhaps informed through unofficial opinion polls—determine that it is not in their best interest to vote sincerely. For example, consider an election in which there are three choices (B, C, P), as in the 1992 Presidential election. A voter who considers

choice P better than choice C , and choice C better than choice B , may vote for choice C (the second choice) if choice P is sufficiently lagging behind choice C in the polls. Thus the voter avoids “wasting” a vote by voting strategically rather than sincerely. When the results of the election are tallied and C is declared the winner, it is impossible to determine how many voters actually preferred C and how many voted for C only to avoid feeling as if they had wasted their vote.

If declared strategy voting is used, the voter described above could cast a strategy that would reflect his or her intentions to vote for P only if the vote would not be wasted. More formally:

A declared voting strategy is a total, first-order function that specifies a single vote in terms of zero or more of the following parameters: the total number of ballots cast for evaluation, the number of ballots that have been evaluated thus far, and the current standing of each candidate in the election.

A function with no parameters—a constant function—specifies a simple, sincere vote. Evaluation resolves each strategy into a simple choice, by substituting actual values for parameters at the time each strategy is resolved (this resolution generally takes place after all votes are cast). Thus, all voters essentially use perfect information about the state of the tally in their decision-making process. Note that the voters’ preferences or utilities for each alternative are not expressed as part of the declared voting strategy. We assume that each voter has determined the utility of each outcome and has used that information to develop a strategy that will cause the appropriate vote to be cast.

Continuing with the example election, the voter described above might cast a strategy specifying that P should be chosen, unless P is more than a certain number of percentage points behind C , in which case C should be chosen. With this strategy, the voter does not have to rely on the unofficial results of an opinion poll to determine whether a vote for P would be worthwhile; the actual standings at the time of evaluation are substituted into the strategy. Moreover, the use of a declared strategy voting system provides elected representatives (and the public) with information about the motivation behind voting decisions.

While the concept of declared strategy voting is intriguing, it must be refined further before it is likely to be useful. In particular, a fair procedure for determining the order of strategy evaluation and an accessible strategy specification system must be developed. These problems will be investigated as part of this research.

2.2. Related Work: Voting Strategies in the Context of Political Science

While declared strategy voting is a new concept, the idea of people voting strategically has been discussed in the literature for many years. Political scientists often use the term *strategic voting* to describe insincere or manipulative behavior on the part of voters in the context of a traditional election. Gibbard [18] and Satterthwaite [35] independently investigated the strategic manipulation of elections with three or more alternatives and proved that strategic manipulation can occur under all voting schemes that are not dictatorial and select a single alternative as the winner. Gardenfors [17] analyzed voting schemes that do not necessarily select a single winner and showed that those which

are not manipulable or dictatorial are also “very undecided.” Barbera [1] showed that strategic manipulation can, in fact, be avoided in decisive voting schemes if the voting procedure relies heavily on chance. However, he dismissed such procedures as inherently “unattractive.”

Others have focused on analyzing the results of strategic manipulation and determining optimal strategies for voters to employ. Merrill [23] analyzed strategic manipulation of several one-stage voting procedures and determined that optimal strategies could be produced using linear or quadratic programming. Hoffman [21] developed a model for strategic voting under a variety of voting procedures. He used this model to investigate ways a voter can vote strategically to maximize his or her satisfaction with the outcome of the election. More recently, Felsenthal and Maoz [14] conducted a comparative study of sincere and strategic voting under two voting procedures. They showed that when voters engage in strategic manipulation, the resulting election violates all six normative properties of voting procedures examined by the authors. Ordeshook and Palfrey [31] analyzed the strategic voting problem using the more realistic assumption that complete information about the preferences of others is not available to the voter. They concluded that their assumption makes the analysis of strategic voting significantly more complex and not nearly as clear cut.

Studies have demonstrated that strategic voting actually occurs in real elections. Brams and Merrill analyzed data collected in the 1992 National Election Study and estimated that 34.5% of Perot supporters did not vote sincerely in the 1992 Presidential election [5]. Cain [7] developed a model of strategic voting in the British electorate. The model suggests that strategic manipulation does occur, especially when voters want to avoid “wasting” their votes or when the race is only close between two of the parties in a three party election.

All of the above work has focused on searching for voting systems *immune* to strategic manipulation, assessing the impact of strategic manipulation, or determining how voters can use strategic manipulation to the greatest advantage. The overall bias here is to view strategic manipulation as something to be avoided, perhaps (as suggested by Gardenfors [17]) because it complicates game-theoretical voting analyses. Others suggest that voters have little faith in voting systems that allow severe manipulation [25]. But these authors do not consider the attitudes of voters towards a system in which the covert strategic behavior of voters is embraced, with voting strategies used as the actual method of specifying choice. In fact, there appears to be little research that seeks to *facilitate* the use of voting strategies in a large-scale election.

One recent paper by Myerson and Weber [26] could be viewed as an effort to facilitate strategic voting. In this paper the authors formally described the phenomenon that occurs when strategic voters repeatedly adjust their intended votes after the observation of pre-election survey results that change their perception about the relative chances of each candidate winning the election. They proved that if pre-election surveys are repeated continuously, an equilibrium will eventually be reached in which the voters’ perceptions are consistent with the survey or election outcome. They also demonstrated that the equilibria vary according to the voting system used. The Myerson and Weber [26] equilibria come about after voters become aware of each others’ preferences through multiple rounds of surveys. I plan to investigate whether similar equilibria can be induced in a single round using declared strategy voting.

2.3. Potential Impacts of Declared Strategy Voting

Declared strategy voting is a novel concept, quite different from any other voting system previously discussed in the literature. This may be due in part to the fact that the mechanics of conducting a declared strategy election with traditional voting equipment (punch card, voting booth, absentee ballot, etc.) would be overwhelming: the functions simply could not be resolved in a reasonable amount of time. However, once networked computers are introduced into the voting process, declared strategy voting becomes feasible for use in real elections.

Now that declared strategy voting is feasible, its potential impact should be studied. The remainder of this section describes several areas where impacts may occur. Methodology for studying these and other impacts is described in the Methodology section.

Impact on group decision-making. Often when a decision must be made between three or more alternatives, the outcome depends on the voting method used. For example, plurality voting selects the alternative most preferred by the most people, while Borda count voting tends to select a good compromise alternative. But every voting method is subject to manipulation by voters who misrepresent their sincere preferences. Declared strategy voting may be a useful method for selecting a good compromise alternative fairly, especially in large committees or geographically distributed organizations in which negotiating a compromise may not be practical.

Impact on the ability of all members of a population to participate in the electoral process. Declared strategy voting is not a simple idea. It remains to be seen whether a declared strategy voting system can be implemented in such a way that voters who use it experience no more difficulty than they experience with traditional voting systems. If declared strategy voting systems prove to be more difficult to use, they may serve to disfranchise some voters.

Impact on the effects of pre-election polls and exit polls. In national and state-wide elections, the media often report the results of pre-election polls before election day. In addition, they report the results of exit polls on election day, often before the polls close. Some voters may formulate voting strategies and evaluate them based on information obtained from these polls. Such information could be misleading, faulty, or even contrived to misrepresent the truth. Even when the best known polling techniques are used, it is currently impossible to ensure that people respond truthfully rather than provide strategic responses that misrepresent their true preferences. Strategic voting is a valid democratic alternative [22] that can be augmented through the use of a declared strategy voting system. Thus, a declared strategy voting system might mitigate the effects of pre-election polls and exit polls.

Impact on the types of conclusions that can be drawn from election results. Under traditional voting procedures, it is impossible to determine if the alternative that receives the most votes is actually preferred by those who selected that alternative. The extent to which election results constitute a mandate is currently difficult to determine. A declared strategy voting system can provide additional information about the preferences of voters, which could be useful for maintaining political stability and guiding the future actions, issues, and decisions undertaken by elected representatives.

Impact on social choice research. Those who study voting behavior have had difficulty determining the extent to which strategic manipulation, bandwagon voting, and other non-sincere voting behavior occur. A declared strategy voting system used as a research tool may provide needed insight into voting behavior.

3. Preliminary Studies

I have done preliminary work in three areas:

- design of Sensus electronic polling system (for computer science master's project),
- design and implementation of a declared strategy voting simulation system, and
- analysis of initial simulation results.

3.1. Sensus

As computer networks grow, opportunities for using these networks to conduct elections and surveys increase. However, if not carefully designed, electronic polling systems can be easily compromised, thus corrupting results or violating voters' privacy. I have designed and am in the process of implementing a security-conscious electronic polling system called Sensus that will be used to conduct mock declared strategy elections over the Internet. I began working on this project after discovering that there are no inexpensive, flexible, security-conscious systems for conducting polls over wide area computer networks. (One commercial software company charges \$12,000 for a system that can be used to poll 10 networked computer users [32].) Sensus was designed primarily as a replacement for mail-in balloting systems and hand tallied surveys. However, Sensus is flexible enough to be used for a variety of other polling applications, including declared strategy voting.

Sensus has been designed as a modular system that can be easily adapted for use on almost any computer platform. I have developed a new language, BLT, for machine-readable ballot specification and communication between modules. As shown in Figure 1, Sensus includes a registrar module for generating a formatted list of eligible voters, a validator module for checking the authenticity of ballots and ensuring that only one ballot from each registered voter is counted in the final tally, a tallier module for counting the votes and reporting a final tally, a pollster module for presenting electronic ballots to voters and recording their choices, and a ballot-authoring module for assisting election administrators in designing ballots. I am building a basic package of modules for use in common polling applications. However, I have designed Sensus to support the incorporation of additional modules designed for specialized polling applications. I envision the future development of pollster modules that can display multimedia presentations and accept audio responses from voters, tallier modules that can compute results based on a variety of voting systems, and validator modules that can verify a voter's identity through finger prints or retinal scans.

The design of Sensus grew from my survey of traditional and (proposed) electronic polling systems. I reviewed several different sets of "ideal" election system characteristics found in the literature [2, 15, 29, 34, 36] and developed a set of four distinct "core properties" that are likely to be desirable in almost any election system:

Accuracy. A system is accurate if it is not possible for a vote to be altered or eliminated from the final tally without detection. Altering includes casting a vote for a registered voter who has not voted. In the most accurate systems, the final vote tally must be perfect. Partially accurate systems can detect but not necessarily correct inaccuracies. Accuracy can be measured in

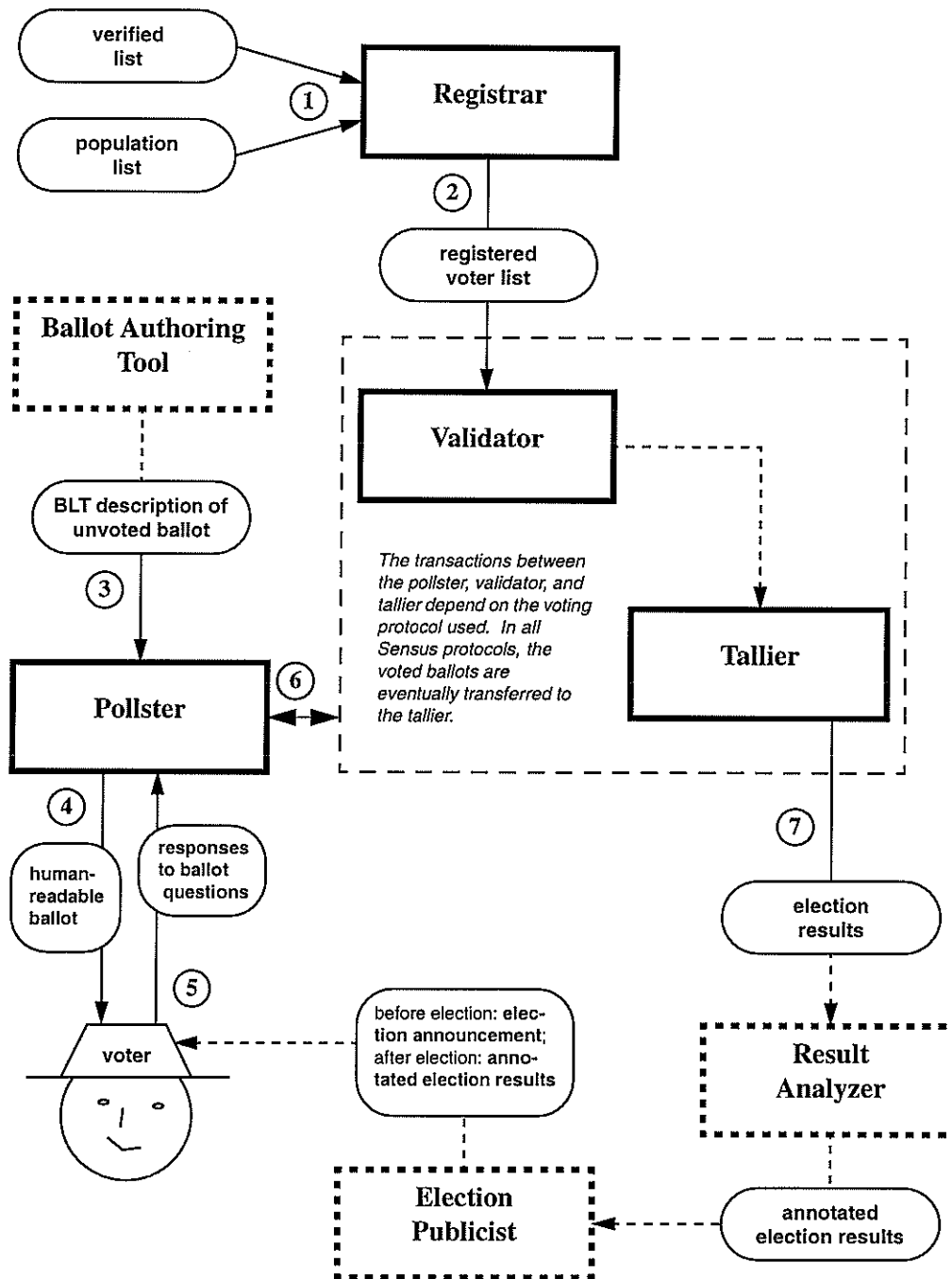


Figure 1: Sensus system overview

terms of the margin of error, the probability of error, or the number of points at which error can be introduced.

Democracy. A system is democratic if (1) it permits only eligible voters to vote, and (2) it ensures that each eligible voter can vote only once.

Privacy. A system is private if (1) neither election authorities nor anyone else can link any ballot to the voter who cast it, and (2) no voter can prove that he or she voted in a particular way. The second privacy factor is important for the prevention of “vote buying.”

Verifiability. A system is verifiable if voters can independently verify that their votes have been counted correctly. The most verifiable systems allow all voters to verify their votes and correct any mistakes they might find without sacrificing privacy. Less verifiable systems might allow mistakes to be pointed out, but not corrected or might allow verification of the process by party representatives but not by individual voters.

In addition, I developed three “extra properties,” that an electronic polling system should possess.

Convenience. A system is convenient if it allows voters to cast their votes quickly, in one session, and with minimal equipment, software, or special skills.

Flexibility. A system is flexible if it allows a variety of ballot question formats including open ended questions (this is important for write-in candidates and some survey questions).

Mobility. A system is mobile if there are no restrictions (other than logistical restrictions) on the location from which a voter can cast a vote.

While developing an electronic polling system design that can simultaneously satisfy the core and extra properties discussed earlier, I considered a variety of public-key cryptographic solutions proposed in the theoretical computer science literature [2, 10, 11]. However most of these solutions are impractical to implement or do not satisfy all the criteria. A few cryptographic solutions look feasible to implement with some minor modifications [15, 29, 36]. The most robust of these solutions was proposed by Fujioka, Okamoto, and Ohta [15] and is based on the concept of blind signatures.³ This scheme requires the voter to prepare a voted ballot, and encrypt it twice: first using a digital signature, second using a blind signature. The voter signs the ballot and sends it to the validator. The validator verifies that the signature belongs to a registered voter who has not yet voted. If the ballot is valid, the validator signs the ballot and returns it to the voter. The voter uses a blind signature retrieving technique to remove the blinding encryption layer from the ballot. The voter then sends the resultant signed once-encrypted ballot to the tallier. The tallier checks the signature on the encrypted ballot. If the ballot is valid, the tallier places it on a list of valid ballots to be published after all voters

³Blind signatures, first introduced by Chaum [8] in 1981, allow a document to be signed without revealing its contents. The effect is similar to placing a document and a sheet of carbon paper inside an envelope. If somebody signs the outside of the envelope, they also sign the document inside. The signature remains attached to the document, even when it is removed from the envelope. Chaum [9] and Schneier [36] provide more background information on public key cryptography, digital signatures, and blind signatures.

vote. The voter then sends the tallier the ballot decryption key. The tallier uses the key to decrypt the vote and add it to the tally.

The main drawbacks of this protocol are that the validator can cast votes for abstaining voters, voters can easily prove how they voted (and thus participate in vote buying), and the voter must participate in a complex set of transactions in order to cast a vote. The final concern can be addressed through some minor modifications in the protocol and the use of a computer system that can quickly carry out the required transactions on behalf of the voter.

I plan to implement the Fujioka, Okamoto, and Ohta protocol as well as some simpler (but less secure) protocols. Software documentation will discuss the degree and type of security provided by each protocol.

Using an early (less-secure) prototype of this system, the Association of Graduate Engineering Students successfully conducted two elections, in which over 700 students were polled.

3.2. Declared Strategy Voting Simulator

I have designed and implemented a simulation of declared strategy and traditional elections that collects statistics about declared strategy voting. This modular Perl [37] computer program allows for the generation of simulated voter populations, generation of a voting strategy for each voter based on a set of rules, evaluation of strategies, and collection of statistics about the election. The simulator can collect statistics about a simulated election using several metrics:

Condorcet efficiency. In any election, there may exist an alternative that could beat all other alternatives in a series of pairwise elections. If such an alternative exists, it is called the *Condorcet winner*. The Condorcet efficiency for a given election procedure is the percentage of times that procedure selects the Condorcet winner when one exists. This metric has been used by Merrill [24] and others to compare traditional voting systems.

Crossover points. Assume that as ballots are counted, the percentage of votes for each alternative versus the number of votes already counted is graphed. If the number of votes already counted is plotted on the X axis in increasing order, the crossover points are the right-most points where the lines representing each alternative cross. These points represent the “points of no return” after which a particular alternative’s place in the final outcome is fixed. Figure 2 shows the crossover points for an example three-alternative election.

First-place outcome stability. A declared strategy voting system may produce outcomes that are sensitive to the order in which ballots are counted. If ballots are shuffled and counted multiple times, the percentage of times each alternative is selected as the first-place outcome can be determined. The first-place outcome stability is the percentage of times that the most popular alternative is selected as the first-place outcome. For example, if alternative A is selected 60 times, alternative B is selected 25 times, and alternative C is selected 15 times, the first-place outcome stability is 60%.

Utility efficiency. Assume that each voter has reported a utility value for each alternative. These numbers correspond to the value the voter believes he or she will receive if a particular alternative wins the election. This value can be thought of as a measure of happiness, money, or

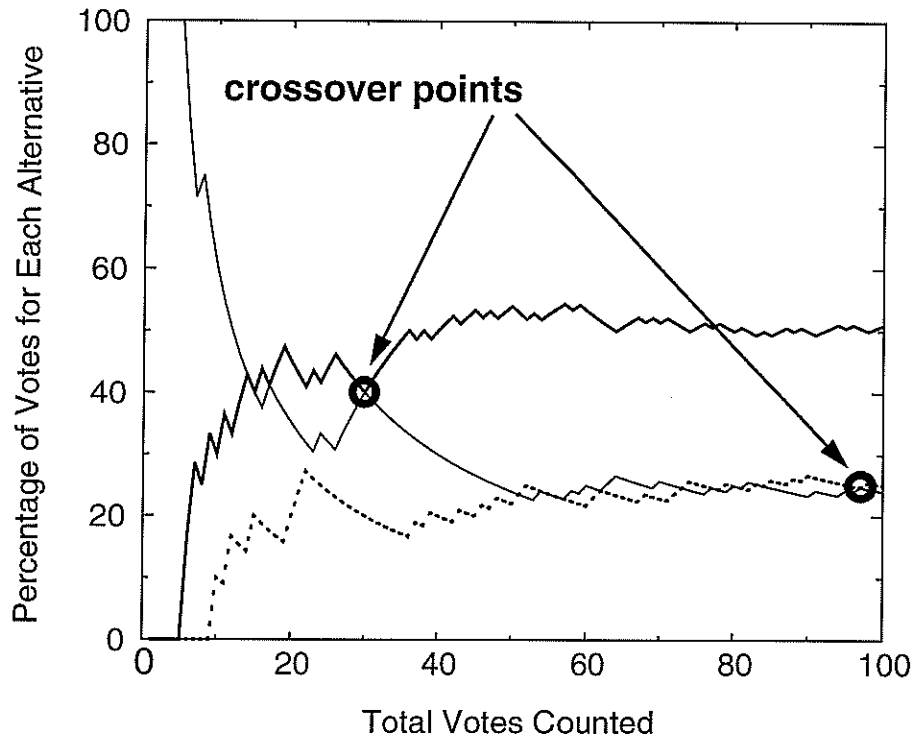


Figure 2: Crossover points for an example three-alternative election

any good. A mean utility value for each alternative can be determined by averaging the utilities of all voters. The alternative with the highest mean utility is the *utility maximizer*. The utility efficiency is the ratio between the mean utility of the first-place alternative and the mean utility of the utility maximizer. This metric was introduced by Weber [38] and has been used to compare traditional election systems.

3.3. Initial Simulation

The initial simulation was designed to explore the effects of several types of strategies on elections in which the order of strategy evaluation is determined randomly. Seven strategy types that I predict voters will use were simulated (future surveys will determine if there are other types of strategies voters are likely to use):

Sincere. Voters vote for their sincerely preferred alternative.

Don't waste my vote. Voters vote for their sincerely preferred alternative only if that alternative is not losing to their second choice alternative by more than a specified percentage (in this case 10%), otherwise they vote for their second choice alternative.

Don't waste my vote unless it doesn't matter. Just like the *don't waste my vote* strategy except that voters also vote for their first choice if their second and third choices are separated by more than a specified threshold (in this case 10%).

Bandwagon. Voters vote for whichever alternative is winning.

Vote against last choice. Voters vote for whichever alternative has the best chance of beating their least favorite alternative.

Time-dependent don't waste my vote. Just like the *don't waste my vote* strategy except the threshold for deciding which alternative to vote for is based on the percentage of votes not yet counted.

Time-dependent don't waste my vote unless it doesn't matter. Just like the *don't waste my vote unless it doesn't matter* strategy except the thresholds are based on the percentage of votes not yet counted.

With the exception of the *bandwagon* strategy, all of these strategies were modeled using the following equation in which p_1 , p_2 , and p_3 represent the percent tallies for the voter's first choice, second choice, and third choice respectively, and U represents the percentage of votes not yet counted.

$$\begin{aligned} &\text{if } p_1 - p_2 \geq f_1 + (g_1 \times U) \rightarrow \text{vote } A_1 \\ &\text{else if } p_2 - p_3 \leq f_2 + (g_2 \times U) \rightarrow \text{vote } A_1 \\ &\text{else if } p_3 - p_2 \geq f_3 + (g_3 \times U) \rightarrow \text{vote } A_1 \\ &\qquad\qquad\qquad \text{else} \qquad\qquad \text{vote } A_2 \end{aligned}$$

Table 1 lists the f and g values used in this model.

Table 1: Parameters used to model voting strategies

strategy type	f_1	g_1	f_2	g_2	f_3	g_3
sincere	-100	na	na	na	na	na
don't waste my vote	-10	0	-101	0	-101	0
don't waste my vote unless it doesn't matter	-10	0	-10	0	-10	0
vote against last choice	0	0	-101	0	-101	0
time-dependent don't waste my vote	0	-2	-101	0	-101	0
time-dependent don't waste my vote unless it doesn't matter	0	-2	0	-2	0	-2

After some preliminary tests, I used the declared strategy voting simulator to model the seven strategies described above with five voter population sizes (10, 25, 50, 100, 250). The following simulation procedure was used:

1. Fifty voter sets of each population size were generated.
2. Each voter was assigned an independent random utility between 0 and 1 for each candidate.

3. Each voter was assigned a strategy based on his or her utilities. (All voters were assigned strategies of the same type.)
4. An election for each voter set was conducted 50 times with the evaluation order selected randomly each time.
5. Steps 3 and 4 were repeated with the other six strategy types.

It is important to note that this simulation models a population with randomly distributed utilities. As a result, the mean utilities for each alternative tend to fall close to 0.5 and the sincere tallies for each alternative tend to be close together. Although random society models have been used extensively to study traditional voting systems, they have been criticized as being unrealistic because members of the electorate tend to be ideological (and thus hold preferences that cluster around particular ideologies). Therefore, some researchers have used spatial models which assume an issue space that has one dimension for each issue. Voters and alternatives are each placed at a point in this space. However, it is not clear that spatial models are entirely realistic either because they ignore the non-ideological behavior of some members of the electorate. Merrill conducted simulations of several voting systems using both types of models and found that Condorcet efficiency and utility efficiency did not change much between the two models as long as candidate and voter dispersion were kept the same in the spatial model [24]. When I used my simulation software to model a Borda voting system I calculated Condorcet efficiency values within 0.2% of those produced by Merrill's random society model.

Table 2: Percentage First-choice outcome stability (50 voter sets, each shuffled 50 times)

strategy type	10 voters	25 voters	50 voters	100 voters	250 voters
sincere	100	100	100	100	100
don't waste my vote	65	55	51	46	44
don't waste my vote unless it doesn't matter	88	82	76	73	68
bandwagon	50	43	42	40	41
vote against last choice	65	53	50	44	43
time-dependent don't waste my vote	71	75	75	80	82
time-dependent don't waste my vote unless it doesn't matter	88	86	84	84	85

My initial simulation results indicate that first-choice outcome stability (shown in Table 2) and Condorcet efficiency (shown in Table 3) vary with strategy type and the size of the voter population. To better illustrate the differences in outcomes produced by each strategy, I created barycentric plots [33] (shown in Figure 3) of the outcome space for one voter set shuffled 50 times. In these plots, the triangle corners each represent an alternative (A , B , or C). The closer a dot is to a particular corner, the more votes the alternative represented by that corner received. A dot in the geometrical center of a triangle represents a three-way tie, while a dot in the corner of a triangle represents a "shut-out" in which one alternative received all the votes. There are fewer than 50 dots shown on

Table 3: Percentage Condorcet efficiency (50 voter sets, each shuffled 50 times)

strategy type	10 voters	25 voters	50 voters	100 voters	250 voters
sincere	85	77	79	80	77
don't waste my vote	70	53	52	45	41
don't waste my vote unless it doesn't matter	90	80	81	71	70
bandwagon	16	25	26	29	31
vote against last choice	70	51	50	43	39
time-dependent don't waste my vote	78	74	79	76	77
time-dependent don't waste my vote unless it doesn't matter	89	81	86	78	79

each triangle because several outcomes were obtained on more than one shuffle. The *sincere* strategy is not shown because all shuffles produce the same outcome (in this case 82 votes for *A*, 86 votes for *B*, and 82 votes for *C*).

The first-choice outcome stability statistics, Condorcet efficiency statistics, and barycentric plots illustrate several interesting characteristics of each of the strategy types simulated.

The barycentric plot clearly shows that the *don't waste my vote* strategy tends to cause one candidate to receive almost no votes. Further analysis indicates that if two of the three alternatives are each chosen by one of the first two ballots, the third alternative will rarely (if ever) be chosen in that election. This phenomena is due to the fact that this strategy is not time (or order) dependent. Therefore, an alternative receiving 0% of the vote is viewed by the strategy in the same way whether 1% or 99% of the votes have been counted. Thus, the results of an election in which all voters choose the *don't waste my vote* strategy will have low first-choice outcome stability and be closely tied to the first two votes counted. Note that the *vote against last choice* strategy produces results quite similar to the *don't waste my vote* strategy. This is due to the fact that the *vote against last choice* strategy is actually the same as a *don't waste my vote* strategy with $f_1 = 0$.

The *don't waste my vote unless it doesn't matter* strategy suffers from a similar problem as the *don't waste my vote* strategy because it is also time independent. As the plots illustrate, one alternative tends to receive much fewer votes than the other two alternatives. This strategy is largely dependent on the first several votes counts.

When all voters choose the *bandwagon* strategy, the election outcome is based entirely on the alternative selected by the first vote counted. While it is not realistic to expect all voters would behave in such a way, this extreme case illustrates an interesting property of the bandwagon strategy: it tends to increase the margin of victory for the winning alternative. Thus, in an election in which many voters use the *bandwagon* strategy, indifference on the part of these voters generally gets interpreted as strong support for the winning alternative.

The time-dependent strategies tend to be much more stable and Condorcet efficient than the other strategies. The plots of both of these strategies have outcome dots clustered near the sincere out-

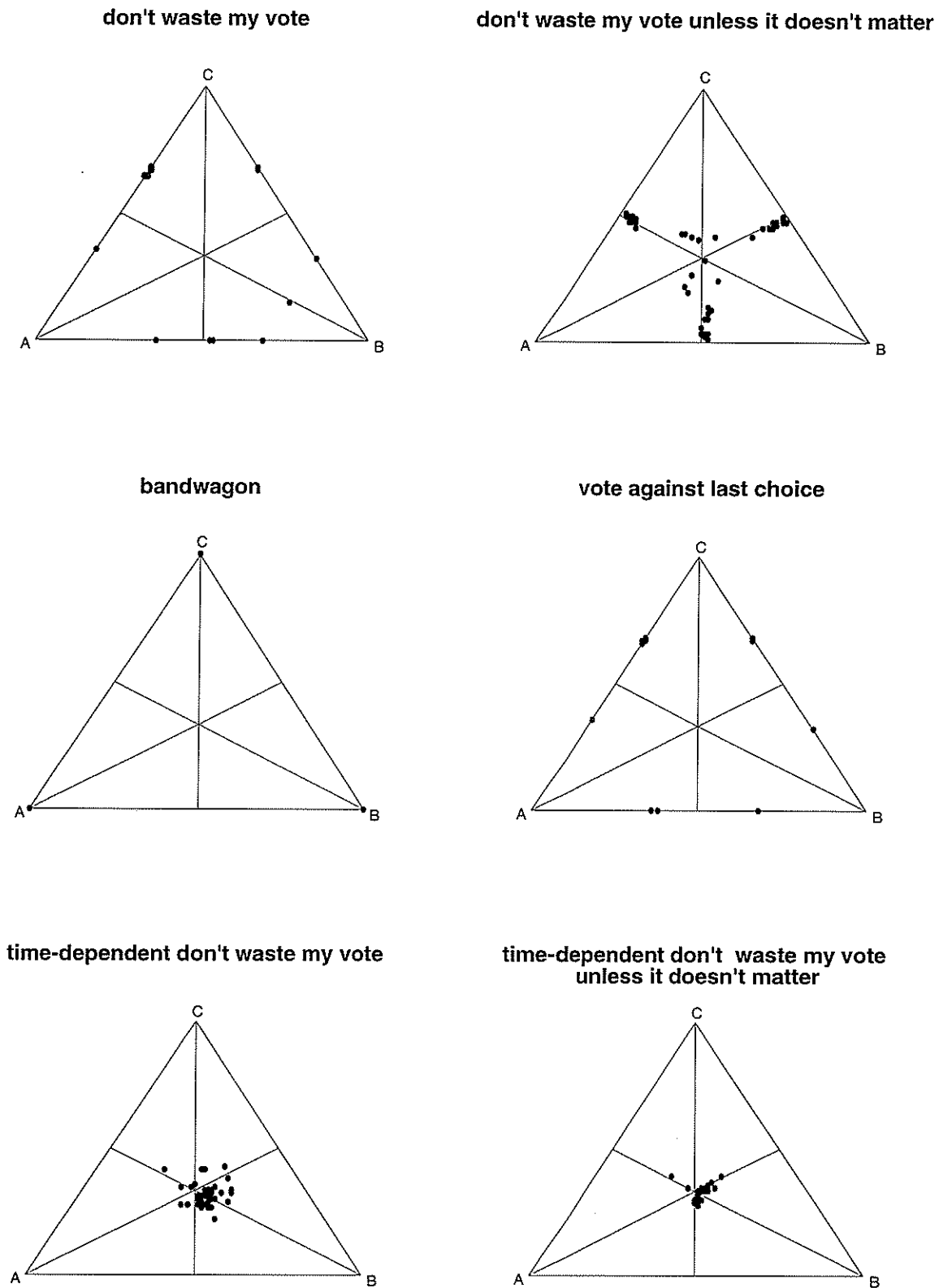


Figure 3: Barycentric plots of the outcome space for 250 voters shuffled 50 times

come. I plan to do further work to see what happens when these strategies are used by more realistic populations.

After analyzing the results of the initial simulation and thinking about how voters might select values for the f and g parameters, I developed another equation for specifying strategies:

$$\begin{aligned} \text{if } t_1 - t_2 &\geq (f_1 \times c) + (g_1 \times u) &\rightarrow &\text{vote } A_1 \\ \text{else if } t_2 - t_3 &\leq (f_2 \times c) + (g_2 \times u) &\rightarrow &\text{vote } A_1 \\ \text{else if } t_3 - t_2 &\geq (f_3 \times c) + (g_3 \times u) &\rightarrow &\text{vote } A_1 \\ &&&\text{else} &&&&\text{vote } A_2 \end{aligned}$$

In this equation t_1 , t_2 , and t_3 represent the total number of votes each alternative has received so far, c represents the total number of votes counted so far, and u represents the total number of votes that remain uncounted. Note that for time-independent strategies (in which all g values are set to 0), this equation is equivalent to the previously described equation, with both sides multiplied by c . The advantage to this equation is that the g values are more meaningful. For example, $g_1 = 1$ allows a vote for the voter's first-choice alternative only when that alternative is guaranteed to win, while $g_1 = -1$ allows a vote for the voter's first-choice alternative whenever that alternative has any chance of winning.

4. Methodology

Because of the novelty of the declared strategy voting paradigm, there are many related areas where work remains to be done. To determine the effectiveness of declared strategy voting as a tool for group decision-making I will refine the declared strategy voting concept; develop an accessible implementation that can be used in mock elections; and evaluate declared strategy voting through mock elections, simulations, mathematical analysis, and historical analysis. Finally, I will conduct an impact analysis to study some of the broader issues related to this new voting paradigm.

This research will study declared strategy voting with respect to one type of voter population: Internet users. This population can be expected to consist mostly of college students and college graduates with at least moderate family income levels and a moderate to strong interest in new technologies. Throughout this section the term "voter population" refers to the population of Internet users under study. Other types of voter populations will be considered only in the historical analysis and impact analysis sections of this work.

4.1. Refinement of Declared Strategy Voting Concept

To refine the declared strategy voting concept I will:

- determine what types of strategies (rational or otherwise) are likely to be used by the voter population,

- develop strategy equations that can express these strategies,
- and find a fair solution to the strategy evaluation order problem.

4.1.1. Strategies Likely to be used by Voters. The simulations described in the Preliminary Studies section modeled strategies developed from personal experience and from informal discussions with several professors. I will survey members of the voter population to determine what strategies they are likely to use. In this survey, I will describe several election scenarios and ask people who they would vote for in each scenario. For example, the survey may include a question like the following:

You are listening to the radio as you drive to the polls to vote. A report on exit polls indicates that in a race between Adams (the incumbent), Baker, and Calvin, Adams is slightly ahead of Baker and Calvin is way behind both other candidates. You are disappointed because you had hoped Calvin would win and because you have been very unhappy with what Adams has done over the past 12 years and do not want to see her elected for another term. You do not have any strong feelings one way or another about Baker. For whom do you cast your vote? (Select Adams, Baker, Calvin, or no vote.)

In addition, I will include questions that will explicitly ask voters to describe the types of strategies they would like to be able to express in a declared strategy voting system.

4.1.2. Strategy Equations. I will employ game theoretical analysis techniques [19] to aid in the development of a set of strategy equations that can represent any strategy that members of the voting population are likely to use. A declared strategy election can be modeled as a game of perfect but incomplete information. This is a game in which all players know how all previous players have moved but do not necessarily know the utilities that the other players place on each potential outcome. This model may be useful for determining the optimal strategy for a voter based on his or her preferences and beliefs, and for determining the correspondence between strategy equation parameters and voter preferences and beliefs.

4.1.3. Strategy Evaluation Order. In a declared strategy voting system, the order of vote evaluation is an important consideration. Because vote functions are based on the ballots already tallied, a voter whose ballot is evaluated towards the end of the tallying process can have more information than a voter whose ballot is evaluated earlier. On the other hand, the earlier a ballot is evaluated, the more strategies it is likely to influence. Clearly, a fair evaluation procedure is needed. The following three types of evaluation procedures warrant further examination:

Complexity ordering. Strategies are ordered in terms of their relative complexity, with simpler strategies evaluated earlier. This has the advantage that the strategies that depend least on tally information are evaluated when little or no tally information is available. However, this procedure may unduly bias the tally information referenced in subsequent ballot evaluations.

Randomization. Ballots are evaluated in random order after all votes are cast. This procedure is fair, but relies on chance. I will study this procedure to determine the extent to which ordering plays an influential role in the outcome. One variation on this procedure would evaluate the ballots multiple times using a different random shuffle each time. Whichever outcome occurred the most times would be considered the winner. Another variation would evaluate the ballots multiple times, with the result of the $(n - 1)^{th}$ evaluation being used as the context for the strategies to be evaluated in for the n^{th} time.

Two-stage voting. Each voter's ballot includes both a voting strategy and an absolute preference ranking. In the first stage, the absolute preferences are tallied. These then form a context in which strategies can be evaluated without any dependence on order. This scheme suffers because the absolute preferences may themselves be insincere.

The randomization procedure seems most promising, assuming that outcome stability is high. Preliminary simulations indicate that outcomes can be kept fairly stable, especially if some restrictions are placed on the types of allowable strategy functions. However further simulations with more realistic utility distributions are necessary. I will use simulations, geometrical analysis and game theoretical analysis to study this problem further and to choose one procedure for implementation.

4.2. Accessible Implementation

In order to demonstrate the effectiveness of a declared strategy voting system, it is important to be able to test such a system. Therefore, I am developing a prototype system that can be used in mock elections. The core of this system will be the Sensus prototype, which will be augmented to handle declared strategies. Because formulating and specifying voting strategies is complicated, I plan to develop a user-friendly system that will help voters specify their strategies. One approach that I am considering is a system that suggests a strategy to the voter based on his or her answers to a series of questions. However, it will be necessary to evaluate potential priming effects of such a system.

4.3. Evaluation of Declared Strategy Voting

The final stage of this research will involve assessing the effectiveness of declared strategy voting as an instrument for group decision-making. Effectiveness will be evaluated in terms of accessibility, acceptability, and several normative properties.

4.3.1. Simulations and Mathematical Analysis. I will use the results of simulations and mathematical analysis to compare declared strategy voting systems with traditional systems and determine the types of outcomes declared strategy voting systems are likely to select. This data should provide indications about the conditions that must exist for declared strategy voting to possess various normative properties.

4.3.2. Historical Analysis. I will use historical data from previous elections to determine how a declared strategy voting system might have affected the outcome of these elections. In particular I will analyze a three-candidate Presidential election such as the 1992 race between Bush, Clinton, and Perot. In addition, I will study elections in which ordinal and cardinal preferences of all voters are known. For example, Ordeshook [30] describes the proceedings of a Jet Propulsion Lab committee that had to select trajectories for NASA's two Jupiter/Saturn space probes. After narrowing down the possibilities to 35 trajectory pairs, ordinal and cardinal preferences were collected from ten teams of scientists. The committee discovered that one trajectory pair won under one set of voting criteria while another pair won under two other sets of voting criteria [12]. I will apply declared strategy voting to this problem or to a similar problem.

4.3.3. Mock Elections and Surveys. After developing an accessible implementation of declared strategy voting, I will use this system to conduct mock elections. The mock elections will be used to study declared strategy voting with realistic voter populations. Participants in mock elections will also be surveyed to assess the accessibility and acceptability of the declared strategy voting implementation.

The Internet provides many opportunities for finding participants for mock elections. By soliciting participants in certain subject-specific or geographically-specific online discussion groups I should be able to obtain a realistic voter population that includes people with a variety of opinions. For example, I may ask participants in a high-level-programming-language discussion group to choose a "standard" extension language that will be recommended for all extendible programs (for example, word processors that allow users to write their own macros). I will also conduct a mock election that shadows a real election, such as the California Republican Presidential primary. Because there is a Democratic Presidential incumbent, the early Republican primaries are likely to have a large pool of candidates, and thus be very susceptible to strategic manipulation.

4.4. Impact Analysis

In the impact analysis, I will consider some of the broader issues related to declared strategy voting. I will use case studies to reason about the potential economic, political, institutional, social, technological, and legal impacts of this voting paradigm. For example, I will study countries and organizations that have switched voting procedures to determine the factors that motivate an institution to switch voting procedures and the institutional impacts that may arise as a result of this switch. I will also examine institutions that use a voting system which requires voters to submit more information than a plurality voting system requires. In addition, I will investigate the legal issues that might have to be faced if U.S. national or local elections were to be conducted using a new voting procedure. I have already identified several cases which may provide insight into the impact of adopting a new voting system such as declared strategy voting.

One interesting case which warrants further study is that of Ireland, a country which adopted the single transferable vote system of proportional representation⁴ in 1920. Since adopting this system,

⁴The single transferable vote system, developed in 1857 by Thomas Hare, is sometimes called the Hare system. In this system voters submit a preference ranking of all the candidates. Any candidate that receives more than a certain number of first place votes is elected. If the elected candidates receive more votes than necessary for election, their excess votes are

Ireland has had a fairly stable government and a relatively high rate of voter turnout. Despite the complicated nature of this voting procedure, voters rejected proposed constitutional amendments to replace it with a plurality system in 1959 and 1968 [16, 39].

The single transferable vote system of proportional representation has proven controversial when adopted by American cities. Adopted by over 20 cities in the first half of the twentieth century, single transferable vote is currently used only by Cambridge, Massachusetts. Cincinnati, Ohio adopted the system in 1924 in response to severe gerrymandering of city council districts. Voters rejected referenda to repeal the system in 1936, 1939, 1947, and 1954, but accepted a repeal referendum in 1957 that replaced single transferable vote with an at-large plurality election system. It is generally believed that the referendum succeeded due to threats that the single transferable vote system would lead to the election of the city's first black mayor. A 1988 referendum to reinstate the single transferable vote system failed in a vote that split mostly along racial lines [13].

The only other public governing bodies in the United States that currently use the single transferable vote system are the 32 community school boards in the City of New York [13]. However, the system is used by other institutions, including the Faculty Senate of Washington University's College of Arts and Sciences.

There are also several interesting cases involving organizations that switched to approval voting⁵ in the 1980s. The Mathematical Association of America, the American Statistical Association, and The Institute of Management Sciences adopted approval voting primarily out of scientific curiosity [6]. ASA and TIMS conducted experimental elections prior to adopting approval voting [4]. The Institute of Electrical and Electronics Engineers, a professional organization with over 300,000 members, adopted approval voting in 1988 in order to prevent the election of a presidential candidate "who was frequently critical of IEEE and its policies," [6]. This candidate had come within 242 votes of beating both the Board-nominated candidates in the 1986 election.

The first political organization to use approval voting was the Pennsylvania Democratic party, which used approval voting for a non-binding Presidential preference survey in 1983 [27]. As part of this survey, the Pennsylvania leaders were questioned about their attitudes towards approval voting. Two-thirds of the 201 delegates reported that they were sufficiently informed about approval voting to form an opinion about it. Nearly three-fifths of these delegates reported that they had formed favorable opinions.

Acknowledgments

I would like to thank my doctoral committee members Donald Cairns, Ron Cytron, Robert Durr, Robert Morgan, and Douglas Schmidt for their comments and suggestions. I am also grateful to

essentially distributed to the other candidates in accordance with the second choice preferences of the voters. Once again, any candidate that receives more than a certain number of votes is elected and the redistribution procedure continues. If the redistribution procedure reaches a point where there are no more votes to be redistributed and there are still more elected positions to be filled, the candidate with the least votes is eliminated and the votes for that candidate are redistributed. There are a variety of variations on this procedure with different methods for calculating the quota needed for election, different redistribution procedures, and different methods for resolving ties [20, 33, 39].

⁵Approval voting, independently developed by at least five sets of people in the mid 1970s, allows voters to vote for (approve of) as many of the candidates as they wish. Generally the winner of an approval voting election is the candidate who receives a plurality of votes [3].

Jack Knight for reading drafts of this proposal and pointing out the confusing terminology.

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