ISSN 1745-6231

Voting matters

for the technical issues of STV

published by

The McDougall Trust

Issue 19 November 2004

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Editorial

Report by Steve Todd

On 9 October this year, New Zealand held a number of STV elections using the Meek counting rules. Several problems arose which delayed the final declaration of the results. It appears that the main problem concerned reconciling the number of voting papers that were scanned into the database with the number that were subsequently sent to the STV calculator.

The realisation that discrepancies were occurring led the local councils and district health boards (DHBs) affected, to call in the Auditor-General's office to audit the entire process. While the computer error was discovered and fixed within a few days, the auditing process meant that it took four weeks to complete all the vote-counting. In contrast, the program which actually performed the count, i.e. the STV calculator, appeared to operate without mishap.

A lesser, but equally frustrating, problem was that the ICR technology used to process the ballot papers was unable to read (with a high level of confidence) a considerably higher percentage of the scanned documents than was expected. This led to much more human intervention than was expected, with a consequent increase in the time taken to process the votes.

The Justice and Electoral select committee of New Zealand's parliament intend to conduct an inquiry into what went wrong. A focus of the inquiry will likely be on why the two Auckland-based companies contracted to process the STV votes in the northern part of the country, did so seemingly without a hitch, and in a timely manner, while the Christchurch and Wellington companies contracted to conduct the remaining STV elections (in respect of 7 of 10 councils and 18 of 21 DHBs) did not.

There has not yet been a full explanation of the problems encountered, but there is a suggestion that the computer systems used by the Christchurch and Wellington companies may not have been completely compatible.

There were also widespread claims of voter confusion (said to have been caused by having FPTP and STV elections on the same A3-size voting documents), leading to many Informal (Invalid) votes (errors) and blank votes (non-participation) being cast, that the select committee will no doubt inquire into.

Informal votes in council areas using STV appear to have been no more than usual — 1.08% in Wellington and 1.49% in Dunedin, for example. However, in the remaining 64 council areas, that used FPTP, the Informal rate in respect of their DHB elections was up as high as 10 to 12%.

A likely explanation for this will be poor voting-document design. There was no bold distinction between FPTP and "tick-voting" for the mayoral and council ward elections, and STV and voting by numbering the candidates in the DHB elections. In fact, apparently due to printing restrictions, the DHB elections were set out under the name of the city or district councils they were associated with! This means that some voters (who did not read the voting instructions carefully) carried on tick-voting into the DHB election — more than one tick for the candidates and the vote was informal.

On the brighter side, the actual ballot data is likely to be made available in respect of most, perhaps all, STV elections and hence it will be possible to 'check' the counts by re-running them.

Voting matters

There are 3 papers in this issue:

- B. A. Wichmann: Tie Breaking in STV. This paper considers a method of handling ties when a computer is used by considering all possible outcomes. It is an unfortunate fact that breaking a tie by a random choice gives an impression that the outcome might be random when this is rarely the case.

- J. Green-Armytage: Cardinal-weighted pairwise comparison. This paper considers the election of a single candidate by adding information to a Condorcet-style count on the strength of the preferences for candidates.

- B. A. Wichmann: A Working Paper on Full Disclosure. This paper attempts to put together major concerns about this issue which have been raised in previous issues of *Voting matters*. The paper was written before the New Zealand election data became available and hence does not mention this.

Tie Breaking in STV

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1 Introduction

Given any specific counting rule, it is necessary to introduce some words to cover the situation in which a tie occurs. However, such ties are only a practical concern for small elections. For instance, it has been reported that a tie has never occurred with the rules used in the Irish Republic.

Probably the most common form of a tie is when the two smallest first preference votes are the same. Unless both candidates can be excluded, a choice must be made, although in very many cases, the candidates elected will be the same.

This note proposes that when a computer is used to undertake a count, all the possible choices should be examined and that the result is produced by computing the probability of election of the candidates.

2 Ties in practice

It is clear that the propensity to produce a tie will depend largely on the number of votes. However, some estimate can be obtained from a collection of election data that has recently been revised [1]. The data base consists of over 700 'elections', but for this paper we exclude artificial test cases. The figures obtained from the other cases, which are like real elections, with three counting rules ([4, 2, 7]) are as in the table on page 4.

Hence, although with the Church of England rules, only 59 out of 299 involved a tie-break, the average number of tie-breaks in those 59 was actually 9.9. The average number of votes in those 59 cases was 102, while the average for the remaining 240 cases was 12,900. It is important to note that Meek only has ties on an exclusion of a candidate, while the hand-counting rules also have ties on the choice of the candidate whose surplus is to be transferred.

For reasons not relevant to this note, the number of cases run with each rule is different. (Larger cases have only been run with Meek.) It is clear that a small number of votes increases the risk of a tie. Also, given that a tie occurs, the Meek algorithm has only half the risk of a subsequent tie arising, almost certainly due to the higher precision of the calculation.

3 The special case of ties with the Meek algorithm

Brian Meek's original proposal rests upon the solution of certain algebraic equations. The algorithm given in [7] provides an iterative solution of those equations. The mathematical nature of the equations implies that there is substantial freedom in handling exclusions, since, once a candidate is excluded, it is as if the candidate had never entered the contest. Hence it is not necessary for two implementations of Meek to handle exclusions in the same way — the same candidates will be elected. (In contrast, the hand counting rules need to be specific on exclusions since it affects the result; ERS97 insists on as many as allowable, while CofE insists on only one at a time.)

As an example, David Hill's implementation of Meek in comparison with my own has revealed differences. We both exclude together all those candidates having no first preferences. David Hill also excludes the next-lowest candidate also (assuming it is safe to do so), while I do not. I will exclude more than one candidate at a time when it is safe to do so, while David Hill sticks to one at a time. Hence both our implementations report a random choice has been made when it is certainly possible to avoid this. Such reporting is undesirable since it might give the impression that those elected have been chosen at random, when this is not the case. Both of us have introduced a tie-breaking rule similar to that in many hand-counting rules based upon the votes in previous stages (but in opposition to that advocated in [5]).

Two other aspects are relevant to the Meek algorithm. The cases reported in [6] indicate that an implementation can report a tie even though in mathematical terms, one candidate is ahead (but by too small an amount to be computed). This situation is not thought to arise in practice. Perhaps somewhat more disturbing is that an algebraic tie can be computed differently, giving one candidate ahead of another. Two implementations of Meek with such a case can even break the actual tie by rounding in different directions. However, since there is a real tie, breaking it by the rounding in the implementation, is not so bad.

4 Results of the proposed method

The only practical method to implement this proposal is to modify software that already implements an existing counting rule. Since I have my own implementation of Meek, I have modified this to analyse all choices when a tie occurs.

The modification works by executing the algorithm once for every possible choice when the rules require a 'random' choice. For my version of Meek, I have provided an option to remove the first-difference rule so that when this rule would otherwise be invoked, a random choice is made[1].

As an example, consider a real (simple) election, R033, having four candidates (A1. . . A4) for one seat. At the first stage, A2 and A3 have the smallest number of votes: if A2 is excluded, then A1 is elected; if A3 is excluded, then there is a tie between A2 and A4 for the next exclusion. These two alternatives also result in A1 being elected. So the final result is:

Probability from 5 choices from 3 passes.

Candidate	*Excluded?*	*Probability*
A1	no	1
A2	yes	0
A3	yes	0
A4	yes	0

We now know that the election of A1 is not dependent upon the random choices made. The computation involved three election runs. The middle column indicates that the candidates A2, A3 and A4 were all selected in one of the runs for random exclusion.

A more complex example is given by R009, electing 2 from 14 candidates with 43 votes. Here, the final table reads:

Probability from 1364 choices from 264 passes.

Candidate	*Excluded?*	*Probability*
A1	no	1/ 4
A2	yes	0
A3	yes	0
A4	yes	0
A5	no	0
A6	yes	0
A7	yes	0
A8	yes	0
A9	no	1
A10	yes	0
A11	no	3/ 4
A12	yes	0
A13	yes	0
A14	no	0

Here we see that only the candidates A1, A5, A9, A11 and A14 were never subject to random exclusion. Nevertheless, A5 and A14 were never elected.

However, the above result was using the variant of Meek without the first-difference rule. If the first-difference rule had been applied, then A1 would not have been elected in any circumstances. Note that in this case, a large number of passes had to be made due to many of the stages resulting in a tie. Hence this technique is only really possible due to the speed of modern computers.

Given the above election, then there are two possible uses of the outcome: firstly to elect the most probably candidates (A9 and A11), or secondly, to randomly select between A1 and A11 according to the specified possibilities. Since in this paper we are attempting to reduce the random element, we choose the first option.

From the database, 55 cases were selected which correspond reasonably closely to real elections. The results are in the table on page 5. The entry 'Random' gives the number of random choices made with the New Zealand version of Meek which has the first-difference rule. The last three entries are from running the new program. The 'Probs.' column includes the probabilities of election of those candidates who are involved in ties and have nonzero probability of election.

[1] The first-difference rule is a method of breaking a tie by examining the votes in all previous stages, starting at the first stage and selecting the one which has the fewest votes at the first stage at which there is a difference. Of course, if the earlier stages give no difference, then a random method must be used to break the tie.

The three examples with approximate results from the new program took too long to run to completion. Here, the tabulated results are based upon the first few thousand cases executed. The majority ran very quickly and only those with 10,000 or more passes took longer than a minute or two. The case R038 was exceptional in having probabilities of 29/168, 11/35, 29/60, 431/840, 431/1680, 437/1680 and 1 (and none were repeated).

If one was only concerned with the Meek algorithm, then the program could probably be made substantially faster since the ties only arise with an exclusion and Meek is indifferent to the order of the exclusions in the sense that excluding A then B is the same as excluding B then A; this situation will typically be the case when A and B tie on the fewest number of votes. The approach here is a general one that could be applied to any counting rule. It also seemed easier to program the general method presented here.

From the 49 cases which were run to completion, all but 7 reported than the random choice had no effect upon the result.

Election R102 is typical of the situation in which a large number of random choices are made. In fact, 28 exclusions are made before an election. This implies that for all these initial stages, the votes are integers. Given the small size of the election, ties are very common. Unfortunately, this implies that the number of choices is too large to compute them all. However, experimenting with removing those candidates who are excluded early, gives the result shown in the last column.

Followers of the Eurovision Song Contest might like to know that although the official scoring system gave a tie in 1991 between Sweden and France, with Sweden being judged the winner on the basis of having more second (preference) votes, this system gives Sweden a probability of election of 71/288 and hence France the clear winner with a probability of 217/288. According to this system, the UK would have won in 1992 with a probability of 5/6, while the official result declared Ireland as the winner which had a probability of only 1/12.

5 Conclusions

It seems that the provision of this program raises more problems than it solves. If one is prepared to ignore the 14% of cases which question the validity of the random choice, then one can continue the current practice with a clear conscience. On the other hand, when a random choice was made in a real election, it would surely be welcome to show that the result was not in question. However, using this program for that purpose might not give a clear answer when only a fraction of all the possibilities could be executed in a reasonable time (as with the three cases in the table). Of course, in those cases, numerous random choices could be tried, but the object here is to avoid such arbitrariness.

When a candidate has been subject to a random exclusion in an election, he/she could naturally feel aggrieved. One solution to that would be to undertake a re-count without randomly excluding that candidate. If this were undertaken by computer, the number of re-counts would be less than the number of candidates and hence very much less than all possibilities which are considered above.

Currently, almost all STV counting rules introduce some rules, like the first-difference rule ([2, 4]) or Borda scores [3], to reduce the need for a random choice to be made. An alternative would be to simplify the counting rules by omitting these provisions, but to use a program like the one presented here to produce a result which is very likely to have no random element.

6 References

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[3] Earl Kitchener, Tie-Breaking in STV. *Voting matters*. Issue 11, April 2000.

[4] GS1327: General Synod, Single Transferable Vote regulations 1990 and 1998. (Obtainable from Church House Bookshop, Great Smith Street, London SW1P 3BN.)

[5] J. C. O'Neill: Tie-Breaking with the Single Transferable Vote. *Voting matters* Issue 18. pp 14-17. 2004.

[6] B. A. Wichmann. The computational accuracy using the Meek algorithm. *Voting matters* Issue 12. pp6-7. November 2000.

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Rule	*Ties*	*Ties per case*	*Average votes with ties*	*Average votes without ties*
CofE	59 from 299	9.9	102	12900
ERS97	55 from 154	7.1	81	2438
Meek	62 from 587	3.3	12692	44180

Table 1.1: Ties with different election rules

ID	Votes	Candidates	Seats	Random	Choices	Passes	Probs.
M002	131	20	5	1	2	2	1
M112	692	25	6	1	2	2	1
R009	43	14	2	4	1364	264	1/4, 3/4, 1
R012	79	17	2	4	256	48	1
R015	83	19	3	6	32640	3840	1
R017	76	20	2	5	64776	7200	1
R018	104	26	2	11	—	$\approx 6 \times 10^{6}$	1?
R019	73	17	2	5	3876	672	1
R020	77	21	2	5	42184	4572	5/24, 19/24, 1
R027	44	11	2	4	114	30	1
R028	91	29	2	8	—	$\approx 5 \times 10^{6}$	1?
R033	115	4	1	1	5	3	1
R038	9	18	3	3	387	115	*see text*
R040	176	17	5	1	2	2	1
R097	45	17	1	6	283742	31190	1
R100	1031	31	10	1	2	2	1
R102	247	49	10	15	—	$\approx 34 \times 10^{6}$	1/12, 1/4, 1/6, 2*5/6, 2*11/12, 6*1?
S002	16	16	1	1	8	4	2 of 1/2
S003	16	16	1	1	7	5	1
S004	20	20	1	2	12	6	1
S005	18	18	1	1	3	3	1
S006	20	20	1	3	60	18	1
S007	19	19	1	2	46	14	1
S008	19	19	1	3	106	31	1
S009	20	20	1	2	20	10	1
S010	22	22	1	3	448	106	1
S011	21	21	1	4	465	97	1
S012	22	22	1	1	2	2	1
S013	22	22	1	3	3888	624	1
S014	22	22	1	1	176	44	71/288, 217/288
S015	23	23	1	3	646	126	2 of 1/12, 5/6
S016	25	25	4	1	2	2	1
S022	25	25	1	4	1592	329	1
S023	23	23	1	3	288	60	1
S024	17	16	1	2	58	16	1
S025	18	18	1	4	480	96	2 of 1/2
S026	18	18	1	5	39703	6297	1
S027	13	19	1	2	30	12	1
S028	17	18	1	3	229	68	1
S029	18	18	1	2	16	7	1
S030	20	20	1	4	1368	288	1
S031	19	19	1	1	2	2	1
S032	16	19	1	2	16	7	1
S033	22	23	1	2	1132	206	1
S034	25	25	1	4	5774	1072	1
S035	25	25	1	6	70560	10080	1
S036	23	23	1	5	14400	2304	1
S037	24	24	1	2	16	7	1
S038	23	23	1	2	28	10	1
S039	26	26	2	5	17760	2880	1
S047	36	24	1	6	12144	1800	1
S048	24	24	1	6	161280	20160	1

Table 1.2: All results from exhaustive tie-breaking

Cardinal-weighted pairwise comparison

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1 Introduction

This paper introduces a new voting method named **cardinal-weighted pairwise comparison**, or **cardinal pairwise** for short. It is based on Condorcet's method of pairwise comparison, but in addition to asking voters to rank the candidates in order of preference, this method also asks them to rate the candidates, for example on a scale from 0 to 100. The ordinal ranking information is still used to decide the winner and loser of each pairwise comparison, but the cardinal rating information is used to decide the relative strength of the pairwise victories/defeats, which determines how majority rule cycles are resolved if they occur.

Sections 2 through 4 are primarily concerned with definition, and sections 5 through 7 are primarily concerned with analysis and justification. In sections 2, 3 and 4, I define some key terms, define the cardinal pairwise method, and give an example computation. In section 5, I argue that pairwise methods in general are superior to other voting methods when the goal is majority rule. In sections 6 and 7, I discuss the advantages of cardinal pairwise over other pairwise methods, which are as follows: First, it takes into account the relative priority of each pairwise preference to each voter. Second, it may greatly reduce the vulnerability to strategic manipulation that is troublesome for pairwise methods.

2 Preliminary definitions

Pairwise comparison, pairwise defeat, pairwise tie: A pairwise comparison uses ranked ballots to simulate head-to-head contests between different candidates. Given two candidates A and B, there is a pairwise defeat of B by A if and only if A is ranked above B on more ballots than B is ranked above A. If the number of A>B ballots is equal to the number of B>A ballots, then there is a pairwise tie between A and B.

> and = symbols: I use these in two slightly different ways. For example, "A>B" can mean that an individual voter or a specific set of voters ranks A above B, and it can also mean that A has a pairwise victory over B. "A=B" can signify an equal ranking of A and B, or a pairwise tie between A and B. The meaning will be made clear by the context.

Condorcet winner, Condorcet-efficiency, Condorcet criterion: A Condorcet winner, also called a 'dominant candidate,' is a candidate that wins all of its pairwise comparisons. If a voting method always elects a Condorcet winner when one exists, the method is Condorcet-efficient, and passes the Condorcet criterion.

Strong Condorcet winner: A Condorcet winner whose pairwise victories are each supported by more than one half of the ballots.

Majority rule cycle: A circular series of pairwise defeats (e.g. A beats B, B beats C, C beats A) that leaves no single candidate unbeaten.

Condorcet completion method: A voting method that chooses the Condorcet winner when one exists, and is also decisive when there is no Condorcet winner. The following four methods (minimax, ranked pairs, river, and beatpath) are Condorcet completion methods.

Minimax method: The winner is a candidate whose strongest pairwise loss (if any) is the least strong compared to other candidates' strongest losses. Equivalent to a method that drops the weakest pairwise defeat until one candidate is undefeated.

Ranked pairs method: Defeats are considered in descending order of strength. They are locked in place unless they make a cycle with already-locked defeats, in which case they are skipped. The winner will be a candidate who is undefeated after all the defeats have been considered. See Tideman [11].

River method: Similar to ranked pairs, except that it does not lock more than one defeat against the same candidate; once the first has been locked, any others are skipped. See Heitzig [3].

Beatpath method: A beatpath is a series of pairwise defeats that form a path from one candidate to another. For example, if A beats B, and B beats C, then there is a beatpath from A to C. The strength of a beatpath is defined as the strength of its weakest component defeat. If the strongest beatpath from X to Y is stronger than the strongest beatpath from Y to X, then X has a beatpath win over Y. The winner of the beatpath method will be a candidate such that no other candidate has a beatpath win against it. See Schulze [8].

Ordinal pairwise: A shorthand term that I will use to refer to versions of the minimax, ranked pairs, river, and beatpath methods that only use ordinal rankings, and measure defeat strength in terms of a sheer number of votes, whether the number of votes in agreement with a defeat, or the margin between the number of votes in agreement and the number of votes in disagreement.

Minimal dominant set: The smallest set of candidates such that every candidate within the set has a pairwise victory over every candidate outside the set. See Schwartz [10]. The ranked pairs, river, and beatpath methods always choose from the minimal dominant set, whereas the minimax method does not.

Resolvability: A voting method is resolvable if the probability that a random solution will be needed to produce a winner approaches zero as the number of voters approaches infinity.

Mutual majority criterion: If there is a single majority of the voters who rank every candidate in a set S_1 over every candidate outside S_1, then the winner should always be a member of S_1.

3 Definition of the cardinal-weighted pairwise comparison method

3.1 Ballot

1. Voters rank the candidates. Equal rankings are allowed.
2. Voters rate the candidates, e.g. on a scale from 0 to 100. Equal ratings are allowed. If you give one candidate a higher rating than another, then you must also give the higher-rated candidate a higher ranking.

3.2 Tally

1. Determine the *direction* of the pairwise defeats by using the *rankings* for a standard pairwise comparison tally.
2. Determine the *strength* of the pairwise defeats by finding the weighted magnitude as follows. Suppose that candidate A pairwise beats candidate B, and we want to know the strength of the defeat. For each voter who ranks A over B, and *only* for voters who rank A over B, subtract their rating of B from their rating of A, to get the rating differential. The sum of these individual winning rating differentials is the total weighted magnitude of the defeat. (Note that voters who rank B over A do not contribute to the weighted magnitude of the A>B defeat; hence it is never negative.)
3. Now that the direction of the pairwise defeats have been determined (in step 1) and the strength of the defeats have been determined (in step 2), you can choose from a variety of Condorcet completion methods to determine the winner. I recommend the ranked pairs, beatpath, and river methods.

3.3 Optional, additional provisions

These additional provisions are not an essential part of the cardinal-weighted pairwise method, but they may prove helpful.

1. **Maximizing in scale provision**: [1] Once a minimal dominant set has been established by the pairwise tally in step 2, it may be a good idea to max-

imize the voters' rating differentials in scale between the candidates in the set. That is, to change the ratings on each ballot so that the highest-rated minimal dominant set candidate is at 100, the lowest-rated minimal dominant set candidate is at 0, and the rating differentials between the minimal dominant set candidates retain their original ratios. (For example, 50,20,10 would become 100,25,0.) The benefit of this provision is that voters will have equal ballot weight with regard to the resolution of the majority rule cycle in particular. Therefore, voters will not have an incentive against investing priority in preference gaps that are relatively unlikely to fall within the minimal dominant set.

2. **Blank rating option**: This allows voters to give one or more candidates a blank rating, such that if I give some candidate a blank rating, my ballot will still affect the direction of pairwise defeats concerning that candidate, but it will not add to the weighted magnitude of such defeats.

   Another possible way to deal with candidates that voters leave unrated is to determine their ratings using a default formula. For example, a candidate ranked in first place could be given a default rating of 100, a candidate ranked in last place could be given a default rating of 0, and remaining default ratings could be spaced evenly within the constraints imposed by surrounding ratings.

4 An example computation

The notation in the first line below is used to indicate that 26 voters rank the candidates in the order Right > Left$_B$ > Left$_A$, and assign the three candidates ratings of 100, 10, and 0, respectively.

4.1 Example

26: Right > Left$_B$ > Left$_A$ (100,10,0)
22: Right > Left$_A$ > Left$_B$ (100,10,0)
26: Left$_B$ > Left$_A$ > Right (100,90,0)
1: Left$_B$ > Right > Left$_A$ (100,50,0)
21: Left$_A$ > Left$_B$ > Right (100,90,0)
4: Left$_A$ > Right > Left$_B$ (100,50,0)
Direction of defeats (using ranking information):
Right > Left$_B$: 52-48
Left$_A$ > Right: 51-49
Left$_B$ > Left$_A$: 53-47

Weighted magnitude of defeats (using rating information): Right > Left$_B$:
$(26\times(100-10))+(22\times(100-0))+(4\times(50-0)) = 4740$

Left$_B$ > Left$_A$:
$(26\times(10-0))+(26\times(100-90))+(1\times(100-0)) = 620$

Left$_A$>$Right$:
$(26\times(90-0))+(21\times(100-0))+(4\times(100-50)) = 4640$

Completion by cardinal-weighted pairwise with **ranked pairs** or **river**: Consider the defeats in the order of descending weighted magnitude.
4740: Right > Left$_B$ keep
4640: Left$_A$ > Right keep
620: Left$_B$ > Left$_A$ skip (would cause a cycle, Right>Left$_B$>Left$_A$>Right)
Kept defeats produce ordering Left$_A$>Right>Left$_B$; *Left$_A$ wins*.

Completion by cardinal-weighted pairwise with **beatpath**: The strength of a beatpath is defined by the defeat along that path with the lowest weighted magnitude.
beatpath Right → Left$_B$: 4740
beatpath Left$_B$ → Right: 620
beatpath Left$_A$ → Right: 4640
beatpath Right → Left$_A$: 620
beatpath Left$_A$ → Left$_B$: 4640
beatpath Left$_B$ → Left$_A$: 620
Complete ordering is Left$_A$>Right>Left$_B$; *Left$_A$ wins*.

5 Why majoritarian election methods should be Condorcet-efficient

The Condorcet criterion (along with the minimal dominant set, which is a generalization of the same principle) seems to be the most authentic definition of majority rule that is available to us. If there is one candidate who is preferred by some majority over every other candidate individually, it seems inappropriate to call anyone else a majority winner. For example, if candidate A is a Condorcet winner, and a non-Condorcet-efficient method elects candidate B, a majority will prefer A to B. If there was an election just between these two candidates, A should be expected to win that election.

Condorcet efficiency has important practical benefits. First, Condorcet-efficient methods tend toward the political center, which should promote compromise rather than polarization. Second, when a strong Condorcet winner exists with respect to voters' sincere preferences, and another method chooses someone else, the result is unstable in that a majority could have achieved a mutually preferable result if some of them had voted differently.

Condorcet-efficient methods minimize the incentive for the **compromising strategy**, which is insincerely ranking an option higher in order to decrease the probability that a less-preferred option will win. For example, if my sincere preferences are R>S>T, a compromising strategy would be to vote S>R>T or R=S>T, raising S's ranking in order to decrease T's chances of winning. (The drawback is that this often decreases R's chances of winning as well.) All resolvable voting methods that satisfy the mutual majority criterion have a compromising incentive when there is a majority rule cycle. But unlike other methods, such as single-winner STV, voters in Condorcet-efficient methods never have an incentive to use the compromising strategy when there is a Condorcet winner [9]. This is an important property because, in the absence of a majority rule cycle, it allows me to vote my R>S preference without worrying that it will undermine my S>T preference. This is a more complete way of curtailing the "lesser of two evils" problem, that is, decreasing the extent to which voters have to worry about earlier choices drawing support away from later choices. Thus, Condorcet-efficient methods allow more candidates to participate on an equal basis, which should lead in turn to substantially higher levels of responsiveness and accountability.

6 Preference priority and defeat strength

Most Condorcet-efficient methods that have been proposed so far limit voter input to ordinal rankings. Hence, voters can express preferences between candidates, but they cannot express the relative priority of their preferences. If I worship my first three choices, but detest my fourth and fifth choices, I cannot express this on my ballot, and it is not taken into account when the winner is decided.

Ordinal pairwise methods measure defeat strength in terms of a sheer number of ballots. The cardinal pairwise method extends the sensitivity of the process by factoring in a measure of how much priority the voters assign to each ranking. The goal is that the weakest defeat in a majority rule cycle should be the one that has the lowest overall combination of these two factors: 1) the number of voters in agreement with the defeat; 2) the relative priority of the defeat to those voters who agree with it.

It seems almost axiomatic that, when faced with a majority rule cycle, one should drop the defeat(s) in the cycle that are of least importance to the voters. The remaining question is how to define the priority of each defeat to each voter, and how to aggregate these individual priorities. The answer that cardinal pairwise gives to this question is relatively simple. For those who agree with a defeat, we look at the rating differential they express between the two candidates being compared. Then we take the sum of these winning rating differentials to find the overall strength of the defeat.

The idea is that the voters will rate the candidates such that the rating differential between each pair of candidates will reflect the relative priority of their preference between those candidates. The fact that each voter is constrained to the same range of ratings (e.g. 0 to 100) assures that everyone has essentially the same voting "power." The point here is not to do interpersonal comparison of utilities, but rather to allow voters to prioritize their own preferences relative to one another, using a fluid and simple high-resolution scale.

When learning the cardinal pairwise method, one may wonder why it only looks at the rating differentials of those who agree with a particular defeat, rather than subtracting the losing rating differentials from the winning rating differentials. To begin with, I will say that I am more interested in dropping the defeats that are of least importance to the voters overall, rather than the defeats that are the closest in terms of the strength of preference on either side. That is, if there is one pairwise comparison that voters on both sides consider to be a very high priority, I think that it is especially important not to reverse this defeat. Such high-priority defeats should be regarded as crucial within the election, and the cardinal aspect of the method should be used to defend them rather than to undermine them.

In this way, looking at only the winning rating differentials greatly improves the *stability* of the cardinal pairwise method. Because the defeats that voters place the highest priority on are the most difficult to reverse, the cardinal pairwise method is unusually resistant to strategic manipulation. This point will be explored in greater detail in the next section.

7 Strategic manipulation

Although Condorcet-efficient methods minimize the incentive for use of the compromising strategy, they are vulnerable to the **burying strategy**. This strategy entails insincerely ranking an option lower in order to increase the probability that a more-preferred option will win. For example, if my sincere preferences are R>S>T, a burying strategy would be to vote R>T>S or R>S=T, lowering S's ranking in order to increase R's chances of winning. (The drawback is that this often increases T's chances of winning as well.)

Imagine that with respect to voters' sincere preferences in a three-candidate election, A pairwise beats B and C, while B pairwise beats C. A is a sincere Condorcet winner, but it is often possible for supporters of candidate B to gain an advantage by burying A under C, that is, by voting B>C>A instead of B>A>C. This can create an insincere C>A defeat, which can cause a majority rule cycle such that the A>B defeat is the weakest of the three, so that B wins. In this way, it is often possible to overrule a genuine defeat with a fake defeat.

The burying strategy may have the potential to cause substantial trouble in elections that use a Condorcet-efficient method. Some have cited this as a reason not to adopt Condorcet-efficient methods. (Monroe [5]; Richie and Bouricus [6]) Unfortunately, Condorcet-efficient methods cannot be completely invulnerable to the burying strategy, which follows from the fact that Condorcet-efficiency is incompatible with the later-no-help criterion [12]. However, cardinal pairwise may be able to make this vulnerability much less severe.

There are many reasons to think that cardinal pairwise will be more resistant to strategy than most other Condorcet-efficient methods. First, it should tend to prevent the most flagrant strategic incursions. Second, it should tend to balance strategic incentive against strategic ability, so that those who are most interested in changing the result via strategic incursion tend to be those who are least able to do so. Third, it should minimize strategic barriers against the entry of new candidates. Fourth, it should create the possibility of more-stable counterstrategies than those that are available in ordinal pairwise.

7.1 Flagrant strategic incursions

I define a flagrant strategic incursion as one that causes a very high-priority defeat to be overruled by a false defeat. Take example 7.1 below. Sincere votes:
46: A>B>C (100,10,0)
44: B>A>C (100,10,0)
5: C>A>B (100,50,0)
5: C>B>A (100,50,0)

A is a Condorcet winner. Clearly, the primary contest is between A and B, as C is the last choice of 90% of the voters. However, using ordinal pairwise, the B>A>C voters can change the winner to B by voting B>C>A. This is a very flagrant incursion.

In cardinal pairwise, however, this particular type of flagrant incursion does not work. The weighted magnitude of the C>A defeat is 4490, and no defeat with a magnitude greater than $3333^1/_3$ can be dropped as a result of a three candidate cycle (assuming 100 voters and a 0-100 rating scale).

With larger cycles (four candidates and above, e.g. A>B>C>D>A), the $3333^1/_3$ limit does not apply, but overruling a high-magnitude defeat is still very difficult. Let's say that there is a candidate B, who is pairwise-beaten by a candidate A. In order for B to win, there must be a chain of defeats from B to A (e.g. B>C>D>A), such that every defeat along that chain has a weighted magnitude that is at least equal to the A>B defeat. The minority who prefer B to A will have a limited amount of weight to distribute along the B>C>D>A chain. A given point of weight can count towards two defeats in this four-candidate chain (e.g. the one-point gap in the vote B>D>C>A (1,1,0,0) counts towards the B>C and D>A defeats), but it cannot count towards more than two.

Cardinal pairwise, unlike ordinal pairwise, does not allow a voter to apply the maximum weight to all of their pairwise preferences. This scarcity of weight produces excellent anti-strategic effects, by placing a limit on the extent to which a strategizing group of voters can build up the weight of multiple pairwise defeats at the same time in order to manipulate the overall result.

In general, flagrant incursions are much less likely to be successful in cardinal pairwise than in ordinal pairwise, because the difficulty of overruling an A>B defeat increases as more voters assign a higher priority to the A>B defeat. I hope that my definition of a flagrant incursion can be seen to have value, and that it can be agreed upon that relatively high-priority defeats should be harder to overrule. Consider that when a defeat of A over B is given a very high priority, we can generally expect B to be very *different* from A (in the eyes of the voters), relative to differences with the other candidates in the election. In order to quantify this difference, we can look at both the average A>B rating differential and the average B>A rating differential for individual voters.

I think it is crucial that we make it as difficult as possible for strategic voters to alter an election result in such a way that the actual winner is considered by the voters to be extremely different from all of the members of the sincere minimal dominant set. Consider how seriously it would undermine the legitimacy of the voting system, if it was found that partisan supporters had pulled off a successful burying strategy which won the election for a candidate who was the ideological polar opposite of the sincere Condorcet winner. Ordinal pairwise unfortunately cannot offer much protection against this disturbing possibility, but cardinal pairwise can.

7.2 Strategic incentive and strategic ability

There are impossibility theorems that show that strategic manipulation cannot be completely avoided in any reasonable election method (Gibbard [2]; Satterthwaite [7]; Hylland [4]), but I'm not aware of a theorem that says that we can't find a method that distributes strategic ability in roughly inverse proportion to strategic incentive.

Let's assume that the intensity of difference that a voter perceives between two candidates tends to be largely independent of their ranking of those candidates, and that the average rating differentials on either side of a defeat will tend to be strongly correlated with one another.

Let's say that there is a candidate A who pairwise beats candidate B. If the incentive for the B>A voters to help B by burying A is particularly strong–that is, if they assign a very high priority to their B>A ranking–then we can expect the A>B voters to assign a high priority to their A>B ranking as well, which will make the A>B defeat very hard to overrule. So, a group of voters' ability to achieve a successful burying strategy generally tends to be smaller in cases where that group has a larger incentive to engage in that strategy.

Conversely, if A and B are considered to be more similar candidates, such that there are low average rating differentials on both sides of the defeat, then it may be more feasible for the B>A voters to help B by burying A, but they would have less to gain by doing so, and more to lose should the strategy backfire.

7.3 Minimizing strategic barriers to candidate entry

In example 4.1 above, Left_B and Left_A can be considered to be relatively similar candidates, in that there is a low average rating differential placed on the comparison between them, going in both directions. If only Left_A and Right were candidates, Left_A would probably win, since he has a pairwise win over Right. In cardinal pairwise, the entry of Left_B does not change this result. However, the winner changes to Right in ordinal pairwise, which defines Right's 49-51 pairwise loss as the weakest in the cycle. In general, it is much harder in cardinal pairwise for the entry of a new, non-winning candidate to do harm to a similar candidate. The reason for this is that if the new candidate beats the similar candidate, but does not win, this defeat will be relatively weak, and hence likely to be overruled in the event of a cycle.

In ordinal pairwise, a voter who would otherwise support a potentially-entering candidate might have some anxiety that this candidate could hurt a similar candidate whom that voter also supports. Because the potentially-entering candidate's support base may feel ambivalent about his presence in the race, entry of the candidate may not occur. Thus, the method retains a certain strategic barrier to entry of new candidates. Cardinal pairwise minimizes this barrier to entry, in that the entry of a new candidate is extremely unlikely to affect the result in opposition to the will of his would-be supporters.

7.4 Stable counterstrategies

If several voters try to coordinate a strategic incursion, and other voters learn about this and consider it to be undesirable, they may attempt to coordinate a counterstrategy, in order to make the initial strategy unsuccessful. One hopes that counterstrategy will rarely or never be needed, but it is nevertheless to the credit of cardinal pairwise that it provides for somewhat more-stable counterstrategies than ordinal pairwise. Actually, this may be important in preventing strategic incursion from achieving a critical mass in the first place.

Example 7.2: Some votes are strategically altered
28: A>B>C (100,60,0)
23: C>A>B (100,40,0)
17: B>A>C (100,60,0)
22: C>B>A (100,40,0)

10: B>C>A (100,100,0) these 10 votes are strategically altered from a sincere ordering of B>A>C

Pairwise comparisons, followed by weighted magnitudes:
A > B: 51-49   C > A: 55-45   B > C: 55-45
A > B: 2040   C > A: 4580   B > C: 3380
Candidate A was a sincere Condorcet winner, but B wins instead using both ordinal and cardinal pairwise, as a result of the B>A>C voters' burying strategy.

There are two basic counterstrategy replies to the burying strategy: the compromising counterstrategy, and the deterrent/burying counterstrategy.

In ordinal pairwise, the **compromising counterstrategy** would entail the C>A>B voters weakening or reversing the defeat against A by voting C=A>B. In cardinal pairwise, a similar effect could be gained by voting C>A>B (100,100,0). Both counterstrategies can return the victory to candidate A. The cardinal pairwise counterstrategy is more stable than the ordinal pairwise counterstrategy, in that it does not risk a change in the winner of the A-C pairwise comparison. This makes it a less perilous choice for the C>A>B voters.

The **deterrent/burying counterstrategy** would entail the A>B>C voters weakening or reversing B's defeat of C, such that the B>A>C voters' burying of A could only backfire by electing C. In ordinal pairwise, this would require some A>B>C voters to equalize or reverse their B>C preference, thus voting A>B=C or A>C>B. In cardinal pairwise, it is possible for the A>B>C voters to get a similar deterrent effect by voting A>B>C (100,0,0).

With the deterrent/burying counterstrategy in general, the counterstrategizers are unlikely to know for sure whether the original strategizers will carry out their incursion or not, until the votes have already been cast. Therefore it is important to have an effective counterstrategy that they can use without severely destabilizing the result, in case the original strategy is not carried out and the counterstrategy punishment is undeserved. In this respect, the cardinal pairwise version of the counterstrategy is preferable, in that it does not alter the direction of any pairwise defeats, and therefore will not interfere with the identification of a Condorcet winner.

Of course, the existence of more-stable counterstrategies in cardinal pairwise does not mean that strategy will never be a problem. However, it suggests to me that the threat of a strategic incursion, should it arise, is less likely to spiral out of control.

8 Conclusion

I believe that voting methods aiming for majority rule should be Condorcet-efficient, and that Condorcet-efficient methods should be improved in two ways. One, they should take the relative priority of voters' pairwise preferences into account; two, they should be more resistant to the burying strategy. I find it serendipitous that the same principle can achieve both benefits simultaneously.

I find both of these potential improvements quite significant, but perhaps the strategic issue is the more pressing of the two, as I suspect that the burying strategy could prove to be a serious problem for Condorcet-efficient methods in contentious elections. It is important to have a method that, in addition to recognizing a Condorcet winner when one is clearly expressed, works to protect sincere Condorcet winners from being obscured by strategic incursion. I believe that cardinal-weighted pairwise accomplishes this to an unusual degree.

So, I do not intend cardinal-weighted pairwise as a frivolous academic exercise or a mathematical curiosity. I intend it as a realistic proposal, and one that I sincerely prefer over other existing proposals. I recognize that it adds an extra layer of complexity, but I feel that the benefits of more-meaningful cyclic resolution and reduced strategic vulnerability far outweigh the cost.

9 Acknowledgments

I thank Nicolaus Tideman, Jobst Heitzig, Chris Benham, and Markus Schulze for their helpful comments on earlier versions of this paper. I am also grateful to many participants of the election methods discussion list for their insight and support.

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A Working Paper on Full Disclosure

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1 Introduction

This document considers the following problem: given an election in which preferential voting is used and the count is conducted by computer, what information should be disclosed? Running an election consists of several stages, but here we are concerned with the counting process only. This process must not only be trustworthy, but needs to be seen as such by the electorate.

With the manual count, the full result is typically declared by a *result sheet* which contains the great majority of the information gathered during the counting process[1]. If a witnessed count is undertaken, which is, of course, the case with public elections, then all the critical information that would be available to the witnesses appears in the result sheet. The same degree of transparency is needed when a computer count is undertaken.

In the USA, under their Freedom of Information Act, full information of the ballot preferences is available for public elections. Of course, although this information is available, the identity of those who voted in a specific way is not available — ballot secrecy is maintained.

In the case of the experimental use of computers in the Irish Dáil elections in 2002, full information was available for the three constituencies polled by voting machines. It appears that the Republic has a similar Freedom of Information Act to the USA.

There are at least three different types of election in which the full disclosure questions arise: public elections; private elections performed by an independent party; and lastly, private elections performed internally. All three types of election occur with the Single Transferable Vote (and computer counting).

[1]Practices vary in this area. Working calculations should be published but may not be. For some elections, the ballot boxes are opened individually allowing a careful witness some information about the relative strengths of the candidate vote.

2 Data Protection Legislation

Public elections are typically covered by national laws, but private elections would also need to adhere to appropriate national laws. For the EU, this is largely the national laws which enact the European Directive on Data Protection. This gives data subjects the right to information held about them, and for those holding information the need to register and control access to the information.

There are two cases to consider here: those relating to the candidates in an election and those relating to a voter. Assuming that the voter is not specifically identified, then, in effect, no information is held and therefore nothing needs to be disclosed.

For the candidate, it is clear that information is held and therefore the candidate has a right to be told the information held. For a preferential voting system, it has been my opinion (based upon the 1984 Act, which was straightforward to follow), that the candidate should be informed as to how many preferences were recorded against him/her at all the various levels. Of course, the number of first preferences would be available from the result sheet, but the other preferences may not be. Hence, with a computer count, there seems little doubt that more information should be available to candidates than is provided in the result sheet.

The situation is rather more confused when one considers disclosure of more than the above. It is clear that ballot secrecy is paramount and therefore disclosure may be limited by that need. The limitation is surely minimal since ballot secrecy has not been called into question in the USA, where full disclosure takes place.

We consider secrecy in the next section and hence for the moment, we note current practice.

For the 2002 Irish Dáil elections, full disclosure took place. Some reservations have been expressed about this in a recent Irish report [6]. Also, in the context of public elections, Otten has pointed out a means of making bribery effective by the use of an unlikely sequence of preferences [1]. It seems that this problem has not been raised in the USA.

In the case of an independent balloting organisation undertaking a count, it is not immediately clear who 'owns' the ballot data. If it is the balloting organisation, then disclosure rests with them, otherwise it rests with their client.

Currently, Electoral Reform Services maintain that full disclosure is not possible even when the client requests it. I cannot understand this position and I am not alone in this.

3 Secrecy

Less that 150 years ago it was argued by some that secret voting was not desirable, but nowadays everyone seems to accept that secrecy is paramount. Given that, then the question arises as to whether this imposes some restrictions in applying the principle of full disclosure.

Secrecy has an important limitation. If the entire electoral process is clothed in secrecy, then the validity of the result will be open to question. Hence public elections are open to substantial external scrutiny. In our context, we are concerned with elections in which the count is undertaken by computer. It is far from clear how the process of validating a *count* should be undertaken under such circumstances. Again, we are assuming that the other parts of the electoral system perform the intended function in a manner acceptable to the electorate. The integrity of the count was part of the concern in the report on the Irish system [6].

One means to overcome part of this problem is full disclosure. Then anybody can use the data to repeat the count in order to confirm the result. (Counting software is needed, but that is readily available for almost all counting rules.) This is a *stronger* validation method than the traditional method of a witnessed manual count. When an STV manual count has been checked afterwards by using a computer, some errors are almost always found — sometimes even affecting the result!

Is ballot secrecy compatible with full disclosure? There are two possible problems: firstly, elections with a small number of votes, and secondly, the problem of a long preference list which can act as a signature for the voter.

3.1 An example — census data

It seems to me that there is a good analogy between the problem here and that in handling census data. Complete disclosure occurs after 100 years. People can also request their own data. However, substantial statistical information is made available without restriction — a clear need for Government planning. The apparent conflict is overcome by grouping information into sufficiently large numbers so that an individual return cannot be identified.

It is my understanding that the protocol that the Office of National Statistics uses was agreed with the Royal Statistical Society.

It is my contention that a similar protocol needs to be agreed for preferential election data.

4 Technical measures to ensure secrecy

It seems that there is no concern about the information available from a result sheet. I have been informed of an example in which the result sheet could be regarded as problematic. This was for the 1999 North Tipperary local election in which a candidate got no first preference votes. One could envisage a situation in which such a candidate was then hostile to his/her friends, family, employees, etc.

The preferences themselves can be revealed. Let us say one is voting in an election in which your preferences are A, B, C and finally D. It is not possible to exclude the possibility that the existence of such a voting pattern will be evident from the result sheet. For an actual example in which a long preference list was evident, see [2], which was evident due to full disclosure.

In practice, the percentage of preferences actually used in an election is quite small, so it is usual for long preference lists to consist mainly of unused preferences (see [4]). It is therefore possible to provide a form of disclosure in which some of the preferences on the ballot papers are omitted or changed, but still provide data which confirms the result of the count. In other words, there is plenty of room to provide a form of disclosure which allows for count validation but nevertheless ensures ballot secrecy.

The statistical analogy to the census data problem would perhaps be to disclose a fraction of the ballot papers. This is not a good method, since the data would then not provide a means of validating the count. I have written a program myself to make a number of changes to ballot data so that both the election and the candidates could not be identified. Unfortunately, such changes make it impossible to perform some reasonable forms of analysis, like determining if there is an alphabetic bias in the voting data.

It is certainly true that if ballot data is provided only for some forms of statistical research that a sampling method could be effective. Such a form of disclosure would be of use, but only to a very limited audience.

I am unclear how small any election should be before full disclosure could not reasonably be undertaken. If full disclosure is not provided, then the issue of count validation remains.

Finally, it should be noted that once any public form of disclosure takes place, the use to which it is put is uncontrolled. Here, we are not concerned with making information available under some form of non-disclosure agreement that might restrict its use for research purposes.

5 Conclusions

From the above, I make the following conclusions:

1. In the interests of openness and the validation of computer counting, full disclosure should be the default.
2. Legal advice should be obtained on any caveats to full disclosure as a result of the Data Protection Directive.
3. Technical measures should be agreed on how full disclosure should be implemented, given the paramount importance of ballot secrecy.
4. Purists may well object to anything other than making the ballot data available without change, but disclosure which is sufficient for count validation is surely required.

6 Postscript

Drafts of this paper have been sent to several people who I know are interested in this subject. I have tried to reflect the views of those who commented on the drafts, but this has not always been possible. Those who provided comments include: James Gilmour, Steve Todd, Joe Otten, Colin Rosenstiel, Anthony Tuffin, Jeffery O'Neill and David Hill.

David Hill was strongly of the view that no change should be made to the ballot preferences. I would prefer that, but think that it is better to have effective disclosure (in which small changes are made), rather than no disclosure which is the position with the majority of STV computer counts at the moment.

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