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Voting matters

for the technical issues of STV

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Editorial

There are 5 papers in this issue, all of which are comments or reviews of other work:

- David Hill: *Comments on Newland's paper*

  Here, David Hill responds to some specific technical points in Newland's paper.

- *Edited comments on Robert Newland's suggestions*.

  Robert Newland's article, written in 1983 made many suggestions which were thought to be an appropriate topic of a moderated email discussion. A heavily edited version of this discussion appears here. It points to a number of topics which could well be the subject of future papers in *Voting matters*.

- Brian Wichmann: *Review of The Machinery of Democracy*

  The report reviewed here is one undertaken by leading experts in the US to show what is needed to avoid some of the problems that occurred during the Presidential election of 2000.

  Parts of this report are relevant to the use of scanning machines for the Scottish local elections to be held later this year. The US Freedom of Information Act ensures that electoral data is open to public scrutiny, whereas the position in Scotland is uncertain at this point. This implies that the transparency of the Scottish STV elections might be less than those of Northern Ireland for which manual procedures are used.

- Jonathan Lundell: *Review of the Second Report of the Irish Commission on Electronic Voting*

  The Irish Commission has completed its work with its second report. It is unclear at this stage what action the Government will take. This report has some similarities with the previously mentioned US report which makes for some interesting comparisons.

- David Hill: *Review of Collective Decisions and Voting by Nicolaus Tideman*

  The book reviewed here is central to many of the issues covered in *Voting matters*, and hence this review should be of interest to many of our readers.

Scotland

The final stages of the legal process for the local STV elections in Scotland have been agreed. The counting method is based upon the Weighted Inclusive Gregory Method, but is as simple as it could be in computer terms. Hand counting using this logic is possible, but would take longer than current manual counts because of the need to examine all of the elected candidate's papers when a surplus is transferred. It is interesting to contrast this with the Meek method, which is more complex, since the quota is recomputed and transfers are made to elected candidates. In electoral terms, Meek has the advantage that the intervention of a no-hope candidate cannot change the choice of the elected candidates — a failing of all the rules used for current hand-counting STV methods.

The Order approved by the Scottish Parliament at the end of January will require the Returning Officers to publish much fuller details about votes and transfers of votes at each stage of the count than the corresponding legislation for STV elections in Northern Ireland. However, the rules strangely include a requirement to publish the numbers of non-transferable papers at each stage but not the numbers of non-transferable votes. That vote is needed because, with WIGM, the non-transferable papers will have different values when they become non-transferable.

Because the ballot papers will be scanned and counted electronically, there is a new requirement for one copy of the electronic information so obtained to be kept for four years after the count, while the paper records need to be kept for only one year, as usual. However, it is most regrettable that the release of any of the electronic information, even in anonymous form, is specifically prohibited. One ray of hope for a more enlightened approach is that the Scottish Executive has given an undertaking to consult on this. I certainly hope that full preferential data will be made available because that would be in everyone's best interest.

Readers are reminded that views expressed in ***Voting matters*** *by contributors do not necessarily reflect those of the McDougall Trust or its trustees.*

Comments on Newland's paper

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1 Introduction

Like all work published posthumously, if there are any faults in this paper [1], the author should not be blamed for them because, had he lived longer, he might well have revised it, or even withdrawn it. The paper is important as showing Newland supporting some of the main features of the Meek method. It is a pity that he did not support all of them, but his disagreement with the Meek method of handling short votes gets no mention here.

It is easy to agree with him that to think of saving time or money, as a result of computer counting, is unrealistic, but he fails to mention other advantages of counting by computer, even if the rules remain those of hand-counting methods. These advantages are that, given a correct computer program: (i) anybody can carry out an STV election without having to understand the rules; (ii) the results are much more likely to be correct, provided that due care is taken in converting the ballot paper information to a computer file. Such evidence as is available suggests that STV hand-counts, even by experienced staff, usually have errors in them.

His saying that "It would be absurd to write a computer program restricting the calculation ... to two decimal places" is therefore not correct. Where existing systems require the two-decimal place restriction, doing it by computer, for the sake of a correct result within those rules, is worth while.

He says that "Using more decimal places would, on occasion, lead to a different, better, result". Although the words "on occasion" need to be noticed, I take his meaning to be that on occasion there will be a difference but, if there is, it will necessarily be a difference for the better. Whether that is so depends upon how "better" is defined. In the hope of avoiding controversy, let us take it to mean, in the context of Newland's paper, "more like the result that would have been obtained by adopting remedies (A) and (B) of the paper". Such work as I have done on it suggests that merely more precision in the calculations does not help to that end.

2 Remedies (A) and (B)

Newland's "Remedy (A)" is to re-commence the count *ab initio* after each exclusion; his "Remedy (B)" is to transfer voting papers to next preferences even if already elected. He says that "If STV counts are to be computerised, it would be foolish not to include remedy (A)". He appears not to have realised that to include (A) without (B) can be troublesome. I take it that he was thinking in terms of the rules of Newland and Britton 2nd edition [2] and adding remedy (A) to those, so I shall do so in the following examples.

2.1 What is wrong with Remedy (A) on its own

Example 1

Suppose 8 candidates for 5 seats, with votes

25	ACDF..
24	BCEF..
7	D..
5	E..
2	F..
6	G
3	HBC

We get a quota of 12 and the count proceeds as:

A	25	−13	12		12		12
B	24		24	−12	12		12
C		+13	13		13		13
D	7		7		7		7
E	5		5	+12	17	−5.00	12
F	2		2		2	+4.80	6.80
G	6		6		6		6
H	3		3		3		3
n/t						+0.20	0.20

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Exclude H and restart:

A	25		25	−13	12		12		12
B	27	−15	12		12		12		12
C		+14.85	14.85		14.85		14.85	−2.85	12
D	7		7	+13	20	−8	12		12
E	5		5		5		5	+2.64	7.64
F	2		2		2	+8	10		10
G	6		6		6		6		6
n/t		+0.15	0.15		0.15		0.15	+0.21	0.36

Exclude G and restart. There are now 6 fewer valid votes, so the quota becomes 11:

A	25		25	−14	11		11	
B	27	−16	11		11		11	
C		+15.93	15.93		15.93		15.93	
D	7		7	+14	21	−10	11	
E	5		5		5		5	
F	2		2		2	+10	12	
n/t		+0.07	0.07		0.07		0.07	

Thus E was deemed elected in the first count, and had a surplus transferred, but had to be unelected and take back that surplus for the second count. Finally E fails to get even half a quota and loses. It might be said that there is no need to say that anyone has been elected until the final result is known, but then how can the surplus transfer be explained, for without it F would have been excluded first instead of H?

Example 2

Suppose 8 candidates for 5 seats, with votes

25 ACDF..
24 BCEH..
7 D..
5 E..
2 F..
6 G
3 HBC

These are identical votes to example 1 except that 24 BCEF.. has been changed to 24 BCEH..

Following through the election in a similar way, those elected are found to be ABCDE. Thus E succeeds if those 24 vote BCEH but E fails if those 24 vote BCEF. So their choice of a later preference has upset the fate of their earlier preference. My memory of Robert Newland says that he would have hated that.

3 Conclusions

We must always remember that it is mathematically impossible to find a faultless system, so these faults of remedy (A) on its own are not necessarily conclusive, but they tell strongly against it. What would be safe would be to restart after each exclusion, provided that no candidate had yet been deemed elected.

4 Acknowledgement

I thank the referee for some very helpful comments.

5 References

[1] R.A. Newland. Computerisation of STV counts. *Voting matters*, issue 22, 11-13, 2006.

[2] R.A. Newland and F.S. Britton. How to conduct an election by the Single Transferable Vote, 2nd edition. Electoral Reform Society, 1976.

Edited comments on Robert Newland's suggestions

Editor
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1 Introduction

A moderated email discussion was held based upon the questions raised by Robert Newland [1] about 23 years ago, but only published in 2006. Those participating in the discussion were (in alphabetical order): Bernard Black (BB), James Gilmour (JG), David Hill (IDH), Michael Hodge (MH), Chris Jerdonek (CJ), Henry Kitchener (HK), Jonathan Lundell (JL), Michael Meadowcroft (MM), Joe Otten (JO), Colin Rosenstiel (CR), Markus Schulze (MS), Nicolaus Tideman (NT), and Paul Wilder (PW).

Although the discussion was initially concerned with ten questions, it soon diverged into other, related, topics. It was agreed that the editor should attempt to edit the material rather than relying upon using only the original email text.

2 The questions and discussion

The questions and the discussion that arose from each are enumerated in the following sub-sections. Not surprisingly, some respondents said the questions were wrong and answered a slightly different point.

Questions raised in 1983 are not necessarily appropriate for today. A count in 1983 would probably have needed a main-frame while today any office computer could do a count in a few seconds.

Direct input to a computer (DRE - Direct Recording Electronic voting) would not typically have been envisaged in 1983, nor was the capability to read ballot papers using OCR as well developed — the questions need to be phrased in a manner suitable for today. On the other hand CR had a counting program working on a ZX81 in 1981.

For this publication, see www.votingmatters.org.uk

2.1 Does computerising STV counts save time/money?

BB: This is of no consequence; the right result is all important. IDH: Not to any noticeable extent, unless a recount is necessary to fill a casual vacancy or for some other purpose. Then it is very substantial. (A point repeated by MH.)

JL: Probably. Certainly, if ballots are cast in a computer-readable form (DRE or optical scan, say). Other considerations are probably more significant.

In particular, Newland's comment that, "Voting machines capable of accepting preferences seem an unlikely investment for infrequent public elections," is probably wrong today, at least in the United States, where Federal law mandates machinery that, as a happy side effect, is capable of implementing STV, given the requisite laws, programming and certification.

On the other hand, the widespread practice of voting by mail will continue to require voting machinery in which the primary ballot is paper. In my county (San Mateo, just south of San Francisco), more than half the ballots cast in the June primary election were cast by mail.

NT: This is an empirical question, so its final resolution will presumably be determined by experience. However, if voting is done on a computer screen, as seems increasingly likely, I cannot imagine how it could happen that a computerised count would not save time and money in elections with more than 100 or so voters. Even if voting is not by computer, as long as voters produce scanable ballots, I would expect computer counting to save time and money. If the votes are made public, as I am inclined to think they ought to be, then there will be programs in the public domain to count them, so it will be a good idea to use a computer to count them, to avoid consequential human errors in the counting process. The availability of such programs, along with the votes cast, will make it possible for anyone who wishes to do so to verify that the accepted program elects the candidates that officials say are

elected.

JG: As someone else has already suggested, this question should now be answered by reference to the data available from recent computerised counts in large scale elections. Modern high-speed scanning of paper ballots and intelligent OCR have almost certainly changed this out of all recognition since Robert wrote his note in 1983.

CR: I agree that when we introduced full computer counting into Liberal Democrat elections it made little difference in time and effort. However, from long experience it is now clear to me that we made a considerable gain in accuracy because copying ballot paper data are inherently simpler than interpreting preferences when making transfers.

2.2 How important is witnessing a manual count?

BB: The opportunity to view the count should be available to candidates or their agents. IDH: Not very. It can appear much more meaningful than it actually is, because witnesses can rarely see much that is really relevant. Having systems that actually get the right answer is much more important, but convincing the public that it has been properly done is vital.

MH: I regard it as vital that candidates (or their representatives) can witness counts, whether manual or computer.

JL: To digress slightly, California law requires a manual count of 1% of the ballots (county by county) as a check on the automated count. This raises obvious problems for STV in general and computation-intensive STV methods in particular.

I witnessed a manual recount recently (city council, at large plurality election for three seats). I had a lot more confidence in the result as a consequence of seeing the count, even though the margin was very small. That is good, albeit somewhat subjective.

I agree with David Hill that, "Having systems that actually get the right answer is much more important, but convincing the public that it has been properly done is vital." That is to say, a witnessed manual count is but a means to an end.

NT: Fairly important, I would say.

JG: I suspect this does not happen in most private elections. It appears to be important in public elections for two reasons; Firstly, it is the only means by which candidates and their agents can have any assurance that the ballot papers have been counted correctly; Secondly, it is the only means by which candidates and their agents can collect some information about voting patterns that they consider useful for future campaigning.

Auditing

Apart from a witnessed count, another method to gain confidence in the result are auditing procedures. There was a lengthy discussion on this which is summarised below.

JL: Have reformers settled the question of the extent to which STV algorithms should be replicable "by hand"? To me this question has primacy over questions of representation and "inclusiveness" because it is about trusting the validity of the tally itself. Some answers may limit which algorithms can be considered.

If proper procedures are followed, it seems to me that no replicability by hand is needed. In the United States there is a manual tally process for machine counted elections that involves manually checking the ballots in 1% of precincts selected at random. (Whether this is implemented correctly in practice is another matter.) It seems that no replicability by hand is needed if (1) the ballot rankings are publicly and digitally released, and arranged by some grouping (e.g. by precinct), (2) the digital data are manually checked against the physical ballots in some fraction of those groupings (e.g. 1% of them), and (3) the voting algorithm is fully specified to the public. This would be enough for any organization or member of the public to verify the tally.

JO: It seems that no replicability by hand is needed if (1) the ballot rankings are publicly and digitally released, and arranged by some grouping (e.g. by precinct), (2) the digital data are manually checked against the physical ballots in some fraction of those groupings (e.g. 1% of them), and (3) the voting algorithm is fully specified to the public.

I agree that simplicity of the rules is important. Meek rules I find the simplest, other rules tending only to appear simple when details about the order in which things are done and so forth are glossed over. However while their simplicity is an advantage, their impracticality for hand-counting is not.

JG: With regard to transparency, so far as the imminent (2007) elections in Scotland are concerned, you should remember that the conventional STV paper ballots will be scanned and the counting all done within a computer program. So the tally-men and tally-women will not be at all able to tally the papers or the votes. Indeed, the STV (local government) and AMS (Scottish Parliament) ballot papers will possibly be scanned together — the software separates the votes.

If DRS stick with the scanning procedure they demonstrated, and *if* the Scottish Executive allow the publication of one of the very useful reports that program produced, it will give the parties and others a great deal of information about the STV preferences, ballot box by ballot box. The report I have in mind shows the numbers of preferences at each level (1, 2, 3, 4 etc) for each candidate. It does not show the patterns of transfers, but it does provide very valuable information for the candidates and their agents, and it does it painlessly. I have written to the Scottish Executive and to lots of others saying this is *one* part of the open reporting we need to have in the Scottish procedure.

PW: Transparency in procedures and counting methods in all elections is important, but in public elections it is crucial to maintaining confidence in and the legitimacy of those elected.

[There was a discussion about the US style of auditing and its potential application to Scotland. This has not been included.]

2.3 Are the ERS76 rules the best for a manual count?

Respondents were given an opportunity to consider ERS97 in their response.

BB: Neither. All possible improvements were not made in the 97 version. IDH: Given that all manual counts are only approximations, for reasons of practicability, the ERS rules are probably almost as good as can be got, though I am still waiting for a proper description of the reduced quota feature of ERS97.

NT: The rules could probably be improved a little, here and there, but the improvements would not add much value to the existing rules. I would guess that 98% or 99% of what could be achieved by the best manual-count rules could be achieved by the existing rules. So the important thing is to get STV in use, and then consider refinements.

JG: To answer this question you must first define "best".

I would suggest there are six sets of rules that *could* be used for manual counts: Dáil Éireann, Northern Ireland, ERS73 (not quite identical to the NI rules), ERS76, ERS97, and my version of WIGM STV. (I exclude the Australian Federal Senate rules based on the Inclusive Gregory Method because the transfer value averaging procedure in those rules means that they do not comply with "one person, one vote" [3].)

Exclusive versus Inclusive rules

Farrell and McAllister [3] use the term "inclusive" to characterise a variant of STV which uses more votes in a transfer thus ensuring that more voters are involved in the election of subsequent candidates. Hence one could characterise a rule as "exclusive" if it minimises the voters involved.

JG: I think it is important that any and all discussions of computerisation of STV counts and of the counting procedures that computerisation might make practicable, should take fully into account the effects of the various procedures in relation to the "exclusiveness" or "inclusiveness" of representation. This essential context is missing from almost all these questions.

You may define "best" in terms of the "exclusiveness" or "inclusiveness" of the procedures in different sets of STV rules; there is a diversity of views on which is "best" in this respect. You may define "best" in terms of practicality; there is likely to be less diversity of view on that.

If maximum "exclusiveness" is your definition of "best", you will choose the Dáil Éireann rules. If any element of chance is completely unacceptable, you will exclude the Dáil Éireann rules from any further consideration.

If maximum "inclusiveness" is your definition of "best", you will choose my WIGM STV rules [4]. If you want the maximum "exclusiveness" without any element of chance, you will choose the NI rules or ERS73.

If you want to maximise the practicality you would probably choose ERS76 or ERS97.

Interestingly, in revising ERS76 to ERS97 some "exclusive" features were dropped, but this does not appear to have been done with any conscious intent of making the rules more "inclusive".

MM: Maybe some rules have defects, but the crucial difference with the rules for Dáil Éireann elections and for those in Northern Ireland, is that they are already entrenched in law and have been used successfully in many elections.

CR: What about the Cambridge, Mass, rules which could be described as more exclusive (I do not really buy the simple linear scale model of inclusiveness/exclusiveness anyway because there are other, more political factors to weight various counting rules by).

Cambridge has no derived surpluses at all. If a candidate reaches the quota during a transfer they are leapfrogged by further votes in that round. The only surpluses they have are first stage ones. They are randomly selected for transfer or not, see [8].

JG: The Dáil Éireann rules have a principled structure, which come at the "exclusive" end of the spectrum (called "exclusive" only because it is the opposite of the "inclusive" variants). The Cambridge, MA. rules certainly present a simplification compared with the Dáil rules, but I don't think their arbitrary handling of what would otherwise be consequential surpluses in any way enhances the "exclusiveness" of the representation they deliver.

2.4 Given a computer count, should improved counting procedures be used?

BB: Yes. IDH: Yes. It is absurd to be stuck with approximations where they are unnecessary. NT: Yes.

MH: No, due to the desire to allow a manual count using the same rules — the procedure adopted by the Church of England.

JG: As noted above, the wording of this question reveals the questioner's prejudice and it presents no context for the assessment of "improved".

2.5 Given a computer count, should more than two decimal places be used?

BB: Yes. IDH: Yes, but merely that without other changes does not help much. NT: Yes.

JG: Before considering the number of decimal places that should be used for calculations within STV procedures, I would strongly recommend that all STV counting rules for public elections should prescribe that when votes are transferred, candidates should be credited with only integer numbers of votes. That would greatly simplify the presentation of the results and would aid public understanding and acceptance. This, however, is not a matter of "rounding for presentation" - that way lies disaster. As in the Australian Federal Senate rules, the candidates are credited with only the integer part of the total vote to be transferred and appropriate procedures have to be specified to deal with the "vote fractions not transferred". I have not tried to apply this "integer only" approach to Meek STV, but it can be applied to all other versions of STV rules, from Northern Ireland rules to my WIGM rules for manual counting. Dáil Éireann STV is already integer only.

Once the practicality of result sheet presentation has been separated from internal calculation (by adopting integer transfers), determining the number of decimal places to be used in calculations becomes essentially an exercise in numerical analysis. We should certainly use more than 2 decimal places because of the significant vote loss than can occur with such truncation, as explained in my paper [5]. Where the possibility of a manual count has to be retained alongside computerised counting, I have recommended 7 decimal places for practical reasons associated with the use of pocket electronic calculators [4].

2.6 Given a computer count, restart after an exclusion?

BB: Yes. IDH: Yes, provided that other changes are made to make it work properly. Merely to do that without other changes is disastrous, see [9]. NT: Yes.

JG: I presume by this you mean "go back to the beginning and start the count again as though the excluded candidate had never stood". This presumably reduces the total valid vote by the number of votes for the excluded candidate that are not transferable (no next available preference) and so reduces the quota for the "new" count. That could have all sorts of interesting effects.

2.7 Given a computer count, transfer to already elected candidates?

BB: Yes. IDH: Yes.

JL: The benefits of Meek's method are compelling, if we use computers for the count. However, a manual count, or recount, or verification, becomes impossible, and while publication of the ballots would make independent computer counting possible, there are significant ballot secrecy concerns associated with such publication.

Moreover, manual verification requires another step prior to the (computerized) count, namely verifying that the ballots in the ballot file represent the will of the individual voters. In California, that's likely to mean examining a voter-verified paper copy of an electronic ballot, another area for ballot secrecy concerns, and one in which truncation of unused preferences will not help (they are already on the paper).

NT: Yes.

JG: This is an illogical question because the decision whether or not to transfer votes to already elected candidates does not depend on computerisation, but on the STV procedures you are using. It would, of course, be impractical for public elections without the use of a computer, but that is a separate issue.

As Robert Newland showed in this 1983 note [2], it would be wrong to transfer votes to already

elected candidates if you are using the Gregory Method of fractional transfers with last parcel only. Robert also showed that, to give coherent results, transfers to already elected candidates are required if you are transferring all ballot papers, as in WIGM and Meek.

Consideration of Meek

The use of the Meek algorithm arose several times within the debate on the main questions, but the issues raised are collected here.

NT: To my mind, the answer to improving and simplifying is the Meek rules. These rules have been around for nearly 40 years now. They eliminate some limitations of the Newland-Britton rules that are very distressing to voting theorists. They have a very straightforward explanation. It would generally take too long to count by these rules by hand, but confirming a count by hand-calculator is reasonably straightforward, if rather time-consuming. The rules have been written into "legislation" by the Royal Statistical Society (and in New Zealand law: Editor).

To make the Meek rules even more acceptable, I would propose that someone write a computer program with even more auditing than the present program. In particular, I would suggest that the program should produce an audit trail that shows the allocation of each vote at each stage of the count.

If you feel that the Meek rules are too complicated, then the rules now in use in Northern Ireland (a slight variation on Newland-Britton) might be considered. Voting theorists will be concerned of the ease with which strategy can be employed against them.

CR: Interestingly, Robert Newland's article, in a few short sentences, shows why Weighted Inclusive Gregory treatment of surpluses is such a nonsense.

This discussion also needs to consider more political aspects of different STV variants. My main objection to Meek (and implicitly to some of Robert's ideas) is that they reduce the effective value of votes of less well-informed voters, those who do not express full preference lists. These voters are likely to be politically skewed, with effects on party representation and on the acceptability of STV to our potential supporters.

JL: During a manual recount in California, witnesses must be permitted. They are generally representatives of the candidates. So, independent of whether a computer is making the primary count, ballots are visible to the (semi-) public during the recount. Is this an issue? Perhaps not; recounts are expensive and rare, and as you say, could be implemented without any one person seeing the entire ballot.

With Meek's method, though, a hand count is not practical. So a "manual recount" must be replaced by some other process, presumably a manual verification of the ballot file, and then making the ballot file available for an independent count, and it is not clear to me that truncation (say) could be part of either step.

I am not particularly concerned about the secrecy problem at this step in the process. Again, just looking at the California process, there are secrecy issues already in a manual recount; a vote-seller could "prove" his ballot by casting a distinctive write-in in an irrelevant race. Worse, our vote-by-mail system, used by a large percentage of the electorate, is wide open to both vote-selling and coercion. That is not a good thing, of course, but introducing STV is not going to make things appreciably worse.

On the other hand, jurisdictions with a stronger commitment to ballot secrecy are likely to have a problem implementing STV, maintaining secrecy, and making counting transparent.

HK: Many voters will only know enough about the candidates to put a few at the top of their list. There may be a "party" in whom they have confidence, and who they would like to use to complete their paper. I have found this with the Friends of the National Trust, and with the ERS Support Group. Adding Party Lists would eliminate, or at least reduce, short votes, which would meet the objection some people have to the way Meek treats short votes.

CR: My political concern, especially about Meek but it could also apply to WIG, is that the votes of people who express short preference lists can be devalued. As it is expecting a lot of voters in mass elections to have enough valid information to make informed preference choices for all candidates this could give some voters an advantage.

2.8 Given a computer count, should all candidates be elected with the same number of votes?

BB: Yes. IDH: Yes, in principle, but it is not necessary in practice to do extra work to reach that, once it known for certain which candidates are elected and which are not.

JL: I like the principle, but I am doubtful that it is practical, if we mean to (say) reduce the quota until all seats are filled at the original quota. If quota q

fills one too few seats (without reducing the quota), and quota $q' < q$ fills all the seats, is there a quota q'' between q and q' that also fills all the seats, but with different winners?

In Green Party (California and US) internal STV elections, we require that a candidate reach the quota to be deemed elected, and leave seats empty if necessary, another way (not always appropriate or practical) to answer this question in the affirmative.

MM: Clearly the search for improvements to the operation of STV is on-going, and the advent of the computer opens up new possibilities, but the nature of STV and the relatively complex (for the average elector) concept of the quota and redistribution according to preferences etc, lends itself to caricature by its opponents.

It is interesting to note that the various arithmetical formulae relating to the distribution of list seats does not attract the same attack.

NT: Yes, provided that there is a restart after exclusions. The quota should be lowered as votes become non-transferable.

JG: It is difficult to imagine why anyone would want to do this. It could be achieved only by a complex iterative procedure with an ever-diminishing quota and a series of transfers among the already known winners until all the winners were credited with an equal number of votes. The purpose of the election is to identify the unique set of winners to fill a stated number of seats. When you reach the stage at which you can do that (according to the rules you are using), there is little point in proceeding further.

If you are using a Droop quota and you have filled all the vacancies and there are some votes (less than one quota) then credited to the runner-up, I can see no useful purpose in transferring those votes, much less any useful purpose in going on to equalise the numbers of votes credited to each of the already elected candidates.

CJ: I can see doing this in cases where a "countback" may be used later on to fill a vacancy. In one version of countback, vacancies are filled with STV using all votes that went to elect the vacating candidate(s) in the last election or countback, together with the exhausted votes. If candidate totals are not first equalized, then some voters will not have a fair say in the countback result. For example, if one candidate has a large surplus at the conclusion of the election and some other candidate vacates, the countback would not be fair to the voters who have votes in that pile with surplus. If the tally had continued and surpluses cleared, a lot of those votes could have wound up in the exhausted pile (affecting the result of the countback).

2.9 Given a computer count, should all papers be considered for transfer of a consequential surplus?

BB: Yes. IDH: Yes, all *relevant* papers.

JL: Yes (Meek)

NT: Yes.

JG: Like several other questions, this question has nothing to do with computer counting but everything to do with the type of STV rules you are implementing. As Robert Newland has shown [2], for rules that are to be internally consistent, you must take only the last parcel for Dáil Éireann, Northern Ireland, ERS73, ERS76 and ERS97 rules. In contrast, for internal consistency in WIGM and Meek, you must transfer all papers. So the real question is, once again, do you want "exclusive" or "inclusive" representation, and by how much?

2.10 Is excluding the lowest candidate the best?

BB: Yes.

IDH: If we stick to the principle that later preferences must not under any circumstances upset earlier ones, it appears to be the only sensible rule available, though it is sometimes unsatisfactory. If we are prepared to abandon that absolute principle then I believe "Sequential STV" to be better, see [10].

JL: Here we presumably mean lowest number of first-place votes. I want to preserve later-no-help/harm, and so am reluctant to consider any but first-place votes, so: yes. I think so.

The attractions of Condorcet methods (for single-seat elections) and Sequential STV (otherwise) are undeniable, but the value of being able to unconditionally assure the voter that subsequent preferences will not harm earlier ones is very valuable, not to be give up lightly.

NT: If exclusions are to be done one by one, I prefer a rule of excluding the candidate who would not be elected if the number to be elected were one less than the total not excluded yet. This rule excludes at each stage the candidate with the least apparent claim to inclusion with the others. This rule is not ideal. Its weakness is apparent in the fact that if just one candidate is to be elected, the rule can exclude a Condorcet winner. But even though the rule is not ideal, it is an improvement on eliminating the candidate with the fewest votes.

If a better exclusion rule is desired, then my recommendation is to not exclude candidates one by one, but rather employ a rule that takes account of

the comparisons of all possible outcomes (sets of elected candidates) with one another, see [6].

MS: An alternative STV method is also available [8].

JG: Here again, it depends on what you mean by "best". Some of us like to give electors an absolute guarantee that a later preference can *never* harm an earlier preference. If you regard this as an important principle, to be upheld in all circumstances, you have no option but to exclude the lowest candidate (or pair, or three, etc). Those who come from a social choice background are concerned (or horrified) that a Condorcet winner could be excluded by this procedure and criticise STV for this effect. But if you once open the door to taking later preferences into account to decide the fate of earlier preferences in any circumstances, you will have opened the door to tactical voting in STV. In public elections, with large numbers of anonymous voters, tactical voting is impossible under the present "lowest candidate exclusion" rules and it would have very serious implications to make any change in that.

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Review— The Machinery of Democracy, Protecting Elections in an Electronic World

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1 Introduction

The document being considered here [1] is a highly significant report which deserves careful study by those nervous about the security aspect of using computers for elections. The report is from a Task Force with many experts with established reputations in the field. Moreover, many others clearly performed studies for the Task Force, including the National Institute for Standards and Technology (NIST).

Equally important to the work were reviews and comments made by those professionally responsible for elections across the USA — Registrars and Auditors.

There are important limitations to the study, namely that the only voting systems considered were ones available at the time, and that postal voting was not considered. For the UK, this last restriction is important, since a recent legal case has indicated fundamental weaknesses in the UK postal voting system [2].

Lastly, this report is specifically written to address problems in the US system, and hence its application to other jurisdictions is for readers to decide.

2 The context

The US has thousands of electoral jurisdictions — many more than one per state. The number of jurisdictions that make their own decisions about voting procedures and equipment is smaller, but runs into hundreds. Hence the issues to be addressed are large and diverse due to the different technologies used. The report divides the electronic voting systems into three classes:

DRE Direct Recording Electronic. A DRE machine directly records the voter's selections in each contest, using a ballot that appears on a display screen. There are at least 9 types of machine like this.

DRE w/VVPT A DRE with Voter-Verified Paper Trail captures a voter's choice both internally in electronic form, and contemporaneously on paper. There are at least 5 machines of this type.

PCOS Precinct Count Optical Scan. PCOS voting machines allow voters to mark paper ballots, typically with pencils or pens, independent of any machine. Voters then carry their sleeved ballots to a scanner. At the scanner, they unsleeve the ballot and insert into the scanner, which optically records the vote. There are at least 3 systems of this type.

Note that all three types of voting systems need to be configured for a specific election. Undertaking this task implies access to the machine that could lead to security issues.

3 The methodology

Given the scale of the problem in the US, a methodology was needed to provide a framework for the work and ensure that the result could be understood without too much difficulty.

From existing electoral statistics from 10 states, an artificial state called Pennasota, was devised. The 10 states were all marginal making them potential targets for an electronic attack. The main analysis was for the Governor of Pennasota with the following voting pattern:

Candidate	Party	Total Votes	Percentage of Votes
Tom Jefferson	Dem-Rep	1,769,818	51.1
Johnny Adams	Federalists	1,689,650	48.8

In addition to the overall figures above, the split of the votes amongst the precincts and polling stations and voting machines was produced.

For this publication, see www.votingmatters.org.uk

The next stage of the methodology was to produce a list of potential threats — 120 in all. These 120 were then analysed to identify the most important ones. The key to this part of the analysis was noting how many people would be needed to undertake a successful attack. The main conclusion from this was that threats against individual polling stations would be unlikely to be successful due to the number of stations needed to swing the Pennasota vote — 40,000 votes out of over 3 million.

There are two forms of analysis — one a generic one concerned with the nature of PC-based equipment, the other arising from the most important of the 120 identified threats.

Basing voting machines on PC technology has obvious problems due to the known security issues with both Windows and Linux. It seems that all the equipment considered use either of these two operating systems. Personally, I consider this inappropriate for polling station equipment since it would be difficult to ensure adequate security both at the polling stations and during storage and transport between elections.

Of course, validation and checking is undertaken of voting machine software. However, it seems this is limited to the software written for the purpose, rather than the entire system (which could be very large). This seems to imply that using the operating system to subvert the voting machine software is a credible line of attack. This supports my own contention that polling station machines should be like other embedded software systems — such as the systems used to control the engine of modern cars.

Another generic issue to be faced with all the equipment is the need to customise it for a specific election. For this purpose, ballot definition files are used. Hence an issue to be considered is whether changes to such a file could be undertaken with a view to changing the election result. Here the threat seems less credible.

3.1 Threat analysis

By way of illustration, we take the most credible attack on each of the three systems.

For the **DRE** system, this attack is a Trojan Horse inserted into the operating system. To remain undetected, it would probably have to be activated carefully so that testing prior to the election would not reveal the Trojan Horse, nor would the limited validation undertaken immediately prior to the election. To me, this attack seems very credible which is why I believe such machines should have embedded software and not rely upon a conventional operating system.

For the **DRE w/VVPT** system, a Trojan Horse again seems to be the most credible form of attack. The difference here is that there is a much more complex task since a paper trail needs to be produced as well. Since this paper record can be checked by the voter it probably means that success would depend upon the voter making no such check, which is usually the case. This threat seems much less credible than the previous one.

For the **PCOS** systems, a memory card is used to record the votes, and hence an attack on this is credible, as is the Trojan Horse attack yet again.

As another example of this analysis, consider the system to be used in Scotland for this year's local elections. Here, there are a small number of counting centres to which the ballot boxes are transported. Hence the security problem for **PCOS**-style machines at these centres is much easier to manage than having equipment at each polling station. Moreover, the process of transport and handling ballot boxes is well established. Hence, although an attack is not impossible it seems very much less credible than in the US context.

4 Conclusions

A large number of recommendations arise from the study: for instance, that no use should be made of wireless components due to the potential security threat. A feature of the analysis is the nature of counter-measures that would be effective against specific threats. Here, statistical analysis of results could reveal unusual voting patterns which could indicate an attack, or perhaps faults in equipment.

There is substantial evidence in this report that the validation, checking and counter-measures against a security threat were inadequate in practice. It seems unlikely that all of the detailed recommendations in the report could have been acted upon for the elections in November 2006.

For the position in Scotland using scanning equipment, the key issue would be how many informed participants it would take to perform a successful attack.

For those with any direct responsibility for elections involving electronic equipment, the report should be studied carefully — it is impossible to summarise the 147 pages adequately here — in any case, the key issues will depend upon the type of system being used.

(Further reports have been issued by the Brennan Center on Usability, Access and Cost of voting systems — these are not reviewed here.)

5 References

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Review— Second Report of the Irish Commission on Electronic Voting

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1 Introduction

> . . . the Commission concludes that it can recommend the voting and counting equipment for use at elections in Ireland, subject to further work it has also recommended, but that it is unable to recommend the election management software for such use.

So reads the conclusion of the Irish Commission on Electronic Voting [1].

The government of Ireland chose an electronic voting system for use beginning with the local and European Parliamentary elections of 11 June 2004. Responding to public criticism, the government established the Independent Commission on Electronic Voting and Counting at Elections in March 2004 [2]. In April 2004, the Commission issued an interim report recommending against using the chosen system for the 2004 elections, citing concerns over secrecy, accuracy and testing. The Commission issued its First Report in December 2004, and its Second (and final) Report in July 2006; the Commission was dissolved in September 2006. Except for a limited pilot test in 2002, the system has not been deployed.

In addition to recommending further work on the voting equipment, and replacement of the election management software, the Commission recommended changes to the overall operation of the elections system, including better physical security for the machinery itself, and noted that more testing will be required:

> The testing of the system as a whole carried out to date, as well as the investigation, analysis and independent testing and certification of its individual components, is insufficient to provide a secure basis for the use of the system at elections in Ireland. There is thus a need for comprehensive, independent and rigorous end-to-end testing, verification and certification by a single accredited body of the entire system as proposed for use in Ireland. While the Commission's work has laid the foundations for this process, more work will be required in this area ([1] p8).

The Second Report runs to more than 350 pages, not including much supplementary information available on the Commission's website: public submissions, technical information on the chosen system, and more. An adequate summary of the report is beyond the scope of this review, but the report itself is quite readable; the interested reader would do well to begin with the report's summary and conclusions ([1] Part 7).

This review generally confirms the judgment of the Commission, but, based on additional information, questions the Commission's conclusion that the chosen system can be made acceptable with further work.

2 The chosen system: hardware

The voter sees a series of up to five paper ballots behind transparent plastic. Each paper ballot lists up to 14 candidates, and beside each candidate is a button and a numeric LED display. In an STV election, the voter presses the candidate buttons in order of preference, and the numeric displays reflect the preference order. When all preferences have been entered, the voter presses another button to record the ballot in a removable nonvolatile memory (Ballot Module) installed in the Voting Machine.

A small LCD screen provides feedback and instructions to the voters. A cable connects the Vot-

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ing Machine to a separate control unit, used by the polling station staff to control the Voting Machine and monitor its operation.

After the close of voting, the Ballot Module is physically transferred from the Voting Machine to a Programming and Reading Unit (PRU) connected to a PC that runs software to read the ballot data and transfer it to a CD for consolidation with ballot data from other machines to be counted.

(The PRU is also used before the election to write information to the Ballot Module that the Voting Machine uses to configure itself, including a description of the layout of the paper ballots affixed to the Voting Machine, with the names of the candidates, which are also displayed to the voter on the LCD screen as voting buttons are pressed.)

The CDs containing ballot information are transported to a central facility where they are read, aggregated, and counted ([1] Part 3.2).

3 The chosen system: software

The Voting Machine software, written in ANSI C, runs on the PRU as well as the Voting Machine.

The "Integrated Election Software" (IES) runs on a "hardened" PC running Microsoft Windows 2000. Written in Delphi, Borland's Object Pascal, IES consists of modules for STV counting, election management, and management of the PRU. In addition, IES uses several third-party tools and libraries, including the Microsoft Access database system.

The Voting Machine software comprises some 25,000 lines of code, while IES approaches 100,000 lines, of which some 40,000 lines are devoted to the counting module ([1] Part 3.2).

4 Public comments

The Commission invited submissions from the public, and has published them on its website. Submissions were received from a variety of sources, including private individuals, opposition parties, voting-system advocacy groups, and the Irish Computer Society. Common to most of the submissions is an insistence on a voter-verifiable audit trail (VVAT).

5 Vendor comments

The Second Report includes an extensive response from Nedap NV, the Dutch vendor of the chosen system. Nedap generally takes the position that the chosen system as supplied conforms to their contract, and that it is trustworthy and secure. Nedap argues that a voter-verifiable paper audit trail (VVPAT) is not just unnecessary but actually undesirable, and argues that an open-source voting system (ie, one in which the details of the hardware and software implementations are made public) is undesirable as well.

Nedap cites a paper by Selker and Goler [3] criticizing VVPAT. However, the paper in question actually advocates VVAT but considers VVPAT inferior to alternative approaches to VVAT (Selker advocates a voter-verified audio audit transcript trail (VVAATT) in which the voter verifies an audio transcript of his or her choices; the audio transcript is recorded for use in a possible audit [4]).

Nedap and their Irish branch, Powervote Ireland LTD, assert that the system has already been adequately tested:

> The hardware and software of the VM, PRU and BM were analysed and tested by the accredited German "Physikalisch Technische Bundesanstalt" who is the body that is appointed by German law to analyse and test electronic voting systems before they can be deployed in Germany ([1] p290).

With respect to the Integrated Election Software,

> The Integrated Election Software can be divided into 3 main sections:
>
> 1. Preparation and Administration
> 2. Programming and reading in ballot modules
> 3. The Count
>
> Sections 1 and 2 have been in use in other countries for many years. Millions of votes have been processed and counted without incident or challenge. These 2 crucial sections are therefore very well proven in practice and form part of the Irish version.
>
> Unlike Sections 1 and 2, Section 3 was developed specifically for Ireland. This was subjected to extensive testing by the Department prior to its deployment at the Dáil election and the Nice referendum. IES is a mature and stable design. Adaptations and enhancements are inevitable for each new country. Changes to electoral practices are common and require software which can be

> readily adapted to meet these changing requirements in a very timely way. Each time a change is introduced requires testing to be carried out.
>
> Once testing is completed satisfactorily then that particular build number is not allowed to be changed and is issued for use ([1] p362).

6 "We don't trust voting computers"

Since the Commission's Second Report was issued, the Dutch group "Wij vertrouwen stemcomputers niet" ("We don't trust voting computers") has demonstrated the ability to compromise the Nedap voting equipment used in the Netherlands [5]. In response, the Dutch government has mandated security changes to their voting machines in advance of their November elections [6]. The Dutch voting equipment is essentially similar to Ireland's chosen system, and it's likely that the chosen system has similar vulnerabilities.

7 Comparative assessment against paper voting

The Irish government added to the Commission's tasks a "comparative assessment of the security and accuracy of the current system (ie, the paper-based system) for voting at elections and referenda." ([1] p147). The Commission found that the paper system is "moderately superior overall" to the chosen system as it currently exists, but that if all the concerns of the Commission could be addressed, the chosen system as improved would be superior to the paper system.

Not addressed is the question of whether the potential benefits of the chosen system outweigh its cost of acquisition and ongoing overhead, as well as the less tangible cost of the potential loss of confidence of Ireland's voters in its elections, a consequence suggested by the public comments.

8 VVAT

A voter-verifiable audit trail (VVAT) is intended to provide a means, independent of the integrity of the voting machinery in use, 1) to determine whether the election was accurately recorded and reported and 2) to provide an independent means of recounting the election should the accuracy of the electronic voting machinery be called into question.

A VVAT is typically accomplished by printing a paper record of each voter's ballot in such a way that the voter can verify that the paper record is correct, while not permitting the voter to retain a copy (which would be contrary to the secrecy requirement). The paper record is then used to spot-check the electronic results and, if necessary, to serve as the basis of a recount.

Implementation of an effective VVPAT is nontrivial, requiring among other things that an adequate proportion of voters actually check the paper record in detail, so that discrepancies are detected, and that a statistically adequate sample of paper ballots be counted to have good assurance that the electronic count is correct. Selker [4] advocates a "voter-verifiable audio audit transcript trail" (VVAATT) instead of a paper trail, but this approach has drawbacks of its own, being more difficult to audit.

9 NIST Discussion Draft

In 2002, US federal legislation [7] effectively mandated electronic voting equipment as a means of correcting election-systems deficiencies that came to light in the 2000 US presidential election, as well as of allowing more disabled voters to vote without assistance. The law charged the National Institute of Standards and Technology (NIST) with assisting in the development of technical guidelines for voting systems. In November 2006, NIST issued a draft document concerned with the upcoming 2007 update of the US federal guidelines. The NIST draft is unequivocal in its opinion of electronic voting systems without independent audit trails.

One conclusion drawn by NIST is that the lack of an independent audit capability in DRE [direct record electronic] voting systems is one of the main reasons behind continued questions about voting system security and diminished public confidence in elections. NIST does not know how to write testable requirements to make DREs secure, and NIST's recommendation . . . is that the DRE in practical terms cannot be made secure [8].

One of the central themes in the debate over voting system approaches such as the DRE is whether the level of certainty in the DRE is still adequate to ensure that the records have been recorded correctly. . . . Trust in an election outcome relies heavily upon trusting the correctness of the DRE's software and upon trusting that the DRE software has not been replaced nor tampered with. But, assuring software correctness and security is very difficult and expensive, and techniques for doing this are still an open

research topic. . . . Simply put, the DRE architecture's inability to provide for independent audits of its electronic records makes it a poor choice for an environment in which detecting errors and fraud is important ([8] p7).

Are there ways to improve DREs so that they can be made secure and fully auditable? NIST and the STS do not know how to write testable requirements to satisfy that the software in a DRE is correct. The use of COTS [commercial off-the-shelf] software in DREs causes additional problems; having, for example, a large opaque COTS operating system to evaluate in addition to the voting system software is not feasible ([8] p9).

(In the context of the chosen system, "COTS" includes Microsoft Windows, the Microsoft Access database system, and the Borland Delphi software development environment.)

According to the NIST, 35 of 50 US states use voter-verifiable paper records entirely, and another 10 states use them on a county-by-county basis. Only five states now use DRE with no paper trail statewide.

10 Commentary

My own background is in the design and manufacture of computer systems, and I find the Commission's conclusions on hardware and software quality all too plausible, though the proprietary nature of the chosen system's software makes it impossible for me to independently verify the Commission's conclusions.

The Commission suggests that the defects of the chosen system could be remedied, in part by completely rewriting the IES election management and counting software. It seems likely that the Commission, had its remit included a determination of best practices, would have seriously considered a requirement for a VVAT of some kind.

The Irish government's selection of an electronic voting system of any kind was in retrospect premature. Such systems have received much attention recently, especially in the US, and the technology is in flux. In any case, the Commission's comparison of the chosen system with paper ballots does not make a compelling case for a change to electronic voting.

One of the difficulties in completely auditing the chosen system lies in being able to guarantee that the software running in binary form on each voting machine, as well as the IES systems, corresponds exactly to the software examined in source form by the auditors. It must be possible for a signed and certified copy of the original source code to be compiled independently into a signed and certified binary copy of the code, and in turn to be able to guarantee that the software running on the voting systems is in fact a faithful copy of the certified binary. This is complicated by the fact that the IES is critically dependent on third-party software such as Microsoft Windows and the Microsoft Access database system, as well as the Borland Delphi software development environment, none of which has been independently audited.

While some of these difficulties can be mitigated, and others entirely corrected, it is impractical, if not impossible, to be able to guarantee that any electronic voting system is completely trustworthy and, as important, is seen to be trustworthy. The fact that a company with the resources of Microsoft has not been able to guarantee the security of its own web browser (let alone the entire Windows operating system) despite years of effort and large incentives, suggests that a fully secure and trustworthy electronic voting system may be an unattainable goal, especially given the complexity of the overall system and the incentives for subverting it, making an effective independent VVAT mandatory.

11 Options

The Irish government is left with several options for moving forward.

Adopt the Commission's recommendations. Improve the voting machine and its software, improve procedures during and between elections, and replace the IES with alternative software that can meet the Commission's standards.

Adopt the Commission's recommendations as above, but require the vendor to provide a voter-verifiable audit trail (VVAT), and adopt appropriate procedures for taking advantage of the VVAT.

Abandon the chosen system, begin a process to define new criteria for a voting system, and then identify and acquire such a system.

Abandon the chosen system and continue to use the existing paper-based system, perhaps with procedural improvements, leaving open the option of considering an electronic voting system at some future time.

The Sunday Business Post (Dublin) reports that the government is leaning toward option 1, estimating the cost of complying with the Commission's recommendations to be approximately €500K, compared with a sunk cost of some €60M. The €500K figure is disputed, however, and regard-

less of the cost of option 1, the cost of option 2 would be substantially higher [9].

My advice? Choose option 4, and establish a new commission that would, with public participation, recommend improvements to the present paper-ballot system, monitor the experience and (dis)satisfaction of other users of electronic voting systems, and develop criteria for the eventual selection of a system for Ireland. The world of electronic voting is evolving rapidly, and Ireland is in a fine position to take advantage of the experience (including the bad experience) of others before taking such an important step.

12 References

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Review— *Collective Decisions and Voting* by Nicolaus Tideman

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This is a very worthwhile book containing a wealth of useful information.

I have seen it said that, when making a speech, it should be divided into three parts: (1) tell them what you are going to tell them; (2) tell it to them; (3) tell them what you have told them. This book certainly follows that plan, not only overall but also within each chapter. It is divided into two parts — Collective Decisions, chapters 1 to 6, and Voting, chapters 7 to 16, before a short summing up in chapter 17. I feel that chapter 16 should really be included in part 1, rather than part 2. Chapters 1 to 6 and 16 are really more suitable for review in economics journals rather than in *Voting matters*, and I shall therefore concentrate here on chapters 7 to 15.

The book seems a little unbalanced in the degree of mathematical knowledge expected of the reader, who is expected to cope happily with $\int$, with ! (in its mathematical usage), with *ln*, with *iff*, etc., so it is surprising that $\prod$ and $\sum$, as multiplying and adding operators, apparently need explaining. Certainly anyone who struggles with mathematical notation will have to skip some parts but could still gain a lot from reading the surrounding plain text; it is unfortunate that those struggling to understand the notation will run into some misprints, that will make their understanding harder because they may not recognise them as being misprints but suspect that the fault is theirs.

I also found it unbalanced in having an 80 page chapter discussing various rules for electing to a single seat, yet only a 26 page chapter for the multi-seat case, which surely deserved more than that.

There are detailed discussions and proofs of how voting cycles can arise, of Arrow's theorem, and of the Gibbard-Satterthwaite theorem. It is useful to have these together for reference. Even those who do not wish to go into the detail of the proofs will gain knowledge of the facts that it is impossible to have a voting system without unsatisfactory features, and impossible to have one that is immune to strategic voting. Personally I find it a pity that Woodall's theorem [1] is not also given a place. I have found Woodall rather than Arrow to be the more convincing, both to myself and to explain to others. However part of this preference is because Arrow deals with trying to form an overall ranking of options whereas Woodall is more specifically about dividing candidates into those elected and those not elected. The book does deal with that point, giving a variation of Arrow's theorem to deal with it.

I also regret that there is no mention, to go with Gibbard-Satterthwaite, of the work of Bartholdi and Orlin [2] who show theoretically that STV is remarkably strategy-proof. This is certainly known in practice by those who vote using it for multi-seat elections. Careful study of the votes after the event may sometimes show where strategic voting could have succeeded, but to know what to do, other than vote honestly, at the time of voting, is virtually impossible.

There is discussion of properties used to evaluate the various proposed methods, under the headings of Domain, Consistency, Responsiveness, Stability and Qualitative Attractiveness: 18 different properties altogether. It would help in reading the book if short definitions of these properties were available on a separate card that could be kept handy. Then those who, for example, do not know their Smith consistency from their Schwartz consistency, or who wish to be reminded of exactly what is implied in this context by Homogeneity, would find things easier. I felt this in particular when finding a mention of non-negative responsiveness. Looking in the index it was not there, so where is it to be found? I found positive responsiveness and had to make the obvious guess from that.

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Many of the particular methods discussed for a single seat elect the dominant option (often called the Condorcet winner) if there is one, while the differences between those methods apply only when seeking to sort out whom to elect when, because of cycles, there is no dominant option. It is a pity that the casual reader might not realise that, in real elections, there usually is a dominant option, and much of the detail of what to do when there is not is then irrelevant. I have too often seen Condorcet voting dismissed as a useful method because this fact is not understood.

Among the methods discussed there is no mention of Supplementary Vote, as now used in Britain to elect town mayors. Perhaps it is thought too silly to deserve serious discussion by adults. If so I agree, but it would be worth just a sentence or two to say so.

Another reference that I should have liked to see is to Moulin's devastating work [3], showing that any system that elects the dominant option if there is one cannot also guarantee that turning out to vote at all is going to be helpful. It is unlikely in practice that abstaining could be better, but the fact that it is theoretically possible is worrying.

In evaluating the methods the author uses both technical considerations and, where preferences are used, a practical look at the voting patterns in a collection of real elections, mostly from the ERS, conducted by STV. In particular he uses these to evaluate the frequency of cycles. It is recognised that to take multi-seat elections and use the data as if for a single seat may not always be realistic. He is wrong in saying that in these elections voters are asked to rank all candidates. It is standard doctrine within ERS that voters should have total freedom to rank as many or as few as they wish.

At the end of the long chapter on single-seat methods, there are 5 pages headed "Summary". This is surely the wrong heading; a summary should refer briefly to what the chapter has already said, not introduce new material. Yet here we find the author's recommendations on the comparative value of the methods. These do not seem to me to concentrate enough on what I believe to be the main point to consider — namely whether one wishes to preserve a promise to voters that putting in later preferences cannot upset the chances of their earlier preferences, or whether one is willing to forego that promise so as to avoid the problems caused by successive eliminations. In the first case it is doubtful whether anything better than Alternative Vote is available; in the second case it makes sense to go for electing the dominant option if there is one, while what to do in the event of a cycle for top place, while it must be decided, is really a secondary matter as such cycles are rare.

The evaluations are mainly in objective terms of whether or not a method possesses each particular property, but for the properties contained in the Qualitative Attractiveness category the evaluations are necessarily subjective and it is easy to disagree with some of them. It is always difficult to find names for such features that will not be misunderstood but, for example, under "ease of use" the author appears to be considering only the relative difficulty of marking a cross against one candidate compared with recording a preference ranking against all candidates, and not to take into account the different degree of strategic thinking that may be needed for properly thought-out votes. Surely that is also a considerable part of ease of use.

Turning to multi-seat elections the author is wrong in saying that "European systems of proportional representation of the party-list type all have added features to give voters some voice in the selection of representatives within parties". British voters in European Parliament elections are not given any such voice.

The main discussion in this section is of STV, mostly well done, but I find the eventual preference for Warren counting rather than Meek counting surprising. Taking the example given, carefully devised so that Newland & Britton, Warren and Meek give three different answers, there are 5 candidates (R, S, T, U, V) for 3 seats. Meek elects R, S, T where Warren elects R, S, U. It is clear from this that, in this case, V is just a nuisance candidate and a useful comparison can be made by treating V as withdrawn [4]. If that is done Warren switches to the Meek result. Furthermore using the author's own CPO-STV method, he finds that the Meek result is the dominant outcome. These facts are not in themselves conclusive because they relate to only one example and it may well be possible to find another example that does the opposite. But I suggest that they are enough to call for further thinking from the author. His view seems to be only that "the Warren variation ... accords with my conception of fairness" rather than any detailed technical analysis. Fairness is a difficult concept and my own view of it points strongly in the reverse direction.

In considering the problems caused by eliminations he includes a mention of a suggestion that I made nearly 20 years ago and regards it as "too *ad hoc* to be satisfying". So do I. But he ignores the fact that it was a very tentative suggestion that was subsequently developed to become Sequential STV

[5]. I should love to see his views on that, even if unfavourable, but it gets no mention.

In considering the refinement-comprehensibility trade-off, he appears to think that more refinement always leads to less comprehensibility. When merely tinkering with rules in minor ways, this is usually correct, but when a major rethink occurs, such as the move from methods designed for hand-counting to the Meek method, I do not believe it to be true at all. Meek is not only more refined but also far more comprehensible. Those who promote hand-counting methods, and claim them to be easy to understand, usually pass over the messy details in their descriptions of them. He also claims that the Meek rules are faster, which is not so in my experience, but it is in any case unimportant. Compared with the time, trouble and expense of conducting an election, what are a few extra seconds in calculating the result?

In the end he favours a hybrid system of allowing STV preferences only for a maximum of perhaps 10 or 12 candidates, followed by a party-list for the rest. I think that this is very inferior to STV throughout and, to echo back his own words, is too *ad hoc* to be satisfying.

On the whole the book is well set out and easily readable, but I do dislike the modern custom of putting footnotes at the end of the chapter, where they have to be searched for, rather than in their proper footnote place.

But for all my criticisms, I should like to end by repeating my first sentence and say again that this is a very worthwhile book containing a wealth of useful information.

1 References

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