IEVS: Computer simulation and comparison of different election methods

June 3, 2007

submitted in response to the solicitation, "Make Voting Work, Requests for Proposals: New Diagnostics and New Solutions," The PEW Charitable Trusts

Principal Investigator (PI) and Primary Contact
Dr. Warren D. Smith
Center for Range Voting
21 Shore Oaks Drive Stony Brook NY 11790 USA
phone 631-675-6128, email (best contact method): warren.wds@gmail.com

Summary Information
Proposed Period of Grant: September 1, 2007–August 31, 2008
Total Funds Requested: $50,000 to $125,000
Nonprofit status: the center for Range Voting has not yet acquired IRS status as a nonprofit. However, if that is a problem (and if you can't just fund me, Warren Smith, directly) I point out that (a) we may be able to get nonprofit status by the time of the grant and (b) there are other voting reform/research groups that *do* have nonprofit status that are likely to agree to serve as an "umbrella" organization to accept the funds and disburse them to me, for this purpose. (In fact, at least one has been considering merging with the Center for Range Voting.) If this is a problem, please let me know ASAP and indicate which course you want me to pursue.

Keywords: Computer simulation of elections, Bayesian Regret, election methods research.

Primary Team Members
Just me, (Dr.) Warren D. Smith (PI)

IEVS: Computer simulation and comparison of different election methods

Warren D. Smith
Center for Range Voting
warren.wds@gmail.com, http://RangeVoting.org

June 5, 2007

Abstract

Many single-winner election methods have been proposed besides the kind, called "plurality voting," most-used in the USA. The most well known are Approval Voting, Instant Runoff, Range Voting, Borda, and Condorcet methods.

This proposal is to fund me to continue to build IEVS (Infinitely Extendible Election Simulator), a public-source program currently downloadable from the http://RangeVoting.org website. IEVS quantitatively compares different election methods using the objective "Bayesian Regret" methodology. It is already by far the best election simulator in the world – e.g. the only one that simultaneously is public source, has by far the most election methods, the most voter strategies, the most utility generators, the only one with graphical output capability, etc.

The benefits to humanity of understanding the Bayesian regret of election methods are large. Specifically, IEVS shows that simply replacing Plurality by Range Voting would yield a comparable improvement to humanity's lot, as was caused by the invention of democracy (e.g. switching from Random Winner to Plurality) in the first place. To put a rough number on it, about 5500 lives are unnecessarily lost for each *day* that goes by without adopting Range Voting. The benefit of this reform is huge and the cost is tiny. So it is worth funding this investigation..

Contents

1 Introduction

In "plurality voting," each voter names one candidate, and the most-named candidate wins. It was recognized even at the dawn of democracy around the French and American revolutions (by Borda, Condorcet, Jefferson) that plurality had significant flaws as a collective decision-making process.

For example (and I will often give URLs of subpages of the `http://RangeVoting.org` website to save space here – might as well take advantage of the work that went into building that site – you can access them from any web browser), the plurality system can easily elect the candidate regarded as *worst* by a *large supermajority* of the voters, see `http://RangeVoting.org/LoseAll.html` for a numerical example. This is not a matter of election fraud or mistakes. This can easily happen even with 100% honest voting and counting. It is a matter of the poor mathematical properties of the plurality voting procedure. Some other well known and quite common problems include

1. "vote splitting" and "candidate cloning," where the very popularity of a view can with plurality voting actually cause its defeat;

2. the "spoiler" and "wasted vote" effects, where voters are incentivized *not* to vote for their true favorite candidate because that is strategically unwise (offering you the choice between being a liar and being a fool);[1]

3. The consequent ("Duverger's law") build up of 2-party domination (or sometimes even one-party domination) causing voters to only have two (or one, i.e. no) choices, the minimum possible number, so that democracy works least well;

4. The lack of expressivity plurality voters have – "just name one candidate, then shut up" is the *least* they could say, rather defeating the purpose of voting as an information-gathering mechanism.

In view of this, many other voting procedures have been proposed. The ones that are most well known include

1. Approval Voting: voters name the *set* of candidates they "approve." Most-approved wins.

2. Borda Voting: voters rank candidates in preference order. A candidate gains $N - K$ points for being ranked Kth by a voter. The one with the greatest point-total wins.

3. Condorcet Systems: voters rank candidates in preference order. If a candidate exists who is majority-preferred pairwise over every possible opponent, then he wins. (If no such candidate exists, then something else must be done; different Condorcet methods differ about what.)

4. Range Voting: Each voter *rates* every candidate on a fixed numerical scale (say 0 to 99, for two-digit range voting). E.g. a valid vote might be "Jefferson=99, Truman=45, Harding=0, Nader=45." Greatest average score wins. One can also permit voters to express "no opinion" about certain candidates, in which case those candidates's average scores are unaffected.

But these are only the tip of the iceberg. Hundreds of voting procedures have been proposed, especially on internet forums devoted to the subject. Some were proposed by political scientists 85 years ago, others by hobbyists yesterday. The latter proposals, while less known, are by no means necessarily worse than the former. There are ways to combine different voting methods to make "hybrids," raising the count immensely further.

[1] For example, that was how Nader supporters in the 2000 US Presidential election felt, and indeed NES survey data showed about 90% of honestly Nader-top voters in fact voted for somebody else.

There are a tremendous number of subtleties, myths, and logical traps in this subject. Our proposal is to bypass them via computer simulation attack. We would also like to write a book. Both the computer simulator, and the book, are already well under way.

2 Research Questions

The most obvious question is "which of these voting methods is the best?" Which then causes us to ask "what does the word 'best' even mean?" and "can we make a quantitative, not merely qualitative, comparison?"

2.1 Previous Work

There have been two main approaches. The first approach, started in the 1950s by Nobelist Kenneth Arrow, was the **properties-based approach**. One makes a list of desirable-sounding logical properties that voting systems might or might not exhibit. One then tries to classify which voting systems obey which properties.

However, Arrow found, to his dismay, that *every* voting system had to disobey at least one of a list of three simple desirable-sounding properties. ("Arrow's impossibility theorem" `http://RangeVoting.org/ArrowThm.html`.) This has often been regarded as "a proof that *no* 'best' voting system can exist." Due to Arrow being awarded a Nobel, a myth arose that Arrow had killed the subject and unfortunately a lot of people heard only this and failed to look deeper. In my opinion that had a negative effect. Let's look a bit deeper right now.

1. Unfortunately, in order to prove his theorem, Arrow adopted a somewhat restrictive definition of "voting system," under which range voting is "not" a voting system. In fact, Range Voting actually *does* obey the precise wordings of all three of Arrow's "incompatible" conditions stated in `http://RangeVoting.org/ArrowThm.html` (and those precise wordings were stated, not by me, but in a tutorial on the topic by Prof. William R. Webb[2]).

2. It was recently realized [7] by re-analysing known observations by entomologists, that range voting is actually the method employed by honeybees to make collective decisions. Over the last 20 million years, honeybees have actually carried out far more elections than humans, and also far more than even a computer can simulate (at least current computer technology at reasonable cost).

But due to the fact that honeybees have never been awarded a Nobel prize, this unfortunately is not very well known.

3. It is my contention that the entire properties-based approach, while educational and useful for increasing our understanding, is a *poor* way to measure the goodness of voting systems. Why?

1. Deciding "how important" each property is, is subjective. If two properties conflict, and I like property A but you like property B, then we can easily enter an eternal argument.

2. Just because a voting method violates a property in *some* situations (which counts as a logical "failure" of that property), means little if those violations only happen in one election in 10^{20}. The Arrow logical-property-list approach is completely blind to degree of rarity.

3. When a property violation happens, it can cause a *far* worse election result, or only worsen it by a tiny amount. The logical-property-list approach is completely blind to degree of severity.

[2]There actually are various possible wordings, which are equivalent on the class of voting systems Arrow allowed, but inequivalent when we allow more general voting systems such as range voting. This is one example of a tricky subtlety. With Webb's wording, range voting "accomplishes the impossible" by satisfying all three Arrow conditions. With some other wordings it does not.

What we want is a *quantitative* and *objective* assessment. Which brings us to the...

Bayesian Regret approach. The realization that Bayesian regret could be used to objectively compare single-winner voting systems, was made by several people including Merrill [5], Bordley [2] and then myself later.

In one sense, Bayesian regret automatically measures every possible property failure a voting method could exhibit (including for properties no human has yet conceived of) weighting each one correctly by its severity and its probability of occurrence.

But that, of course, is not the best way to view it from the standpoint of actually performing a Bayesian regret measurement. For a layperson's introduction to the Bayesian Regret technique, please see `http://RangeVoting.org/BayRegDum.html`.

In a nutshell, we perform computer simulations of elections using different voting methods with artificial "voters" and "candidates." Different "utility generators" can be used to cause each voter to have different opinions about the goodness of each candidate. Voters can vote "honestly" or "strategically" with different strategies. Voters can act based on utility-information polluted by variable amounts of "ignorance." If voting method V elects candidate C, but the "best" candidate (based on all the exact values of the candidates's utilities for each voter) is B, then that causes "regret" which is the difference between B and C's summed-over-voters utilities. By simulating enough elections, we can measure the regret value of V to any desired accuracy.

I first did this in 1999-2000. My computer simulations at that time [6] were the first ever to allow "strategic" voters, and the first ever to allow voter "ignorance," and the first to make the simulation program available for public download. They also were far more extensive than any previous simulations, both in terms of number of elections simulated, and the number of different kinds of election methods and utility generators and probabilistic models that were tried. In particular, they were the first to include "Range Voting" [4] as a contender.

Much to my surprise (since range voting was at the time not mentioned in any political science book, although heavily used in e.g. Academia to select valedictorians, and the Olympics to select gold medalists in judged events) range voting came out superior to every other voting method simulated by the Bayesian regret yardstick. This superiority was extremely robust against changes in simulation assumptions. No previous simulation had ever found robust superiority for any voting method, not surprisingly since no previous one included range voting as a contender.

Bayesian Regret, being quantitative, can be converted roughly to tangible units such as "money" and "lives wasted." One also can just ask (without any attempt to convert units) how much humanity's lot would improve by switching to range voting, versus how much it improved by inventing democracy (we can estimate the latter as the Bayesian regret reduction got by switching from "random winner" to "plurality winner" – this is a valid upper estimation under the assumption the pre-democratic rulers were comparable or better for society than random ones would have been[3]).

When you do this, the results are very impressive. It appears range voting is comparable in objective importance to the invention of democracy, and worth roughly 5500 lives per day. For one such estimate, see `http://RangeVoting.org/LivesSaved.html`, for another see `http://RangeVoting.org/BaileyNum.html`, and/or make your own estimates or consider the discussion of Barro's estimates here `http://RangeVoting.org/MDLecture.html#Barro`.

Obviously, such estimates necessarily are less reliable, than, say, a physicist measuring a frequency, but we only need crude "order of magnitude" estimates, which can and have been done by

[3]Monarchs were trained from birth to rule. So they probably were superior to random candidates on average. If so, then that makes the argument for range voting's value "more true." On the other hand, some critics have suggested that perhaps monarchs were *worse* for society than random candidates. That would weaken the case for range voting.

many different methods, to see how immense the potential is. The benefit is immense and the cost (of switching to range voting) very tiny. So in terms of "bang per buck," this is one of the most profound possible improvements for humanity. But it is little known.

That (little-knowness) is partially my fault. I am trying to raise the level of world knowledge but am poor at it. For example, one recent reviewer rejected one of my papers with the comment that claims like my above remarks about Arrow's theorem and 5500 lives per day, were outrageous, or at least needed to be backed up with extraordinary evidence. However, this reviewer apparently did not bother to go to the URLs I have given above where these claims actually *are* backed up. He felt, apparently, that my paper had to discuss them in depth (which would have taken perhaps 6 pages) even though that paper was not directly about them and had a 10-page length limit. That, however, presumably also would have been unacceptable. Another paper I wrote [7] about voting and honeybees, was rejected by *NATURE* as "unsuitable." Political scientists note that I do not have a degree in political science. (I have a PhD in Applied Math.) And so on. The point I am trying to make here is there are considerable weird forces that make publication difficult for me. Further, publication in the scientific paper literature is in any case largely irrelevant to political reform. Internet sites get far more readership and can supply more evidence than publication constraints permit in any journal paper.

Now after I discovered (in 1999-2000) the immense benefits of range voting as measured by Bayesian Regret, I was discouraged by all from pursuing it because "there's no way to get this to happen in real life." Unfortunately, at the time I believed that discouragement. But over the next 7 years, other developments happened:

1. Colorado engineer and voting reform activist Jan Kok pointed out the (non-obvious) fact that range and approval voting will work on every voting machine in the USA, computerized or not, without any modification or reprogramming, right now. That makes it more-painlessly adoptable than one might naively think. `http://RangeVoting.org/VMSumm.html`.

2. Most voting-methods reforms are politically unachievable because the politicians in power all are motivated to stay with whatever system elected them. That is why, e.g, the USA still has not eliminated gerrymandering, even after almost 200 years of worldwide universal recognition that it is a bad thing. *But* for the purpose of US Democratic and Republican presidential *primaries*, the ones who can decide to implement range voting actually *are* motivated to do so. (And the USA's *third* parties are even *more* motivated to get range voting.) That, it seemed to me, makes reform possible. It is merely a matter of education.

3. People, including myself, made interesting analyses of the old-style property approach vis a vis range voting. For example, a theorem I recently proved (and mathematician and voting activist Forest Simmons also proved a similar theorem soon after; see [8] and `http://RangeVoting.org/SimmonsSmithPf.html` for this and other modern impossibility theorems) is that *no* nontrivial rank-order voting method – the only kind considered by Arrow – can simultaneously satisfy these four criteria:

AFB = avoids favorite betrayal = voters never have strategic motivation to vote their true favorite choice below maximum

ICC = immune to candidate cloning = if "clones" of a candidate are added to or removed from to the election, that does not affect the winner (except perhaps up to replacement by a clone).

No vetoer = There does not exist a voter who can single-handedly prevent a candidate of her choice from winning, regardless of how the other voters vote.

Neutrality = symmetry under candidate renaming = permuting the candidate names on the ballot rankings permutes their winning probabilities in the same way.

But range voting satisfies them all. That theorem provides a sense in which range voting is superior to *every* rank-order voting system, even those nobody has yet invented. Also it was shown

that range voting exhibits certain optimality properties in the presence of strategic voters, see `http://RangeVoting.org/AppCW.html` and `http://RangeVoting.org/PleasantSurprise.html`.
4. Exit poll studies were carried out about range voting for real voters both in the USA (by a team that included me) [9] and recently in France [1]. These demonstrated some impressive and sometimes unexpected effects. For example, range voting, in all experimental studies I know of so far, actually exhibits *fewer* invalid "spoiled ballots" than plurality and (especially) rank-order ballot systems, despite the naive perception range voting is "more complicated." (And this finding is highly statistically significant.) For another example, range voting yields comparatively enormous (compared to now with plurality) vote totals for "third party" candidates. In 2004, Nader would have gotten about half of Kerry and Bush's (approximately equal) vote totals, had range voting been used. With plurality, Nader and all third-party candidates *combined* got below 1%! That's just one illustation of the immense distortion of democracy plurality voting causes. In France 2007, Bayrou would have won with range voting, but lost big with the official system. See `http://RangeVoting.org/FunnyElections.html` for the world's largest collection of historical national-level examples.
5. Human range voters are found to be much more "honest" and less "strategic" than human plurality voters. ($\approx 75\%$ of human range voters cast manifestly not-optimally-strategic votes.)
6. Interesting analyses were made of "secondary effects" such as Duverger's law of 2-party domination. It appears range voting probably will not lead to (and will gradually permit elimination of) 2-party domination.
7. Independent follow-up computer simulation studies were made both by me and by others. None of these were as ambitious as my original 1999-2000 study, but all of them continued to reach the same conclusion of range voting's superiority versus all the usual alternative voting-method proposals found in political science books.
8. The internet arose and made large scale education and communication possible cheaply.

All these factors made Jan Kok and I believe that range voting might be an achievable dream. We founded the *Center for Range Voting* in 2005 to do education, research, and hopefully lobbying on the subject.

2.2 Questions to be addressed

My 1999-2000 range voting study and the Center for Range Voting have attracted a fair amount of attention, feedback, and criticism.[4] Some of that criticism is justified.[5]

Essentially, the problems with the 1999-2000 study are:

1. Even though that study tried more voting methods than any other, that wasn't enough. Generally, the critic will say "but you haven't tried *my* voting method!"

2. Even though that study investigated more voter-strategies and utility & probability models than any other, that wasn't enough.

3. Even though the program's source code was made public, it wasn't nice enough and well-designed enough to make it easily expandible enough by other investigators, and it now is known to have contained at least two bugs (which didn't matter much, but they were there).

[4] `http://RangeVoting.org` gets about 200 unique new site visitors per day, which probably exceeds the amount of attention paid to almost all papers in the scientific literature, especially the voting-methods political science literature.

[5] On the other hand, some of it is unjustified and based on mythology, e.g. the entirely false perception I ignored strategic voters as opposed to designing them in from the start, or the false perception I designed IEVS to artificially favor range voting because I am a biased range voting proponent, whereas in fact I became a range voting proponent *after* rather than before doing that study, and the robust superiority of range voting came as a surprise.

All these criticisms are valid. Furthermore, the first two criticisms *always* will be valid!

I have come to recognize that the simulator program needs to be perpetually available and perpetually improving, because there will always be new voting methods and new issues raised by critics to worry about, and the simulator needs to be able to look at them.

For that reason, I wrote in 2006-7 a new simulator called IEVS (Infinitely Extendible Election Simulator), and made it publicly available for source download at this URL:
`http://RangeVoting.org/IEVS/IEVS.c`.

So far, IEVS contains about 70 voting methods, some of which had never been implemented before (e.g. Woodall DAC [10]). It is by far the most extensive and available voting simulator in the world; there is no competitor that even comes close. Furthermore it has been redesigned and rewritten entirely.

It works, it runs, and it produces interesting results. In particular, it has found some new voting methods are superior in terms of Bayesian Regret to the old champion, range voting.[6] However, IEVS still has a long way to go. IEVS's main deficiencies are the following.

1. Needs better documentation to make it realize its design potential as an easy-for-all-to-modify program.

2. Needs wider recognition and publication.

3. No serious voting simulator yet written (including the current version of IEVS) permits rank order voting methods with rank *equalities*. That is a very large class of voting methods. Many investigators on the `Electorama`[7] voting-methods internet forum (who, by the way, are far ahead of the political science paper literature on this issue) have convincingly argued that this is an extremely important class of voting methods, especially when it comes to getting better behavior in the presence of strategic voters.

4. More kinds of voter strategic behaviors need to be permitted.

The research proposal is simple, therefore: you pay to support my efforts to further develop, document, and publicize IEVS and its findings. Most of IEVS work so far has been unfunded.

3 Approach

3.1 System Architecture

IEVS's main new design insight is that if you have A election methods, B utility models, C voter strategies, and D ignorance models, then the bad way to design the program takes programming work of order $A \times B \times C \times D$. Meanwhile the good way to write the program takes $A + B + C + D$.

If I may make an analogy, the same insight was reached by Richard Stallman and the other designers of the (then revolutionary) public domain software compiler `gcc`. They saw that if you want to make compilers that translate L human-compatible computer languages (C, BASIC, FORTRAN, PASCAL, ADA etc.) into machine code for M different machines (Intel, Motorola, IBM, DEC etc.) then that requires programming work $L \times M$, *but* they could (and did) design it to require only work of order $L + M$. They did this by translating the human-compatible languages into "gnu intermediate language" (L different translators) and "gnu intermediate language" into

[6] However, because range voting seems not much worse, and has simplicity and adoptability advantages over, these other methods, I still currently prefer range voting for most uses.

[7] `http://wiki.electorama.com/wiki/Main_Page`

the machine languages (M different translators). Furthermore, anybody can add new languages and new machines to the gnu world – this design is easily expandible.

It's an economy of scale, and it pays off big when A, B, C, D, L, M get to be big numbers.

3.2 OS support

IEVS was written in ANSI C, a very well known and widely available language. It was originally developed under the LINUX operating system (OS), and Apple's OS-X system; but Oklahoma voting activist, electrical engineer, and programmer David W. Cary kindly "ported" the code so that it now also runs under Microsoft Windows. Those are the top 3 most common OSs.

3.3 Graphics support

Ka-Ping Yee, a grad student at Berkeley, invented a very nice way to use computer power to produce computer graphics which enable you to see at a single glance the results of 40000 elections and gain some very rapid and interesting insights. IEVS currently offers full support for Yee-type graphics. To see and understand such graphics (a large set of pretty pictures output by IEVS, with some accompanying verbiage), please point your browser to `http://RangeVoting.org/IEVS/Pictures.html`.

3.4 Reality-based utilities

Dr. Nicolaus Tideman emphasized to me the important point that he thought such simulations as IEVS's ought to be based on real human behavior.

IEVS currently can access a database of real-world human elections conducted with advanced voting methods. The dataset currently contains about 95 elections, most of which were kindly contributed by Dr. Tideman; see `http://RangeVoting.org/TidemanData.html`. We can expand this dataset. [I in fact have a backlog of contributions that have not yet been converted to sane data formats.] Probably it then will reach about 120 elections.

IEVS currently has a "reality-based utility" generator which is based on this data, making it the only Bayesian Regret program in the world to do so. At least so far, though, it appears that reality-based and artificial utilities do not lead to any major differences in results. But this was an important finding.

3.5 Web support

IEVS also has an experimental interface to the world wide web permitting anybody to use IEVS instantly to tabulate the result of any small election (that they type in) by all the voting methods IEVS knows about. You can try it at `http://RangeVoting.org/VoteCalc.html` although you are warned that there currently are bugs in this.

3.6 Documentation

I need to write a nice user guide. Currently it is documented only with extensive comments in the code, and written with readers in mind. That is good, but not good enough.

More generally, I would like to publish a book about "mathematics and democracy" discussing all of what I have here above, IEVS's findings, as well as many other topics. I in fact have written about 80% of such a book already. Your support would help.

3.7 Location

Program development can happen anywhere on the internet, it doesn't matter where. I currently live in New York and the `http://RangeVoting.org/` web server is in Pittsburgh PA, but if either or both change, it won't matter.

4 Work Plan / Timeline for major tasks

The "timeline" is simplicity itself: Development of IEVS will be ongoing perpetually as far as the eye can see; it is just that a lot more of it will happen sooner if you fund me.

You don't have to worry that it might not work, or I might not be good enough for the job – it already does work and and is the best available voting simulator in the world.

Furthermore, I can hire people if funded. More precisely, what I have in mind (it'll have to be tried to see how well it works, and this can only happen *after* writing better documentation) is to offer, say, $100 per voting method that somebody programs and adds to IEVS.

Right now, I get a lot of criticism by email and on internet forums (incidentally `http://RangeVoting.org/` has its own forum) saying "you should add *my* voting method to IEVS!" But I currently just don't have the time and funding to handle all those requests. That's a pity because IEVS makes it clear that professional political scientists have little or no advantage over hobbyists in designing voting methods with good Bayesian Regret scores, and there are plenty of intuitively appealing voting method ideas out there which both work and do not work well. It'd be nice if I could come back at them and say "why don't *you* add it to IEVS yourself, here's examples and documentation showing how to do it, and I'm willing to pay you $XXX to do it."

That will probably get some action, and it'd also have the public benefit of getting a lot more people thinking and acting about this.

If you want some concrete timespans, I believe I could get good documentation done in 1 month, and get rank-equalities (and a lot of voting methods involving them) working within a few more months.

As far as me writing and publishing the Mathematics and Democracy book is concerned, the timing on that could be highly adjusted depending on what publication route we take and how much funding you would be interested in giving for that purpose. I'm amenable. The book is over 80% done right now (I estimate). It got favorable reviews from Cambridge University Press, but not a publication contract. The difficulty is that as a mixture of math, computer work, history, political science, and psychology, it is not easily pigeonholed into an academic market category, and many readers in these categories react in a somewhat peculiar way when confronted with the others. What should be done about that, is not clear. One course I'm considering is publishing it myself on `www.lulu.com` as print-on-demand publishing. This has the advantage that the book (usually) is cheaper, it can be continually updated, and many delays inherent in old-style book publication are eliminated. I actually think this is the wave of the future in most academic publishing aside from high-volume textbooks.

(If any reviewer wants to see my book-draft, please contact me.)

I believe the entire book as it stands could be rewritten as necessary and completed for publication in under a year after I got a "go ahead." If you really are gung ho to get it published, then you could fund me hiring a professional editor to knock it into better shape.

5 Staffing Plan

Just me and whomever I hire over the internet to do small pieces of programming work.

5.1 Short biography

Warren D. Smith (Co-PI) (PhD, Applied Math, Princeton, 1988). Co-founder of `http://RangeVoting.org` multi-language voting reform and educational organization and creator of 90% of its web content and programming.

Author of numerous scientific papers, including many on voting and cryptology-related topics; recent papers online at
`http://math.temple.edu/~wds/homepage/works.html`.

Worked for about 15 years plus at NEC Research Institute (now defunct) AT&T Bell Labs (now largely defunct), Temple University Maths dept, and other companies.

6 Budget and Budget Justification

Suppose you pay me $50/hour to program, debug and test (720 hours), write documentation (80 hours), plus write up results and correspond as needed (up to 1500 hours depending how much writing I do, e.g. if you want to support the book or not).

That'd be $40000 for the former plus up to $75000 for the latter.

Further, if I pay $100 per voting method (average; I'll pay more for harder ones) to contributors on the internet, that could be $10000 for 100 methods.

Actually there is no limit to the amount of programming that can be done (as I say, this project will be perpetually ongoing) but I think the main goals can get done in this timespan. After some point, there are clearly diminishing returns.

References

[1] Michel Balinski & Rida Laraki: LE JUGEMENT MAJORITAIRE, `http://www.ceco.polytechnique.fr/jugement-majoritaire.html`.

[2] Robert F. Bordley: Pragmatic method for evaluating election schemes through simulation, Amer. Polit. Sci. Rev. 77 (1983) 123-141.

[3] S. Brams & P. Fishburn: Approval Voting, Birkhauser, 1983.

[4] Center for Range Voting `http://RangeVoting.org/`.

[5] Samuel Merrill: Making multicandidate elections more democratic, Princeton Univ. Press 1988.

[6] Warren D. Smith: Range Voting, paper #56.

[7] Warren D. Smith: Ants, Bees, and Computers agree Range Voting is best single-winner system, paper #96.

[8] Warren D. Smith: The voting impossibilities of Arrow and of Gibbard & Satterthwaite, paper #79.

[9] Warren D.Smith, Jacqueline N. Quintal, Douglas S. Greene: What if the 2004 US presidential election had been held using Range or Approval voting? paper #82. This and preceding Smith papers available online here:
`http://www.math.temple.edu/~wds/homepage/works.html`.

[10] Douglas R. Woodall: Monotonicity of single seat preferential election rules, Discrete Applied Maths. 77,1 (1997) 81-98.