Some Thoughts on Electronic Voting

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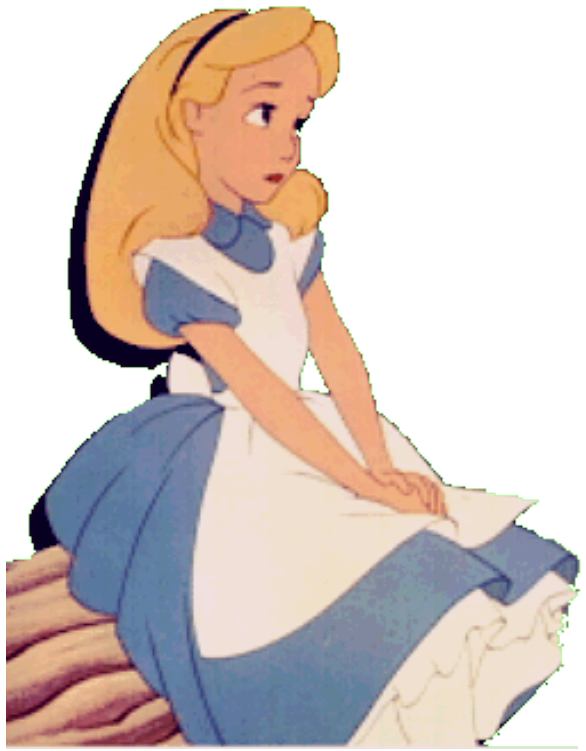
DIMACS Voting Workshop
May 26, 2004

- "What's one and one and one and one and one and one and one and one and one and one?"
  "I don't know," said Alice. "I lost count."



Outline

- 12 "debatable propositions"
- A "pedagogical variant" of Chaum's voting proposal

12 Debatable Propositions

- We give some "propositions" worth consideration and debate.
- These are arbitrarily phrased, so as not to imply support, one way or the other.
- We give a couple of pro/con arguments each way for each proposition.
- "Sometimes I've believed as many as six impossible things before breakfast." (*White Queen*)

1. Voting in private is not important

- Pro:
  - If so, why do we allow such widespread use of absentee ballots or vote-by-mail??
  - Threats affecting large number of vote counts are more important.
- Con:
  - Voter privacy is necessary to defeat coercion and vote-selling.
  - History of voting shows privacy to be important.

2. Voting fraud is rare

- Pro:
  - Few convicted of voting fraud
  - Problems in manipulation of *registration* seem much more prevalent.
- Con:
  - *Absence of evidence* is not *evidence of absence*.
    "We've never seen a problem" does not mean problems don't exist!
  - Maybe *unsuccessful* voting fraud is rare.

3. Voter is not a computer

- Pro:
  - Gee, this seems obvious.
- Con:
  - Much existing cryptographic voting literature *assumes otherwise*.
  - Someday voters will have their own "trusted computing base" (a cell phone?) that can act on their behalf in a trustworthy manner…

4. Voting by machine is "proxy voting"

- Pro:
  - Gee, this seems obvious.
- Con:
  - Well, we don't consider a pencil a "proxy" for the voter, do we?
  - Is a DRE (or a computer) more like a pencil or more like a corruptible person?

5. We must "trust the machines"

- Pro:
  - It's either that, or back to #2 pencils…
  - Because we can
- Con:
  - Why outsource our elections to vendors?
  - Necessity has not been demonstrated; good audit and controls seem possible
  - Because we can't

6. Trustworthy software is possible

- Pro:
  - We fly in planes, don't we?
- Con:
  - Planes have no field-upgradable software.
  - Avionics software is enormously expensive. (DO178B regulations)
  - Insider threat less serious for planes.

7. Code review is sufficient

- Pro:
  - Gee, it's what we're doing now…
  - Open source could make this even better…
- Con:
  - Need to trust compiler, and even that's not enough (Ken Thompson)
  - Undecidable in general
  - Very hard even in simple cases:
    - » Does this program ever refuse to let someone vote? :
      - On input n (e.g. n is the blank ballot, as an integer)
      - *While n>1: if n even n← n/2 else n←3x+1*
      - Proceed to ordinary voting code…
    - » It is an *unsolved problem* even for this program!

8.Testing is sufficient

- Pro:
  - As long as voting machine can't tell if it is being used "for real", it can't cheat.
- Con:
  - Easy for an accomplice to "signal" software that it is being used "for real".
  - Sufficiently extensive parallel testing is very expensive.

9. Paper is necessary

- `I think I should understand that better,' Alice said very politely, `if I had it written down: but I can't quite follow it as you say it.'
- Pro:
  - Without (voter-verified) paper ballot, voter doesn't really know how he voted.
  - Without paper output, voting machine isn't *committed* to any particular behavior or action.
  - Electronics can't audit itself (at least, if made by same manufacturer…)
- Con:
  - Same investment can yield equivalent results in other ways…

10. Transparency helps security

- Pro:
  - Publishing source code, lists of voters, ballot images, etc. seems like a good idea
- Con:
  - Not easy to do and protect voter privacy.
  - Giving voters more chances to complain can cause more problems than it solves.

11. We'll see fewer close elections

- Pro:
  - Populations are growing
- Con:
  - Sophisticated polling allows candidates' resources to be spent efficiently, narrowing margins in close states.

12. If it's close, it doesn't matter

- Pro:
  - No matter which way it goes, about the same number of voters are unhappy.
  - "Which road do I take?" asked Alice.
    "Where do you want to go?" said the cat.
    "I don't know…" said Alice.
    "*Then it doesn't matter!*" said the cat.
- Con:
  - Rule by minority is not democracy!

A pedagogical variant of Chaum's voting proposal

- Used in my class this spring as introductory example, before going into details of Chaum's and Neff's schemes.
- Captures many significant features, but not all; some problems/concerns not well handled.
- Intended to be simpler to explain and understand than full versions.
- Related to Jakobsson/Juels/Rivest mix-net scheme.
- Little novelty here; main ideas (e.g. cut and choose) already present in Chaum's scheme.

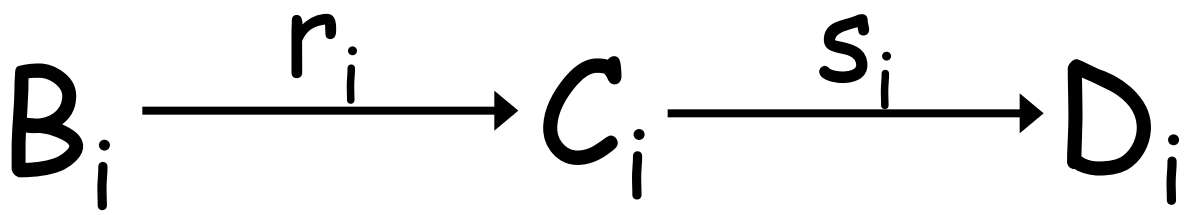
Pedagogical variant (overview)

- Voting machine produces *ciphertext* that is encryption of voter's ballot.
- Ciphertext posted on bulletin board as "official cast ballot" (electronic).
- Voter given *receipt copy* of *ciphertext.*
- Voter given *evidence* that ciphertext correctly encodes his intended choices.
- Ciphertexts "mixed" for anonymity.
- Ciphertexts decrypted and counted.

Pedagogical variant (details)

- Voter V_i prepares ballot B_i
- Machine prints and signs B_i, C_i, D_i, r_i, s_i and gives them to voter.
  C_i is encryption of B_i (randomization r_i)
  D_i is re-encryption of C_i (randomization s_i)
- If voter doesn't like B_i , he starts over.
- Voter destroys either r_i or s_i , and keeps the other information as *evidence* (paper).
- Voting machine signs and posts (V_i, D_i,"final"), and gives (paper) *receipt copy* to voter.
- Final D_i's mixed up (mixnet), decrypted, and counted.

Pedagogical variant (details)



- El-Gamal encryption and re-encryption:
  $C_i = (g^{ri}, B_i * y^{ri})$, $D_i = (g^{ri+si}, B_i * y^{ri+si})$
- Voter keeps only one link as evidence (similar to Jakobsson/Juels/Rivest, or Chaum)
- Voting machine can cheat undetectably with probability at most 1/2 per vote.
- Voter can check evidence on exit.
- Signed B_i's are easy to get…
- Can add "visual crypto" to hide B_i's…

Pedagogical variant (summary)

- Official ballot is *electronic ciphertext.*
- Voter's *receipt* allows him to ensure his ballot is counted.
- Voter's *evidence* supports claim that ballot captures his intended vote.
- Schemes such as these (Chaum / Neff) provide an interesting degree of *"end-to-end"* security…

(The End)

"Begin at the beginning," the King said gravely, "and go on until you come to the end, then stop."

(The End)