

Verifying Australian election outcomes whose job is that?

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Based on joint work with Michelle Blom, Jurlind Budurushi, Andrew Conway, Patrick Keyzer, Ronald L. Rivest, Philip B. Stark, Peter J. Stuckey, Damjan Vukcevic and coauthors of “Public Evidence from Secret Ballots,”

Col statement: I have received consulting contracts or grant money from The Swiss Federal Chancellery, Microsoft, and the Colorado Department of State. None of these endorse the analysis or opinions in this talk, which are mine.

Why do some elections look like this?



Photo credits: US: Tyler Merbler from USA, CC 2.0 [https://commons.wikimedia.org/wiki/File:2021_storming_of_the_United_States_Capitol_2021_storming_of_the_United_States_Capitol_DSC09254-2_\(50820534063\).jpg](https://commons.wikimedia.org/wiki/File:2021_storming_of_the_United_States_Capitol_2021_storming_of_the_United_States_Capitol_DSC09254-2_(50820534063).jpg)

Brazil: TV BrasilGov, CC 3.0 https://commons.wikimedia.org/wiki/File:Ataque_bolsonarista_ao_Congresso_Nacional_do_Brasil.png

When ours look like this?



Differences in voting technology and process



- Brazil & the USA are the only large democracies to have had substantial dependence on paperless Direct Recording Electronic (DRE) machines for years
 - But they were mostly gone in the USA by 2020
- Aus is (almost) all manually-counted paper ballots
 - But there was no riot when iVote went down.

I'll distinguish three kinds of attacks:

Physical the actual violence. (Lucky for us, not our job to defend against.)

Psychological stirring up the mob by persuading them the election has been attacked.

Technical Manipulating election results through technology.

The theme of this talk is *Public Evidence* as a defence against both technical and psychological attacks.

The great and glorious history of democracy in Australia



The great and glorious history of democracy in Australia

“In 1843 elections were held for 24 members of the 36-member Legislative Council of New South Wales. For the election, the colony was divided into 24 districts, including Port Philip (now Victoria), which was then part of New South Wales.

These first elections were run according to British Practice... ”

The great and glorious history of democracy in Australia

Excitement ran high on polling day. As each elector handed in his voting paper the returning officer called out to the crowded booth for whom he had voted. Applause, hisses, and threats greeted the voter from the rival factions. We cannot wonder that 235 of the 791 electors on the borough roll refrained from voting.

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From *The Argus*, Sat 29th Sep 1934. "Australia's first election - 1843." Accessed through Trove <https://trove.nla.gov.au/newspaper/article/10974245>

The great and glorious history of democracy in Australia

"In four districts, Australia's first election day ended in violence and riots, including in Sydney and Melbourne. Police and soldiers struggled to control drunken mobs armed with staves and pickets... "

When did it change?

Designed by Chapman for the 1856 Victoria-only election.

"Councillor William Nicholson ... moved that the elections be conducted by secret ballot. It would prevent voter intimidation, he argued, ... and it would stop the practice of treating... No one would bother to buy a voter a drink, he said, if they couldn't check whether he kept his side of the bargain..."

The voter would pick up a ballot from the polling clerk, who would mark his name off the roll and sign the back of his ballot to prevent fraud. The voter would then pass into an inner room where he would vote in private ... then return to the polling clerk and put his folded ballot in the box. "

It's not just a proposal for a secret ballot, it's a proposal for a secret ballot *without sacrificing public evidence*.

Public evidence from secret ballots

Deriving public evidence from secret ballots is an aim as old as democracy.



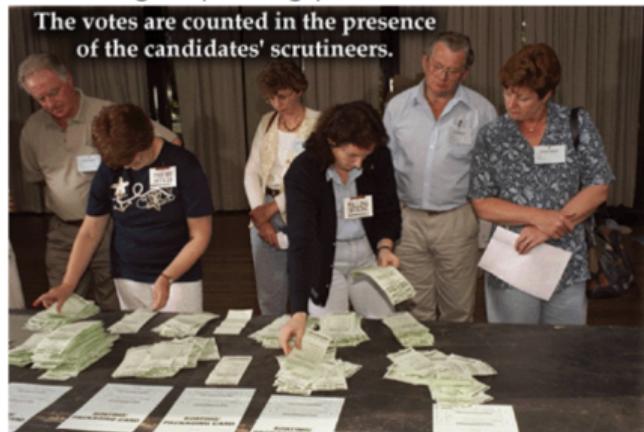
Photo: Sharon Mollerus, CC 2.0 https://commons.wikimedia.org/wiki/File:Athenian_Secret_Ballot.jpg

We have had transparent counting processes for a long time

Election Night

The counting of votes, known as the scrutiny, begins as soon as polling places close their doors at 6pm on polling day. Only ordinary votes are counted on election night.

Counting at polling places



But how can we scrutinise computerised processes?

Computerised Senate Scrutiny



The Senate scrutiny treated ballot papers marked above the line separately from ballot papers marked below the line. The Senate ballot papers marked above the line were manually counted in the Divisional Office and the first preference figures for each party and group were tallied.

The ballot papers marked below the line were forwarded progressively to a central scrutiny in each capital city where the computerised scrutiny took place. Following legislative change, the AEC was able for the first time at the 1998 election to conduct the Senate scrutiny by a computer process known as the Senate Scrutiny system.

A way of using technology without sacrificing public evidence from secret ballots

- ① vote on paper
- ② scan and count electronically

Common throughout the US and in Australia for upper-house elections including the Senate.

But how do scrutineers verify the electronic scanning and counting?

Risk Limiting Audits (RLAs)

Invented by Philip Stark et al.

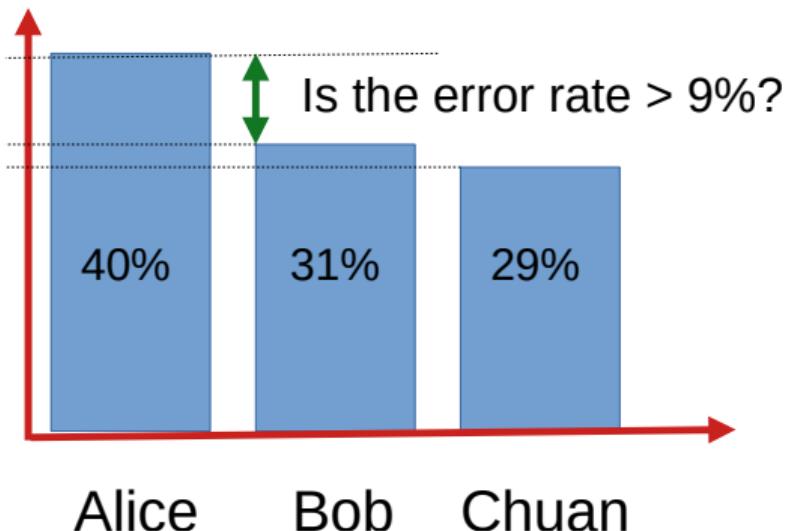
- Needs a trustworthy record of paper ballots
- Use random sampling of paper ballots to test an announced election result
- Either accept the result based on the evidence, or do a full manual count
- Early literature only considered plurality (first-past-the-post) elections
- General open-source implementation: <https://github.com/pbstark/SHANGLA>

Security goal: Risk Limiting

Choose a *Risk Limit* α . If the election outcome is wrong, the result will not be accepted except with probability at most α .

What is a Risk Limiting Audit?

- A process for testing an announced election outcome
- Sample ballots until you can reject the *null hypothesis*, which is that someone different really won.



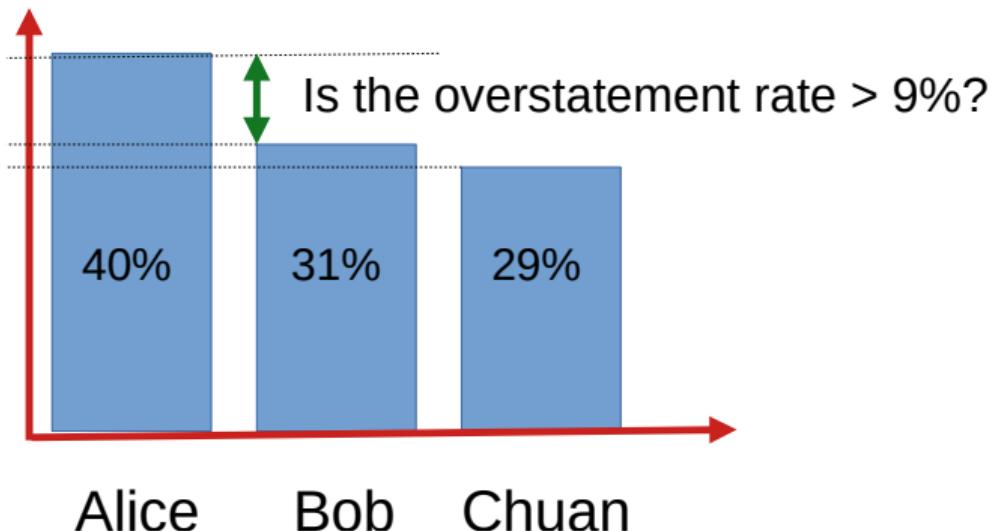
What is a Risk Limiting Audit?

- The **risk** is the maximum chance that the audit fails to correct an apparent outcome that is incorrect, no matter what caused the outcome to be incorrect.
- A **risk-limiting audit** has a guaranteed minimum chance of progressing to a full hand count if the apparent outcome is incorrect.

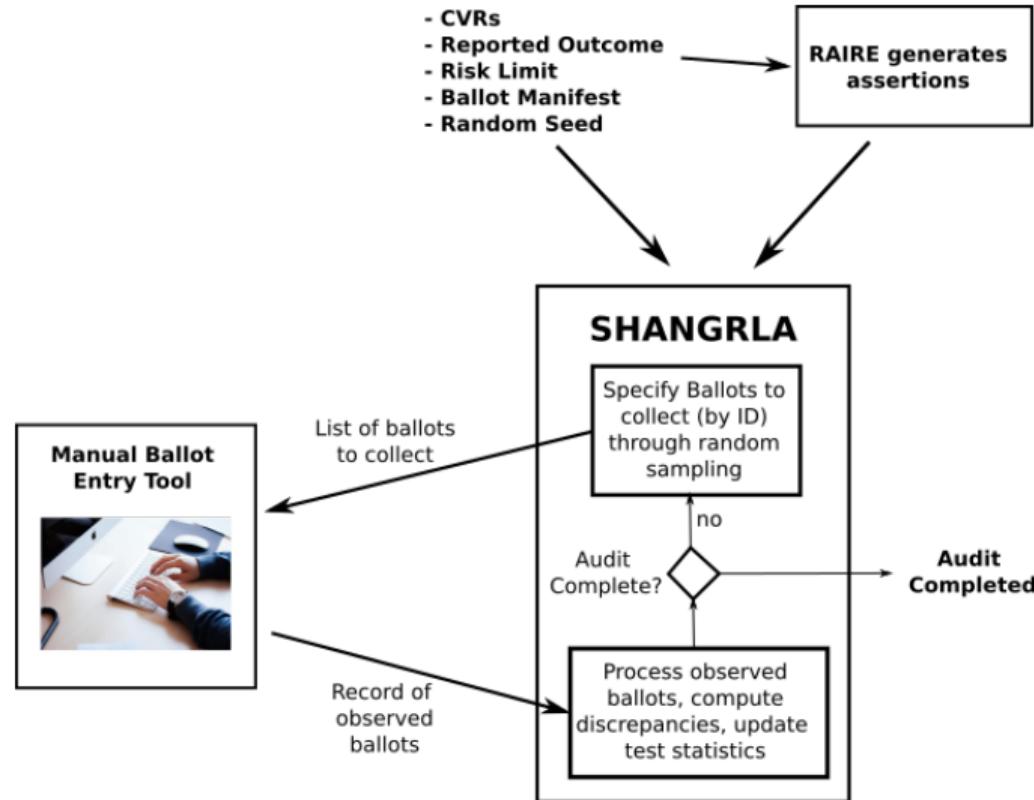
The measured risk is the P-value of the hypothesis that the outcome is incorrect, given the data collected by the audit.

Refinements

- An error that increases an apparent margin is an overstatement
- These are the bad ones
- If the margin is less than the total overstatements, the outcome is wrong



Performing the Audit – Process



Can Risk Limiting Audits derive public evidence?

- Yes!
- Scrutineers can observe (and even actively participate in)
 - Seeding the random number generator that selects ballots for audit
 - Reading the ballots
 - Independently redoing the risk calculations
- In practice, most implementations will require a bit more work to get there

Instant Runoff Voting (IRV)¹

- Preferential voting scheme
- A set of candidates \mathcal{C} , one winner
- Each vote is a ranking over \mathcal{C}
- Each vote can be a *partial* ranking
e.g., [Mary Hill, Joe Smith, John Citizen]

House of Representatives
Ballot Paper

Victoria
Electoral Division of Higgins

Number the boxes from 1 to 8 in the order of your choice

EQUALITY	1	O'BRIEN, Rebecca MARRIAGE EQUALITY
	2	TREGEAR, Jessica DERRYN HINCH'S JUSTICE PARTY
LIBERAL	3	O'DWYER, Kelly LIBERAL
THE GREENS	4	BALL, Jason THE GREENS
LIBERAL DEMOCRATS	5	KENNEDY, Robert LIBERAL DEMOCRATS
Labor	6	KATTER, Carl AUSTRALIAN LABOR PARTY
X	7	BASSETT, Nancy NICK XENOPHON TEAM
ANIMAL JUSTICE PARTY	8	GULLONE, Eleonora ANIMAL JUSTICE PARTY

Remember... number **every** box to make your vote count

Instant Runoff Voting (IRV)

Initially, all candidates remain standing (are not eliminated)

While there is *more than one* candidate standing

For every candidate c standing

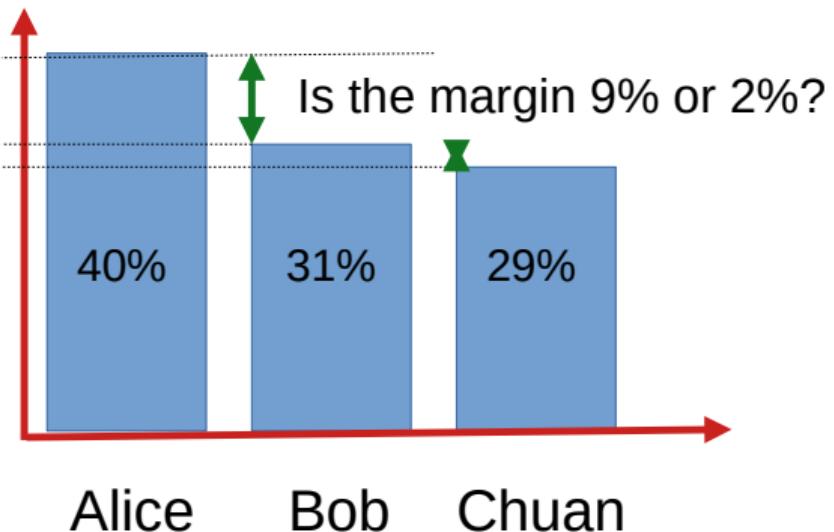
 Tally (count) the votes in which c is the highest-ranked
 candidate of those standing

 Eliminate the candidate with the smallest tally

The winner is the one candidate not eliminated

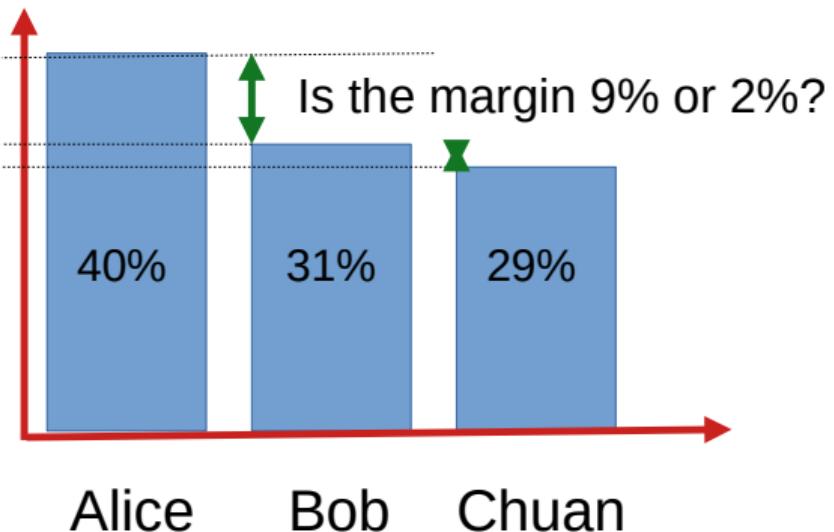
Extending RLAs to preferential (IRV) elections - first try

- Audit each elimination step
- Sound but wastes effort on comparisons that don't matter



Extending RLAs to preferential (IRV) elections - second try

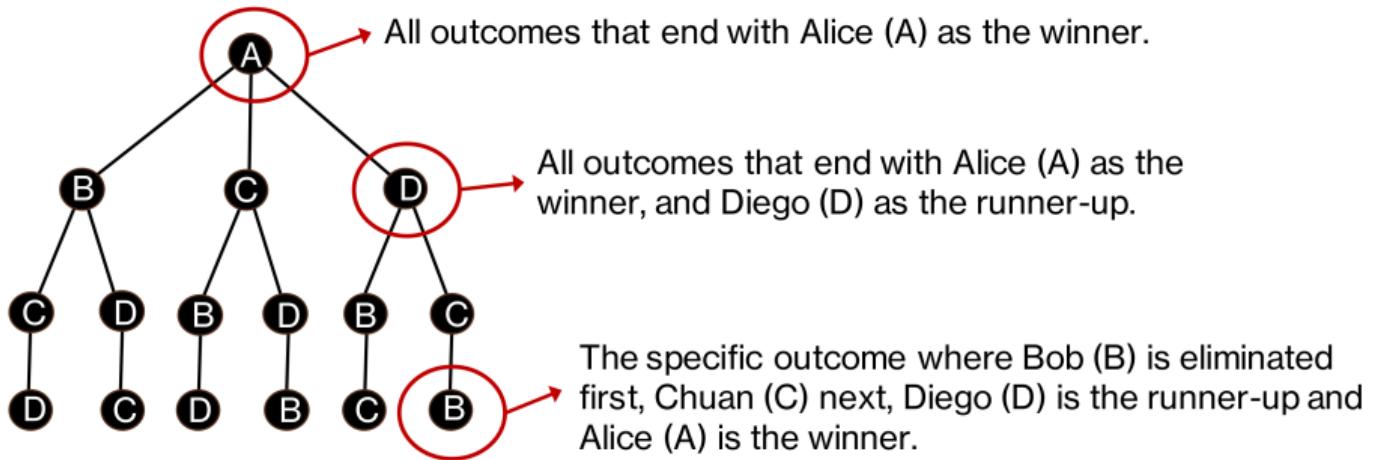
- Compute the margin and check for the number of errors
- Sound, but counts all the errors as overstatements



Extending RLAs to complex voting methods - something that works

- Think of the RLA as a test that compares two “candidates”
- Express the complex voting method as a series of two-“candidate” comparisons
- Be creative about what the “candidates” are
- Generate a set of *Assertions*, i.e. a set of sufficient conditions for the election outcome to be correct
- Test them all with an RLA
- If the election outcome is wrong, one of the assertions must be wrong
- The RLA will not accept the wrong one except with probability at most α .

Visualising IRV outcomes



Our leaves are complete outcomes while each intermediate node describes a set of outcomes.

Efficient Audits

Create an *audit specification* consisting of a set of *assertions*.

Assertion: A winner vs. loser comparison in a context. The ‘context’ is a set of candidates that we assume have been eliminated.

- Each assertion represents a plurality election that can be audited;
- Find a set of assertions that, if proven, rule out all outcomes in which the reported winner *does not win*.
- Find a set of such assertions that requires *the least estimated auditing effort*.

Assertion Types

We use two kinds of assertions:

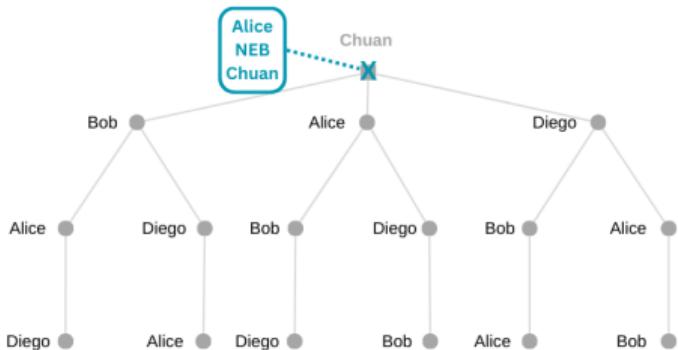
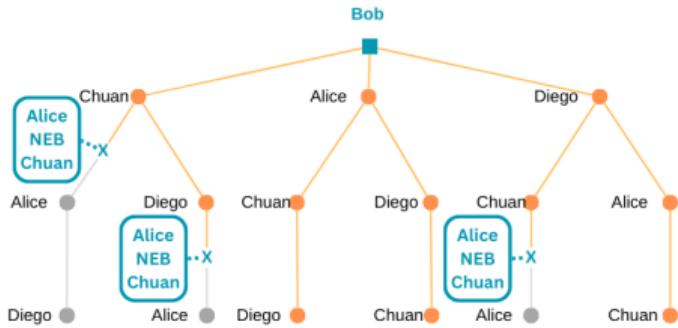
Not-Eliminated-Next. NEN: $w > /$ when only S remain

Candidate w beats (has more votes than) candidate $/$ in the context where candidates S are still standing.

Not-Eliminated-Before. $w \text{ NEB } /$ (Never eliminated before)

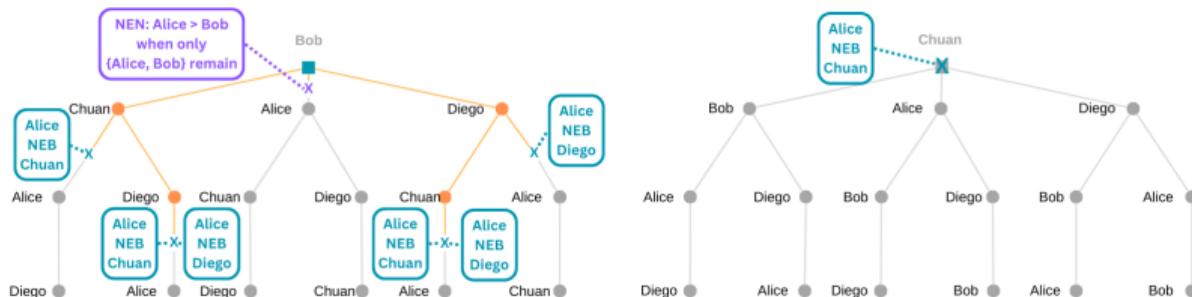
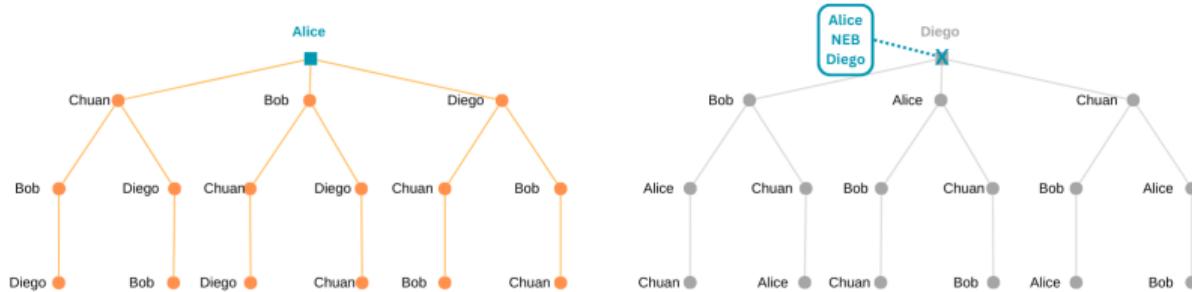
Candidate w 's first preferences beat the total number of votes on which $/$ is ranked higher than w .

Implications of Alice NEB Chuan



Sufficient set of assertions

Implications of Alice NEB Chuan, Alice NEB Diego and NEN: Alice > Bob when only { Alice, Bob} remain



Generating the assertions is hard

We have a branch-and-bound heuristic for finding easiest-to-audit sufficient sets of assertions.

- By Michelle Blom:
<https://github.com/michelleblom/audit-irv-cp/tree/raire-branch>
- By Andrew Conway: <https://github.com/DemocracyDevelopers/raire-rs>

But you don't have to trust the assertion generation—you can verify that the assertions are sufficient.

- In SHANGRLA: <https://github.com/pbstark/SHANGRLA/blob/main/shangrla/Examples/RAIREExampleDataParsing.ipynb>
- Or using Andrew Conway's visualiser:
<https://democracydevelopers.github.io/raire-rs/>

The First Pilot

San Francisco District Attorney Race

November 2019

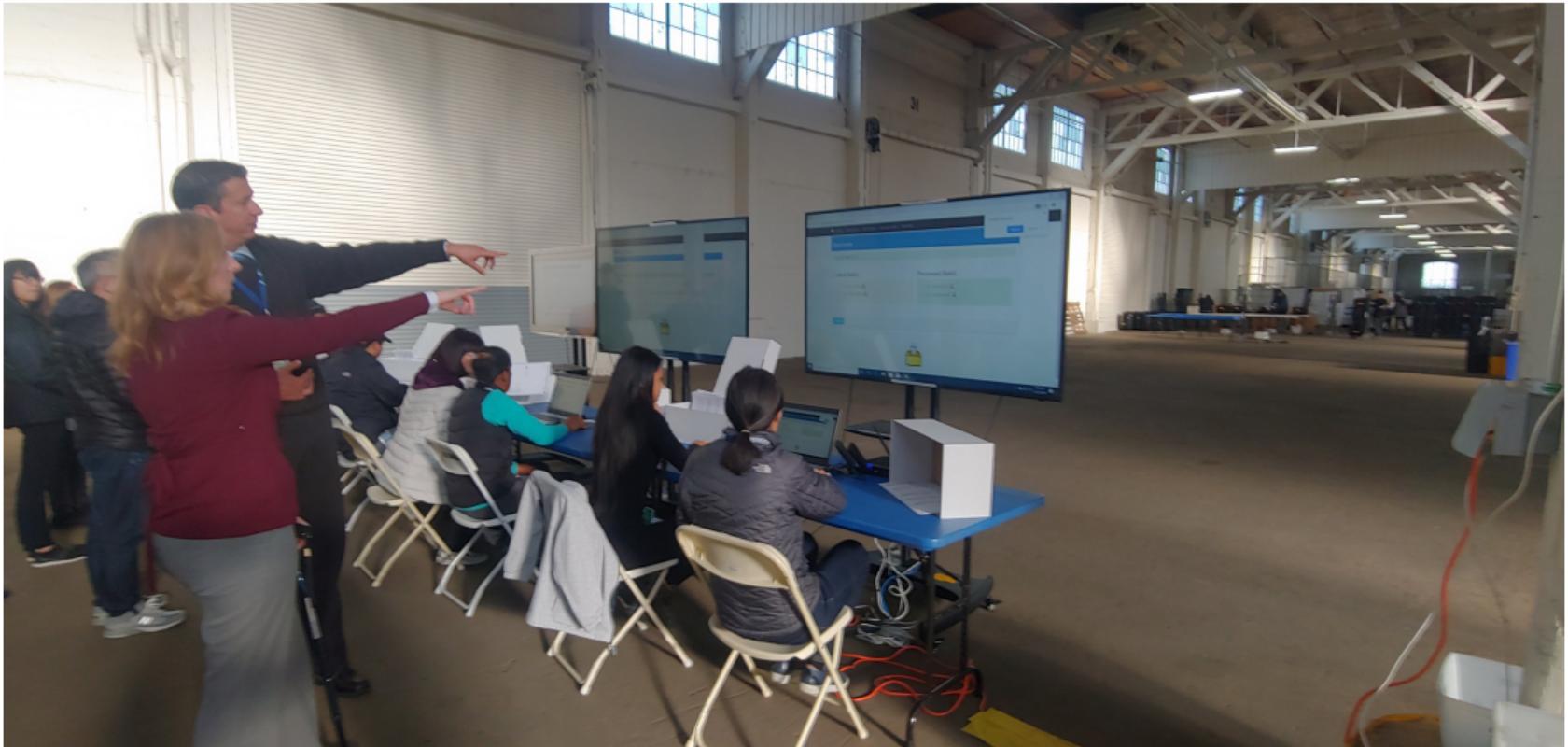
Tools: Performing the Audit

- **RAIRE** finds the set of assertions we need to audit;
- **SHANGRLA:** a Jupyter notebook that takes these assertions, and the election CVRs, and steps a user through the audit;
- A data entry tool developed by the City of San Francisco to enter the rankings observed on sampled paper ballot. Any error between the paper ballot, and associated CVR, is computed by the SHANGRLA notebook which then updates risks;
- Audit completes if the computed risk associated with each assertion falls below the risk limit.

Performing the Audit – in San Francisco



Performing the Audit – in San Francisco



Performing the Audit – the Stats

- 293,555 ballots involved in the pilot audit;
- A sample of 200 ballots was required to complete the audit;
- 11 IRV Elimination assertions;
- An overall risk of 3% was attained.



The future

- This process will be used in Colorado by 2025
- and could be used in Australia for single-seat preferential voting

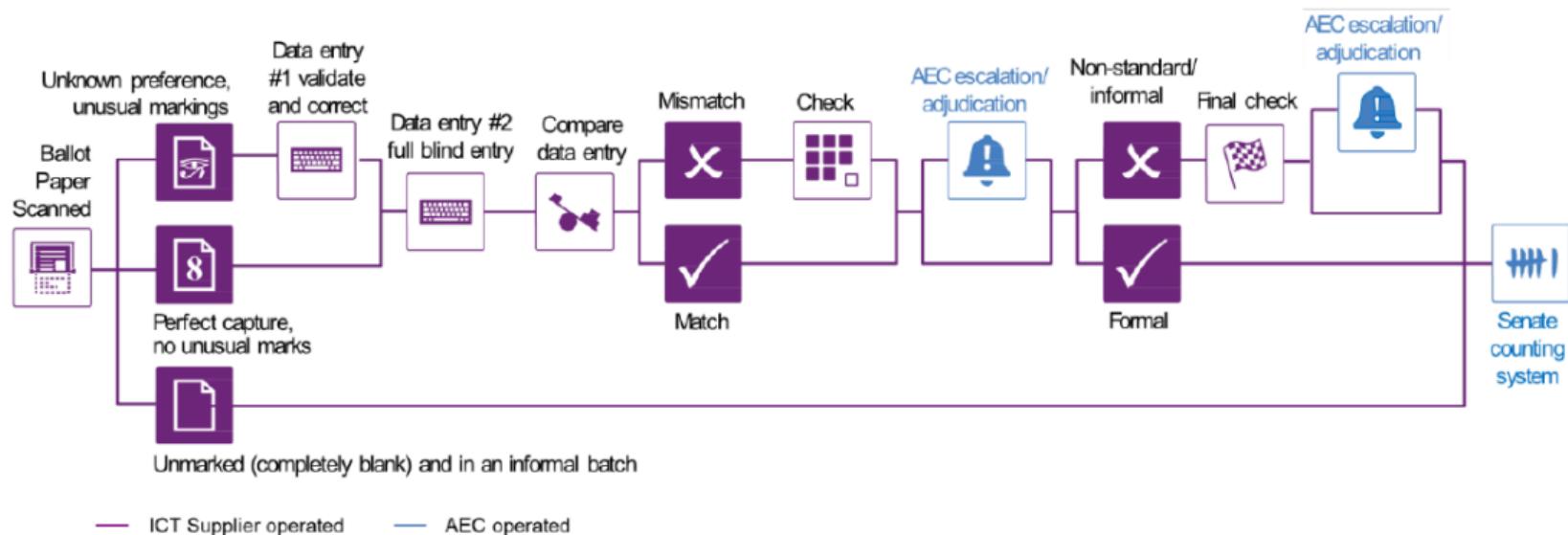
What about the Australian Senate?

And the upper houses of many states.

All these are counted using the Single Transferable Vote (STV)

1. Senate ballots are electronically scanned and counted

ANAO's simplified diagram of the Senate Scanning and counting process (2019)



What is the error rate? How do we check?

Electoral Legislation Amendment (Assurance of Senate Counting) Bill 2021

273AC Ballot paper sampling assurance throughout computerised scrutiny of votes in Senate election

- (2) The Electoral Commissioner must arrange for statistically significant samples of ballot papers to be checked throughout the scrutiny of votes for the election to assure that the electronic data used in counting the votes reflects the data recorded on the ballot papers.

This is a huge step forward for both real and perceived security & integrity of Australian Senate elections

The Senate Count Audit Outcomes

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The Senate Count Audit Outcomes

- The audit² sampled 10,000 ballots
- In 33 cases, the marks were incorrectly interpreted
 - This is expected
- In 6 cases, the ballot had no matching digital image in the database
 - This is not expected

Could we do better?

A bit.

- Assess the margin
- Check whether the error rate is less than the margin

Code for margin bounding: <https://github.com/AndrewConway/ConcreteSTV>

Details of audit process: <https://arxiv.org/abs/2205.14634>

Future work: broader, more rigorous, better explained

- STV
- formal examination of risk-limiting audits as a protocol for providing public verifiability
- explaining it to the public

The interesting research problems are about extending public evidence to more scenarios without sacrificing the secret ballot

But wait, wouldn't everything be quicker, cheaper and more convenient if we all voted over the Internet? Wouldn't our elections be as secure as everything else on the Internet?

Yes.

But...

It's not the reliability issues, or even the security issues.

ABC NEWS Supreme Court orders re-vote after iVote crash in NSW local government ..

Supreme Court orders re-vote after iVote crash in NSW local government elections

ABC Illawarra / By Ainslie Drewitt-Smith and Tim Fernandez
Posted Thu 17 Mar 2022 at 3:54pm, updated Thu 17 Mar 2022 at 6:01pm



But...

We do not currently have any real way to produce *public evidence from secret ballots* over the Internet.

But...

The NSW Electoral Commission says it best.

13. For all types of elections it appears appropriate and proportionate, given modelling based on previous results data and the proposed small-scale of TAV, for an election not to be invalid on the basis only that TAV was not available. For multi member proportional representation elections (such as the Legislative Council and local government councillor elections), however, it also may be appropriate to extend such protection to address risks of performance issues after votes have been cast. Such consideration is warranted because the scale of the risks and costs involved in re-running multi-vacancy elections, and the consequent detriment to the public interest.
14. For other contests (such as Legislative Assembly elections, local government mayoral elections and local government by-elections), a savings provision may also be appropriate even if votes cast by TAV cannot be verified or counted. This could apply if the Electoral Commissioner determines prior to the declaration of results that the number of votes cast by TAV in that election (but which could not be included in the count for any reason) was greater than the smallest exclusion point.
15. Overall, the scenarios for applying a savings provision to technical performance issues for TAV require a clear legislative framework before online voting is offered again (para 184).

From the NSW Electoral Commission's Technology Assisted Voting - Paper 2 - Interim review report:

<https://elections.nsw.gov.au/technology-assisted-voting-review>

Conclusion

- Democracy is an inherently resilient system of government
- Reality matters. Not as much as we'd like, but more than we fear
- Electoral processes that provide *public evidence from secret ballots* are the right defence against both technical and psychological attacks
- We can do Risk Limiting Audits for single-seat preferential elections
- The multi-seat (Senate / STV) case is not completely solved, but there are reasonable options