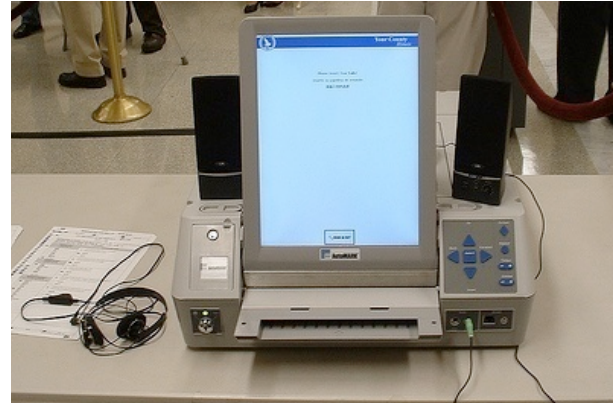# Weight, Weight, Don't Tell Me: Using Scales to Select Ballots for Auditing

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David Wagner

Election Audits are Important

Auditing Methods

- Precinct-based:
  - Standard practice
  - Choose a sample of *precincts* to audit
  - Every ballot in a sampled precinct is audited
- Ballot-based[1,2,3]:
  - Newer idea
  - Choose a sample of *ballots* to audit
  - Sample from the set of all ballots, across precincts

1. Neff, C. A., Dec. 2003.
2. Johnson, K. C., Oct. 2004.
3. Calandrino, J. A., Halderman, J. A., and Felten, E. W., EVT 2007.

Ballot-based vs. Precinct-based

- Ballot-based auditing is more efficient
  - Confidence based on number of audit units rather than number of ballots

- E.g., Virginia 2006 election results[1]
  - Ballot-based auditing would have required the recount of between 1/17 to 1/400 as many ballots as precinct-based auditing did.

- Our focus is on ballot-based auditing

1. Calandrino, J. A., Halderman, J. A., and Felten, E. W., EVT 2007.

How ballot-based auditing works
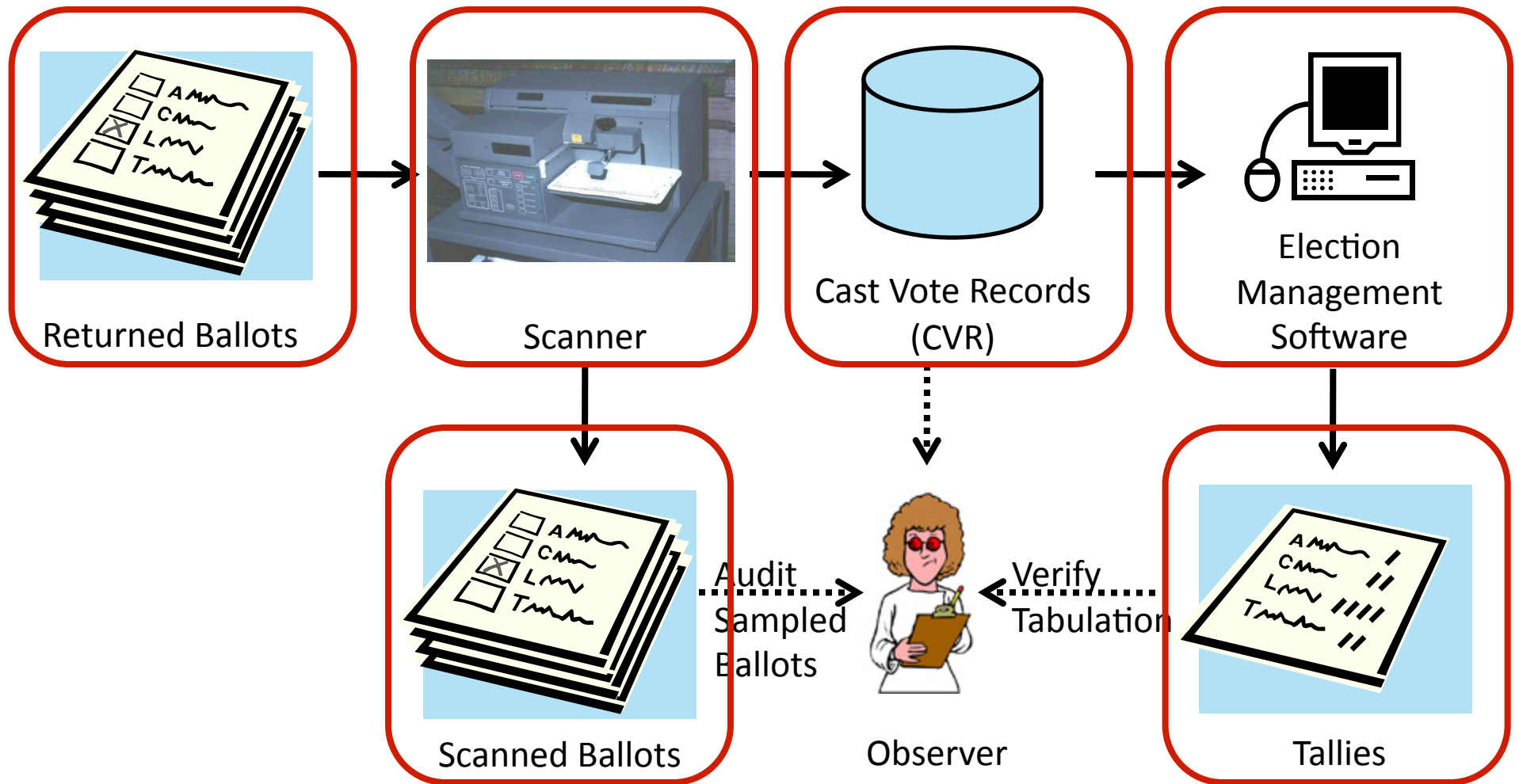
A Challenge for Ballot-based Auditing:
Finding the sampled ballot

- Key steps of ballot-based auditing:
    1. Picking cast vote record
    2. Finding paper ballot
    3. Compare paper ballot to cast vote record
- Requires a way to link each cast vote record to its paper ballot
- Different proposals do this in different ways

Finding the Sampled Ballot Approach #1:

- Approach:
  - Pre-printed serial number
- Advantages:
  - Conceptually simple
- Disadvantages:
  - Violates privacy
  - Scanners require modification - software
  - Finding particular ballot may be slow

Finding the Sampled Ballot Approach #2:

- Approach:
  - Serial number stamped on after election
- Advantages:
  - Protects privacy
  - More efficient ballot selection
- Disadvantages:
  - Scanners require modification – software & hardware
  - Modifies already-voted ballots

Our Contribution

- Explicit serial number not necessary
- Location in stack + Stack number = Implicit serial number

Finding the Sampled Ballot Approach #3:

- Approach:
  - Hand count to find implicit serial numbers
- Advantages:
  - Protects privacy
  - No scanner modification required
  - Voted ballots are not modified
- Disadvantages:
  - Finding particular ballot may be slow
  - Possibility for human error

Finding the Sampled Ballot Approach #4:

- Approach:
  - Use ballot weight to find implicit serial numbers
- Advantages:
  - Protects privacy
  - No scanner modification required
  - Voted ballots are not modified
  - Faster than hand counting
- Disadvantages:
  - Possibility for selection error

Flipping

5
6
7
8
9
10
11
12

Ballot Stack

4
3
2
1
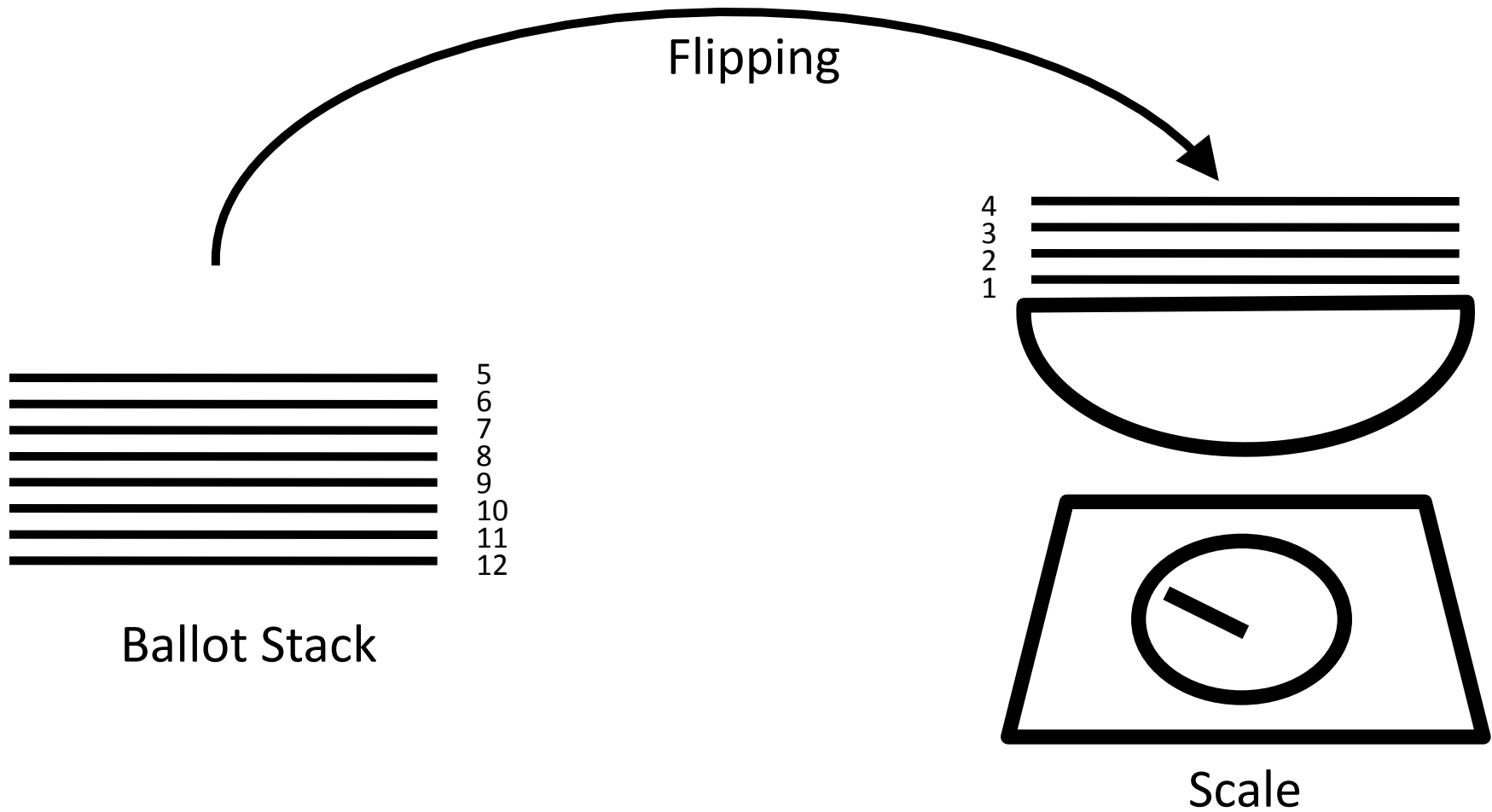
Scale

Index into the stack by finding the sub-stack with the correct number of ballots.

A counting scale efficiently counts the number of ballots in a stack

Selection Experiment

- Methodology
  - 50kg x 0.002kg counting scale
  - 350 Ballots – calibration and selection
- Results
  - 20 Trials
  - Longest time, 31 seconds (early trial)
  - All trials resulted in correct ballot selection

Sources of Selection Error

- Scale error

- Variation in ballot weights

- Mis-estimating mean ballot weight

Projected Selection Error

- Calculate estimated mean ballot weight
  - 1000 ballots sampled with replacement
- Generate stacks of 500 ballots
- For each position i in the stack, would we correctly estimate stack size?
- 100,000 trials

Simulated Error Rate Resulting from Variation in Ballot Mass
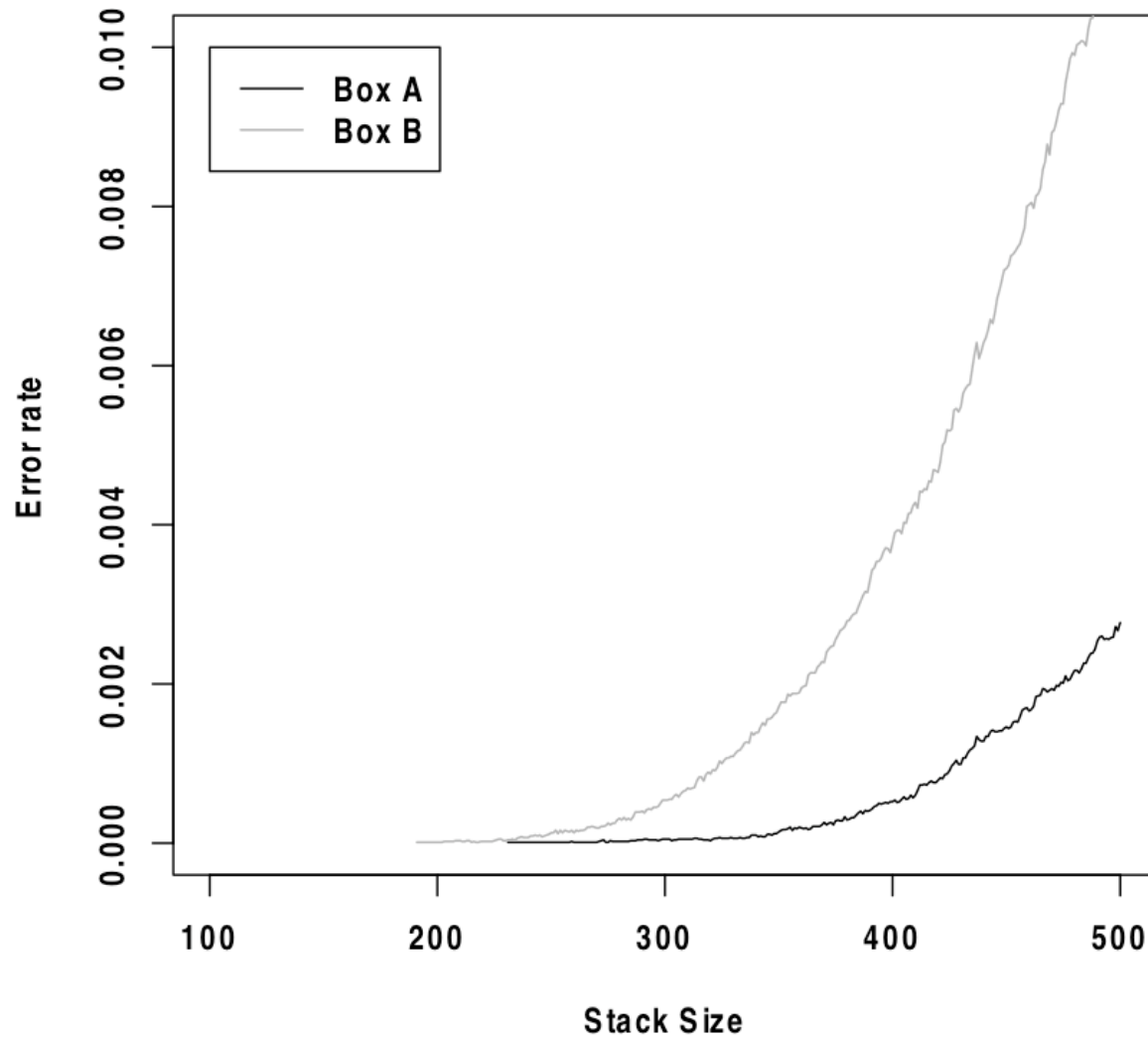
Limitations of this Research

- Unknown:
  - Variation in weight of voted ballots
  - Homogeneity of ballot weight distribution across different boxes of ballots
  - Practicality of keeping ballot stack order
  - End-to-end efficiency of scheme

Conclusion

- We present a new scheme to enable ballot-based auditing

- Advantages over prior schemes
  - Compatible with legacy hardware
  - No modification of voted ballots
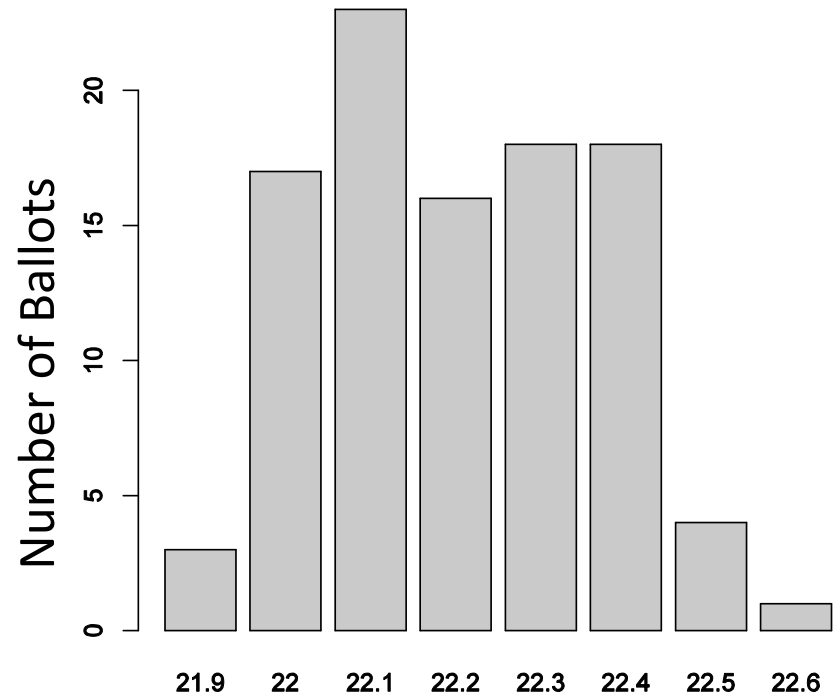
- A promising idea, more research warranted

End

Variation in Ballot Weight
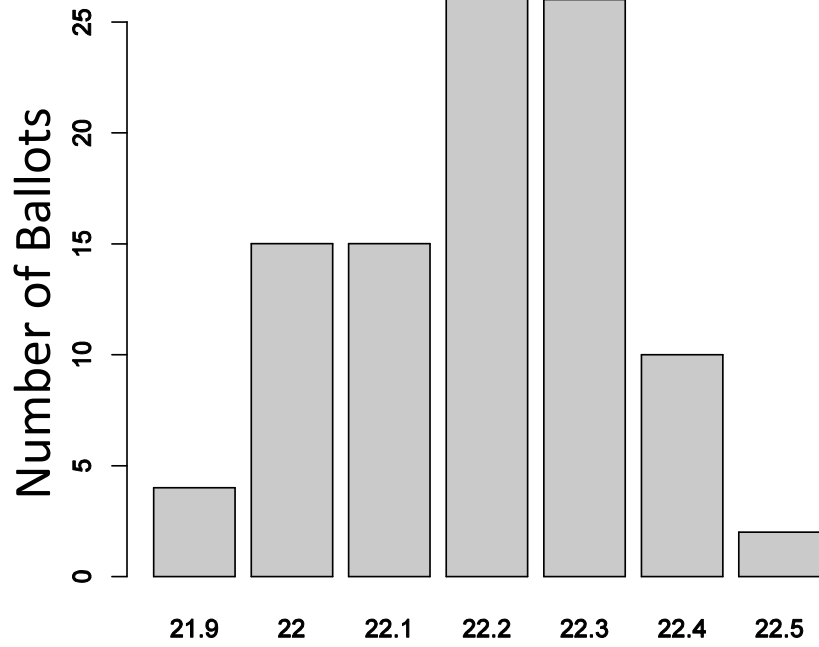
Ballot Weight Variation Accumulates