Science You Can Use

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Dear Science: The Georgia (GA) Secretary of State says that the GA votes for the candidates for US President will be "fully recounted by hand", as a check on the machine-generated vote counts. The current difference between the machine-counted votes for the Presidential candidates is about 0.3%. Can hand-counting tell us whether the machine-counts are in error? -- Buck R.

Dear Buck: The short answer to your question is that hand-counting can't show that the machine-counts are in error unless the machine-, and the hand-, counts differ by more than about 3%.

For a more detailed answer, we first need to distinguish at least two types of electronic voting systems and two types of hand counting.

Types of voting machines. Some of the simplest electronic voting machines require the voter to use an approved pen to fill in an ellipse beside the name of the candidate of the voter's choice. Once the ballot is completed, it is scanned by an optical scanner. This kind of voting system is subject to several kinds of errors. A voter might not fill in an ellipse completely and as a result, the scanner does not count that vote. A voter might make smudge marks on the ballot, and these can be mistaken for voter-selections. Or a voter might use a pen that has a color (e.g., red) the scanner does not recognize.

In contrast, the GA voting machines have touch-screen data entry that generates a corresponding paper ballot. The voter touches the name of the candidate the voter prefers on a screen. The machine then produce a paper ballot/record, one per voter. This paper ballot is then fed into a scanner/tabulator.

Types of hand-counting. "Hand-counting" is more problematic than most people think, and it can mean various things. In the simplest case, one person counts a batch of ballots once. I will call this mode of counting "single-pass hand-counting". Alternately, each of several people can count the same set of ballots once. I will call this mode of counting "multiple-pass hand counting". Let's look at these in turn.

***Single-pass hand-counting*.** Three examples are enough to illustrate the kinds of problems that can arise in single-pass hand-counting in the GA voting environment.

Example 1. Suppose the hand count says that the counts for the two candidates differ by 0.5%, which on the surface seems larger than the difference (0.3%) in the machine-counts. Is this difference really a difference? There are at least two reasons why we can't say.

First, the error rate in single-pass hand-counting is about 1%, i.e., in a count of 100 ballots, on average one ballot is miscounted (Smith, D. J. (2005). *Reliability, Maintainability, and*

Risk. Elsevier. Appendix 6). All else being the same, the error rate in machine-counting, *using the GA voting machines,* is less than 0.1%, i.e., in a count of 1000 ballots less than one ballot is miscounted (Patterson, S. M. (2016). Technology confirms that ballot error is less than 0.001%. *Networkworld.* https://www.networkworld.com/article/3133114/technology-confirms-election-ballot-error-is-less-than-001.html.) Therefore, counts from the GA voting machines have an error rate which is less than 10% of the error-rate of single-pass hand-counting. This means that single-pass hand-counting can't be nearly as accurate as the GA voting machines.

Second, single-pass hand-counting, with a 1% error rate, evidently cannot detect machine-count errors of 0.5%, which only half the size of the error in single-pass hand counting. You can think of this problem on analogy with a foot-long ruler (which plays the role of a 1% error hand-counting) that has no internal division marks. A machine-count error of 0.5% corresponds to about a 6" on that scale. Using an unmarked foot-long ruler to measure 6" just isn't possible.

Example 2. Suppose the hand count says that the counts for the two candidates are exactly the same, e.g., they differ by 0.3%. Does this seeming agreement mean that the machine-count is correct? No. No counting method, including single-pass hand-counting, can confirm count agreements more closely than the error rate in that method.

Example 3. Suppose the hand count says that the vote counts for the two candidates differ by 10% or more. In this case, there is good reason to believe that something is seriously wrong with the machine-, or the hand-, count (or possibly, both). Which, if either, method is more reliable cannot be determined on the basis of this information alone. This problem is like having two thermometers that report values differing by 10% or more. Which one is right?

Multiple-pass hand-counting. Assume that a given sent of ballots is counted by more than one person. In this case, elementary statistical theory tells us that we would have to hand count the lot about 100 times, and average the counts, in order to have 95% confidence that that average is the "true" average of the lot. GA is not going to count all the ballots anywhere close to 100 times.

In summary, hand-counting can reliably detect differences between two vote counts that differ by more than about 3%, but it cannot reliably detect differences between counts that are less than 1%.

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