Double-entry Accounting Provides Software-Independent Algorithm for Confirming the Integrity of Automated Election Tallies

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Abstract: This paper proposes the use of double-entry accounting to maintain the integrity of election data as they go through the processes of counting, canvassing, consolidation, and reporting. Double-entry accounting brings to election tallies its well-known benefits of minimizing errors, deterring fraud, and maintaining the integrity of large collections of numeric data. Its superiority to single-entry methods, which are currently in use in the electoral tallies of most countries, is universally acknowledged in business and is increasingly appreciated by governments. This paper describes how double-entry accounting can be applied to election tallies, proposes the equations that govern the accounting of ballots and votes, and discusses the advantages that this brings. It also responds to arguments that the method is not appropriate for election tallies.

1 Introduction

Persistent concerns about the integrity of electronic voting (e-voting) systems have slowed down their adoption in many countries.

One response to this concern is the suggestion to make e-voting systems "software-independent." For instance, the U.S. National Institute of Standards and Technology (NIST), with the support of the U.S. Association of Computing Machinery (ACM), had recommended to the Technical Guidelines Development Committee (TGDC) that only software-independent e-voting systems be certified. The TGDC adopted this recommendation and, in turn, proposed it to the U.S. Election Assistance Commission.

Thus the TGDC Voluntary Voting Systems Guidelines (VVSG) now include software independence as a voting system requirement: "Software independence (Rivest06) means that an undetected error or fault in the voting system's software is not capable of causing an undetectable change in election results. All voting systems must be software independent in order to conform to the VVSG" [TG07].

One way to make an e-voting system software independent is to retain a paper ballot as the original document expressing voter intent. Since errors due to software cannot alter the paper ballot, these errors can be detected in a ballot-based recount. Thus in their paper cited in the VVSG, Rivest and Wack call the paper ballot approach "strongly software-independent" [RW06].

This paper proposes the use of the double-entry accounting method to provide a simple, robust, and time-tested way to detect errors in voting machine counts that is also software-independent.

2 Data items as equalities

Double-entry accounting is based on an algorithm that detects errors in real-time from a numeric data set, regardless of its size, by imposing a consistency check on every data item that goes in and comes out of the data set. This consistency check is implemented by requiring every data item to be recorded *as an equality*. As data items are accumulated, recorded, totaled, reported, and rerecorded at various levels of data consolidation, equal amounts are being manipulated all the time. Thus the totals of the left and right hand sides of the equality (henceforth, LHS and RHS) must remain equal *at all times*.[1] Most errors in recording, arithmetic, and reporting will cause the equality to fail. So if the consistency check is done in real-time, errors will be automatically detected in real-time too. This method can detect errors in the original data set–as submitted by optical ballot scanners or human counters, for instance–as well as errors in the data set introduced by the machines, software, or human operators that update, manipulate, and report this data set. As long as the raw data sets are made available, this method can be implemented independently of the specific software or hardware platform used in an e-voting system. The accounting profession implements this automatic checking by recording the two sides of the equality in two corresponding columns, and regularly ensuring that the two columns are "balanced," i.e., their totals are equal.

Over the centuries, businesses and the accounting profession have developed and standardized systems and procedures–familiar to managers, auditors, accountants, and bookkeepers worldwide–for maintaining a generally high level of data integrity using this method, which can be implemented manually or in software. When businesses shift from manual to computerized data operations, more sophisticated means of ensuring data integrity become possible. Still, this highly-robust, time-tested, and standardized double-entry method is invariably retained as a way to keep data operations machine- and software-independent. So it remains a universal workhorse of businesses.

First described in the late fifteenth century, the superiority of the double-entry system to single-entry methods has made it the standard system of business accounting for several hundred years throughout the world.

[1] Accountants call the left-hand side (LHS) of the equality debit (Dr), and the right-hand side of the equality credit (Cr).

Increasingly, double-entry accounting has made inroads in governments too, although they have been slower in recognizing its benefits. It was only in the nineteenth century when it saw widespread use in the public sectors of France (1815) and Great Britain (1829) [Ni01]. Some countries adopted the system only in the late twentieth century. In the first few years of the twenty-first century, the European Commission was still using single-entry accounting [Kh02], shifting to the double-entry system only on 1 January 2005 [EU06]. In other countries, especially among local governments, its introduction is still in the planning stages, as part of public sector financial reform.

It is therefore understandable if election authorities have not yet made the conceptual leap to adopt double-entry accounting in vote tabulations.

3 Election tallies today: single-entry

Most election tallies today still use the single-entry accounting method of recording and accumulating individual isolated numbers, not equalities. This method is susceptible to undetected errors that can be passed on to intermediate levels of vote consolidation up to the final tabulation. The common practice of recording, maintaining, and reporting vote totals at every level of consolidation is *not* double-entry accounting. Few election authorities strictly enforce a requirement that blanks (or undervotes) and invalid votes (such as overvotes) be counted, recorded, reported, and included in the totals at every consolidation level, in the same way that votes for candidates are. If small unexplained discrepancies arise which are deemed immaterial to the final outcome, local voting officials tend to simply agree to "clean up" the figures. Few, if any, set aside special accounts to keep track of small discrepancies that could not be reconciled in time. Since special accounts such as blanks, invalids, missing, and excess votes are necessary to implement a true double-entry election accounting system, there cannot be many countries, municipalities or election jurisdictions, if indeed there is even one, that use this system in vote tabulations and election accounting today.

4 Every vote counts

It is sometimes argued that the requirements are more stringent in accounting for money than in accounting for votes. According to this argument, a win by a small margin is no different from a win by a large margin. Hence, the argument goes, accuracy to the last vote is not as important as accuracy to the last cent.

On the contrary, accuracy to the last vote is also important for the following reasons:

- A single vote may not make a difference to an election outcome, just as a single cent hardly makes a difference to a businessman's bottom line. But a one-vote or one-cent discrepancy may hide larger, but undetected discrepancies in the system. Worse, they may indicate procedural or system flaws or loopholes that can result in more serious errors in the future. Businesses take one-cent discrepancies seriously not because one

cent matters to them, but to make sure that the discrepancy does not hide more serious problems in their accounting system. Just as banking automation made possible large-scale fraud through the accumulation of fractional cents and round-off errors, election automation makes possible fraudulent election outcomes through the accumulation of small discrepancies in many voting precincts. Through its simple consistency check of equalities, the double-entry algorithm can detect even single-vote discrepancies, as soon as they occur. This imposes, at very low cost, a high-quality standard for election data sets and voting machines, which can only enhance the public perception of e-voting systems.

- The size of a winning margin is significant as far as a winner's mandate is concerned. Thus, vote discrepancies may not affect the final outcome, but they may still affect the publicly-perceived mandate or lack of mandate of an election winner. In the 2004 Philippine election for president, for instance, the winner who was eventually proclaimed was secretly caught in taped telephone conversations, subsequently made public, as she instructed a senior election official in manipulating election results to ensure herself a winning margin of at least one million votes.

- In many countries, the sanctity of the ballot is enshrined in their constitution, which emphasizes that every single vote–and voter–counts. To win public trust, it is best that e-voting system vendors adopt a similar attitude.

5 Basic features of a double-entry election tabulation system

This paper describes the basic features of a double-entry election tabulation system for a one-slot position (e.g., president) and for a multiple slot position (e.g., senator, where twelve slots are available in the Philippine case). The examples given are also applicable to other single- or multi-slot positions. It is assumed that voter-prepared paper ballots are used, for scanning by optical ballot scanners.
In business accounting, the fundamental equalities are **Assets = Capital + Liabilities** and **Revenue = Expenses + Profit**. In double-entry election accounting, the fundamental equalities are discussed below.
Ballots are the heart of the election process, because they represent a permanent record of voter intent, the "will of the people." In keeping track of ballots, the following **ballot equation** can be used:

Received Ballots + Excess Ballots = Cast Ballots + Spoiled Ballots + Unused Ballots + Missing Ballots

Received Ballots record the number of ballots allotted to the voting jurisdiction. Ballots end up as either **Cast** (i.e., given to the voter and filled out), **Unused**, or **Spoiled**. The total ballots cast, unused or spoiled should equal the number received, which accounts for every single ballot, at every level of consolidation. The **Excess** and **Missing** accounts are used to force a balance and transparently record anomalous situations where some ballots could not be accounted for, even after repeated efforts to do so.

6 The ballot status report

Table 1 shows a sample ballot status report for one precinct, based on the ballot equation:

Table 1. Ballot Status Report		
Ballot type	LHS (Dr)	RHS (Cr)
Received	200	
Excess	0	
Cast		45
Spoiled		3
Unused		152
Missing		0
Column Total	200	200

Under Ballot Type, the RHS accounts (Cast, Spoiled, Unused, and Missing) are indented, in accordance with common accounting practice. The LHS of the two numeric columns represents the total number of ballots received by the polling center. The RHS breaks down how these ballots ended up. The LHS total is equal to the RHS total and the report is balanced. If an imbalance exists, the reason for the discrepancy must be identified and corrected. If it persists–which is anomalous–and time does not permit another round of double-checking, the discrepancy should be recorded on the side that is smaller, as Excess or as Missing. This balances the report in a transparent manner, which allows for a subsequent audit later if the Excess/Missing accounts appear abnormally high.

In every ballot are the votes, the key to the whole process. Two equations govern the accounting of votes:

No. of Slots for Position x Cast Ballots = Available Votes
Available Votes + Excess Votes = Valid Votes + Invalid/Blank Votes + Missing Votes

For executive positions like president or vice-president, there is only one slot for the winner. Hence, the number of validly cast ballots is also the number of total available votes. For legislative positions like senator or councilor, there are usually several slots, fixed by law. Then, the number of total **Available Votes** is the number of validly **Cast** ballots multiplied by the **number of slots** available for the position being contested. Available votes can end up three ways. They can be cast as **Valid** and counted in favor of a particular candidate. They can be deemed **Invalid**; for example, a non-candidate is voted in or if two names or more are listed or marked (also called an "overvote"), or for any other reason as defined by law. Finally, an available vote can remain **Blank** (also called an "undervote"). The total votes counted in favor of each candidate plus the

Invalid/Blank votes should equal the Available Votes. The Caltech/MIT Voting Technology Project lumps together all Invalid/Blank votes that did not go to any candidate under the term "residual" votes, and studied the role of variations in county, technology, demography, and other factors that tend to increase or decrease them [AS04].

The vote equation was separately proposed in 2004 by Saltman as well as by Jones. Saltman suggested that "for each contest, the total number of ballots cast multiplied by the number of legitimate votes cast per ballot should equal the sum of votes assigned to each candidate plus the number of overvotes plus the number of undervotes". [Sa04]. Jones proposed essentially the same equation B = C + O + U, where B is the number of "ballots found in the ballot box," C is the "sum of votes for specific candidates," O is the "number of overvotes," and U the "number of undervotes" [Jo04]. Writing about e-voting systems, both authors also referred to double-entry methods, but in the context of financial transactions and business accounting. Saltman wrote: "As in accounting, where double-entry bookkeeping has been standard for about a century, there needs to be cross-checking that distributes the total responses possible with each ballot to each category that could have been used by each user" [Sa04]. And Jones wrote: "Thus, we issue carbon copies of the paper receipt for a financial transaction to both parties in the transaction, and we develop systems such as double-entry bookkeeping" [Jo04]. Neither author, however, proposed setting up special Excess or Missing Accounts, which are essential to an auditable double-entry accounting system in election tallies.

7 Vote status report: single-slot positions

Table 2. Vote Report, for President		
No. of Slots: 1	Cast Ballots: 150	
Votes	LHS (Dr)	RHS (Cr)
Available	150	
Excess	0	
Invalid/blank		12
Candidate 1		70
Candidate 2		50
Candidate 3		18
Missing		0
Column Total	150	150

Table 2 is a sample vote report for a single-slot position in one precinct, where candidates 1, 2 and 3 are hypothetical candidates.

Available Votes is equal to the No. of Slots times the Cast Ballots in the Ballot Report (taken from Table 1). Invalid/Blank Votes are the slots which have been left blank, which contain unrecognizable names, or which were not counted for one reason or another.

Procedure-wise, the main difference between the double-entry and single-entry methods is the extra work, throughout the consolidation process at every level, of keeping track of invalid/blank votes–votes in a validly cast ballot that did not go to any candidate. This extra work is equivalent to an additional candidate in every position. *This data is essential in a double-entry election accounting system, to make possible a balanced vote report.*

As in standard accounting practice, the LHS and RHS column totals (debits and credits in accounting parlance) must balance before the next step in the process can proceed. The Excess/Missing accounts can be used to force a balance in a transparent way, to document unexplained discrepancies in the count. These should also be recorded, added up, and reported throughout the process, at every level of consolidation.

8 Vote status report: multiple-slot positions

In multi-slot positions, voters may write several names on the ballot for the same position. In this case, Available Votes is equal to Cast Ballots (this number is taken from the Ballot Status Report, Table 1) times the No. of Slots (1,800 equals 150 times 12). Table 3 below is a sample vote report for a multi-slot position in one precinct.

Counting the invalid/blank votes in a multi-slot contest is only slightly more complicated, because each ballot may hold a mix of valid and invalid/blank votes. Aside from the valid votes per candidate in the contest, the number of invalid/blank votes in the ballot must also be counted and recorded. Note that for each position, the total of the valid votes per candidate plus the Invalid/Blank Votes should always equal the number of slots available for the position (12, in the example given).

Table 3. Vote Report, for Senator		
No. of Slots: 1	Ballots cast: 150	
Votes	LHS (Dr)	RHS (Cr)
Available	1800	
Excess	0	
Invalid/blank		640
Candidate 1		110
Candidate 2		105
Candidate 3		100
Candidate 4		95
Candidate 5		90
Candidate 6		85
Candidate 7		80
Candidate 8		75
Candidate 9		70
Candidate 10		65
Candidate 11		60
Candidate 12		55
Candidate 13		50
Candidate 14		45
Candidate 15		40
Candidate 16		35
Missing		0
Column Total	1800	1800

9 Special accounts: the Excess/Missing accounts

Election officials point out that a vote count at the precinct level often ends up with a few extra or missing ballots or votes which could not be accounted for. Then they simply agree among themselves to sweep these small discrepancies under the rug and send in a report with consistent totals.

Under a true double-entry system, separate accounts (often called "errors and omissions") are created and maintained, so that discrepancies which cannot be explained within the time available to the election authorities are transparently recorded under such accounts, thus maintaining the required balance between the two columns. These accounts can be called Excess (a LHS account) and Missing (a RHS account). The following algorithm will force a vote report to balance:

- compute the difference between the two column totals;
- record the difference under the column with the smaller total, as Excess if the LHS-column total is smaller or as Missing if the RHS-column total is smaller;
- recompute the column totals, which should now balance.

The Excess/Missing accounts record a potential vote padding/shaving problem, which election officials are unable to resolve immediately. Documenting the forced balance in such a transparent manner facilitates a subsequent audit should it prove to be necessary.

These accounts should be maintained, recorded and reported at every level of consolidation, together with vote and ballot counts.

10 Advantages of double-entry election accounting

If governments are slow to recognize the superiority of double-entry election accounting, the private sector, including the e-voting industry, can take the initiative in its advocacy, citing their current business accounting practices. The latter, for one, should welcome the strict consistency check on the data, which facilitates machine and software testing, helps improve software quality, and gives them more confidence in the internal consistency of their system, a clear marketing advantage. For governments, election authorities and the ordinary voter, double-entry election accounting will bring the following specific advantages:

- The double-entry method is a simple, easy-to-understand, highly standardized, and widely-known algorithm for enforcing data consistency that has withstood the test of time. Its universal use in the business sector and widespread use in the government sector attests to its superiority over the single-entry election tabulation method that is used today in most countries and localities. Failure to balance is an automatic warning about problems in the election data set. It can flag clerical errors such as recording or addition mistakes that often creep in and stay undetected when single-entry methods are used, or errors introduced into the data set by the machine or its software. It can also locate errors more easily by testing which section of the data set fails to balance.

- It provides a logical step-by-step upgrade path for electoral reform and modernization. In countries like the Philippines, where the manual system of election tabulation itself suffers from substantial flaws [Ca04], undertaking automation before existing systemic flaws themselves are corrected seems foolhardy. Introducing a new level of complexity on a shaky foundation of uncorrected systemic and procedural defects is a formula for expensive failure. Automating a flawed single-entry system could result in an equally flawed automated system that would sooner or later have to be redone. Given the costs and risks associated with any automation project, it would make sense for countries which are considering election automation to first modernize their tabulation system by adopting double-entry accounting. This simple, low-cost step can tap existing pools of expertise that even the least developed countries already have and immediately provide dramatic improvements in minimizing clerical errors, maintaining the integrity of election data, and deterring fraud.

- On the stable platform of a modern election accounting system, countries may choose to upgrade to an intermediate hybrid system that uses spreadsheet software to implement the modernized method with computers, or they can skip this step and proceed directly to full automation, using the same double-entry system. In each upgrade step towards automation, the double-entry system provides a built-in check during the period of conversion that facilitates the process, in a way that is independent of vendors, machines, and software. Existing voting machines outputs in standard formats like Comma Separated Values (CSV) or Election Markup Language (EML) can be fed to third-party software to check for consistency using the double-entry system. Later, vendors may add an accounting module in their software to tally votes using double-entry methods, as an option or as a standard feature. Whether the election only covers one position (typical in the European context) or many (as in the U.S. and Philippine context), implementing the double-entry method involves the equivalent of accounting for the votes of an additional candidate. At worst, this means 50% more work if there are only two candidates vying for a position. In jurisdictions that are required to keep track of invalid/blank votes anyway, then this is not additional work at all.

- Strictly enforcing the requirement that reports balance will instill among election officials the discipline of providing necessary information which may not relate directly to the question of who won or lost the elections, but which is essential in detecting errors and other anomalies. This information includes the number of invalid/blank votes, the number of ballots cast (or voters who actually voted), the number of excess/missing ballots, and the number of precincts tallied. Under single-entry methods, the discipline of submitting such information may be imposed through instructions and administrative orders, but local election officials may simply ignore the requirement. In the Philippines, for instance, one-third (thirty-three out of ninety-eight) of the cities and provinces submitting their reports to the National Canvassing Board in the May 2007 elections did not provide the number of precincts tallied or the number of voters who actually voted [Ha97]. Under double-entry accounting rules, officials have no option, but to provide this information or the reports will not balance. Election officials may still force a balance by using special accounts specifically meant for this purpose, but doing so will make such moves transparent and subject to subsequent audit.

- The data consistency imposed by the double-entry system sets high-quality standards among e-voting vendors, forcing them to seriously check every single vote discrepancy in their machines and their software. In so doing, it enhances the public perception of the integrity of e-voting systems. While voting machines today do incorporate their own internal data checks, these checks may vary from one vendor to another, from one software to another, and from one model to another. A change of vendor, model or software version can introduce new problems that may not be detected in time, allowing errors to creep to higher levels of vote consolidation. By adopting an election tabulation platform that is independent of vendor, machine or software, mistakes and errors can be detected as soon as they are made.

- The additional information requirement to implement double-entry election accounting facilitates fraud control. The number of invalid/blank votes and the number of ballots cast set an upper-bound on the fraudulent votes that a dishonest candidate may accumulate and help detect ballot stuffing or its electronic equivalent. The number of excess/missing ballots, if significant, can trigger deeper investigation. The number of precincts tallied enables the computation of per-precinct averages and other statistics, which are useful indicators for detecting abnormal events, such as highly improbable or even impossible statistics as well as wild swings in some averages.

11 Limitations

Double-entry accounting should not be seen as a magic bullet that will eliminate election fraud. Even in business, where double-entry methods have been in use for several hundred years, fraudulent business practices continue to be uncovered and business owners as well as consumers must remain vigilant. For instance, double-entry methods will have no effect on electioneering with government resources, election overspending, or vote-buying. It cannot prevent the suppression of votes caused by fouling up voters' lists, precinct assignments or precinct locations. It cannot prevent goons from taking over voting precincts and operating the voting or counting machines directly. For best effect, it needs to be used together with other tools for fraud detection, investigation, and control.

In particular, two common errors will not be detected. If two erroneous, but offsetting errors are recorded, preserving the equality in the two columns, the errors are not detected. Thus, the double-entry method will not detect a vote padding/shaving operation where votes are subtracted from one candidate and the same number of votes is added to another candidate. If two entries in one column are switched, the column total will also stay the same. Thus vote switching between two candidates will not be detected either.

Despite its limitations, double-entry accounting will catch most clerical errors and a number of intentional errors, as every business will testify. It will make it more difficult for fraudulent entries to enter the system, and will save time that would otherwise be spent in detecting, locating, and correcting the errors that managed to creep in. Thus the double-entry approach is still recognized as an enormous advance compared to single-entry systems in minimizing errors, improving auditability, and reducing fraud.

12 Conclusion

Ballot and vote tabulation can benefit significantly from standard double-entry business accounting methods, which involve the recording of equal values at all times. By replacing the single-entry election tally methods practiced today in most countries with double-entry methods, slow election counts due to endless disputes over errors can be avoided and canvassing fraud can be detected more easily.

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