



Paper Records and Electronic Audits

A Step Towards Regaining Voter Trust

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Abstract: *The shortcomings of the voting systems used in the 2000 presidential election raised the awareness of the need to replace these systems. As a result, with the funds of Help America Vote Act (HAVA), many US states switched to Direct Recording Electronic (DRE) voting systems before the 2004 elections. Unfortunately these paperless voting machines were not as secure and efficient as state officials had hoped. Since their implementation, many studies have shown the threats of these systems and their flaws. While some data security experts tried to improve these voting systems, many discouraged their use and recommended more transparent methods.*

Although, several countries in Europe and around the world have successfully utilized E-voting, many US districts and states still don't trust this technology and are returning to paper ballots. In this paper, we will propose a new system as a solution to the current problems. This approach combines the advantages of both paper ballots and Direct Recording Electronic (DRE) voting systems while avoiding the major flaws of these systems.

Keywords: US elections, Minnesota Senate race, paper ballots, E-voting, Direct Recording Electronic (DRE), Voter Verified Paper Records (VVPRs), electronic audits

The general election that we witnessed in November 2008 was proof that we are still far from a perfect election system. Despite the malfunction of DRE's around the country, the media, having aggressively focused on similar failures in 2004, did not pay much attention to the errors due to the large winning margin for then President-elect Obama. All over the world, activists and organizations lean towards paper ballots -also known as Australian ballots- assuming they are the safest and least complicated option. For example, in 2008, the Netherlands decided to go back to paper ballots and banned the use of any form of electronic voting (Loeber, 2008). Paper ballots have many advantages over E-voting machines, such as the transparency of the election process and the existence of physical evidence, which gives the ability to recount the ballots. However, it is obvious that this method still can suffer from ballot box stuffing, buying and selling votes and tampering with the ballot box during transport and counting (Cranor, 2001). To provide transparency, many states now require the addition of a paper audit trail to the electronic voting machine (VerifiedVoting, 2008). Unfortunately, due to many potential security threats and performance issues, the use of paper audit trails is not the optimal solution (Ansari et al., 2008).

Another advantage of the Australian ballots is the simplicity. For example, elderly voters are more likely to successfully cast their votes using a paper ballot instead of advanced touch screen systems (Bederson et al., 2003). We believe that our proposed system combines the simplicity and transparency of paper ballots while tallying and allowing recounts in an efficient manner.

1. Minnesota Paper Ballots

The dispute over the Minnesota Senate race in 2008 shows that tallying votes correctly can still be challenging even when using straightforward paper ballots. 2,920,214 voters voted using paper ballots; unlike in the presidential race where Democrat Barack Obama defeated Republican John

McCain by almost 10 percentage points, the Senate race resulted in a tiny margin less of than 0.0075%. The Republican Senator Norm Coleman, who had held his seat since 2002, won over Democrat Al Franken by 215 votes in the initial count (Tibbetts & Mullis, 2008). This close margin triggered an automatic recount. This outcome showed that some of the voters who voted for a Democratic president did not vote for a Democratic Senator. This could be true for many reasons; however, the number of challenged ballots raised many concerns. Over 6,500 ballots were challenged by both campaigns. When the winning margin is less than 0.0075%, every ballot is important to count. Unfortunately, there were more than 6,000 cases where the canvassing board was not sure of the voter's intention. Some of the actual challenged ballots are displayed in Figures 1 and 2 (Tibbetts & Mullis, 2008).

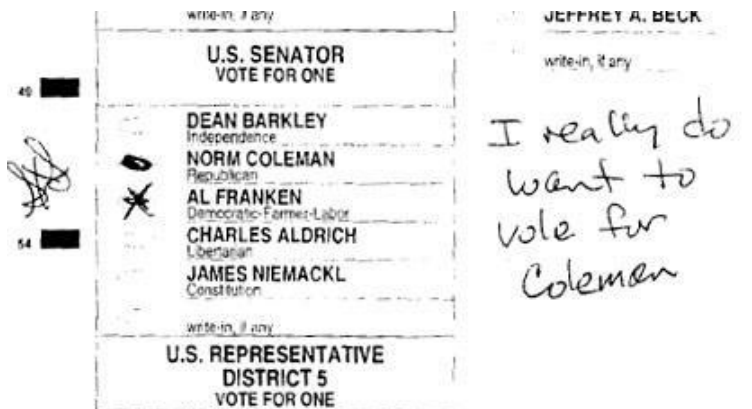


Figure 1: Both campaigns challenged this Hennepin County ballot with the Coleman campaign saying the voter's intent is clear and the Franken campaign saying what appears to be initials constitute an identifying mark on the ballot (Tibbetts & Mullis, 2008).

The recounting process, which lasted for about three weeks, resulted with Republican incumbent Norm Coleman leading Democrat Al Franken by 188 votes (Tibbetts & Mullis, 2008). However, on December 15, 2008, the state canvassing board began inspecting disputed ballots in Minnesota's US Senate recount. The canvassing board asked both campaigns to reduce the number of disputed ballots to be inspected. By January 5, 2009, the canvassing board certified the results of the recount with Franken holding a 255-vote lead. Coleman's campaign filed an election contest with the Minnesota courts, and by May 2009, the challenge is still far from being resolved. The recount is an expensive proposition with both campaigns asking for donations to fund it.

The huge number of challenged ballots points out one of the shortcomings of the Australian ballot system. The use of paper ballots allows voters to overvote and mark or sign their ballots. The use of E-voting could have minimized or even eliminated the challenged ballots; as a result, the recounting process would have been accomplished faster. This promised efficiency requires that the E-voting machines function properly. In previous elections, E-voting machines have failed to record thousands of votes. These machines also caused many troubles during the 2008 general elections, especially in Philadelphia, Pennsylvania, where officials had to issue and use emergency ballots on Election Day (Borenstein, 2008). When it comes to the recounting process, many activists and data security experts would rather spend weeks recounting than using a DRE machine that will give the same results for every recount. This is because many of the current E-voting machines do not provide any auditing method. However, recently many states have begun to require their electronic voting systems to be equipped with voter verified paper records (VVPRS) (VerifiedVoting, 2008). These machines are supposed to generate paper records that can be used for recounting purposes. Further on, we will discuss and explain the limitations of such an auditing approach.

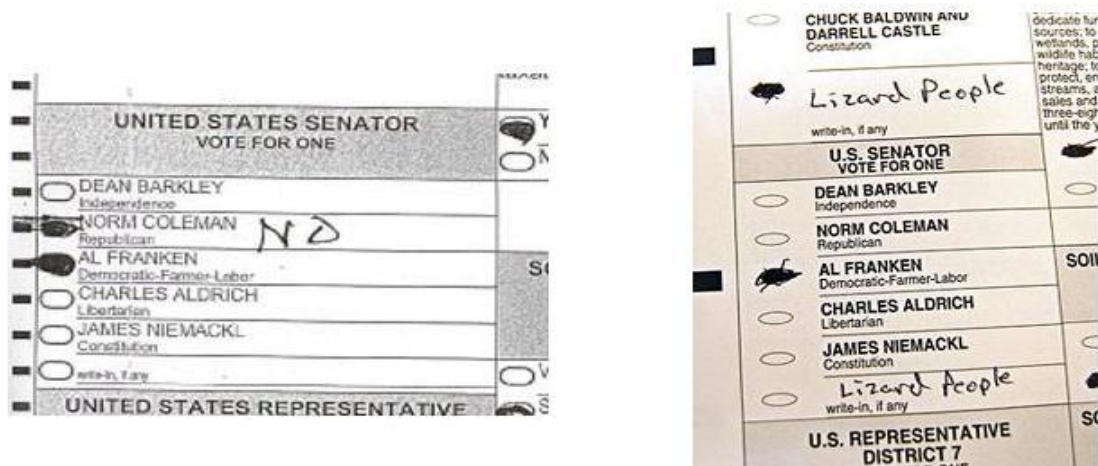


Figure 2: Left: This ballot was challenged in Dakota County because two ovals were filled in. Minnesota law says a ballot is valid if election officials can determine the voter's intent. Right: The voter cast the ballot for Al Franken, but also put "Lizard People" as a write-in candidate, not only in the U.S. Senate race, but for several others. The county auditor/treasurer ruled that the vote should not be counted because it's considered an overvote (Tibbetts & Mullis, 2008).

2. Verified Voting Methods

Activists, politicians, and data security experts all over the country are encouraging the addition of paper audit trails to the current DREs. A DRE without a paper audit trail means that every recount will give the same result. It also means that voters and election officials must have blind trust in the vendor that developed the machine. A paper audit trail compensates for many of the shortcomings of DREs. Paper audit trails can be used as a backup for the DRE in case of an intentional or unintentional failure. They also provide the voter some assurance that his vote was recorded as intended. No one can deny the importance of paper audit trails; however, many recent studies show that even paper trails have their own drawbacks. These drawbacks include the security of the printers and the occurrence of paper jams. The ability to count votes in a relatively short time is the major advantage of DRE machines over paper ballots, as counting the paper trails manually can be time consuming. Another study shows that around 63% of voters fail to notice errors on the summary screen and the paper trail (Everett, 2007). Given these findings, it sounds logical to assume that audit paper trails are not a perfect solution. A study by MIT Media lab has proposed a new idea for an audio audit. The proposal for a Voter Verified Audio Audit Transcript Trail (VVAATT) would work similarly to the printer trail except that the audit created would be in an audio form instead of on paper (Selker & Cohen, 2005). Voting booths with audio trails provide voters with headphones. Each time the voter makes a selection, he hears a confirmation in the headphones. For example, if the voter selects candidate X, the DRE will say "selected candidate X". The DRE audio output is also passed to the VVAATT recording unit which records the voting session on some physical medium such as an audio cassette (Cohen, 2006). The proposal assures that the recorder will only record what the voter hears in his headphones. However, the idea of an invisible audit method is still very hard to digest. The main idea behind equipping DREs with audit trails is to provide physical evidence to assure the voter that his vote was recorded as intended. There is no doubt that monitoring the performance of a printer is more feasible than that of an audio recorder.

In a study that compared paper audit trails and audio audit trails (Cohen, 2006), a group of voters was asked to vote on two machines, each having one of the mentioned auditing methods. The voters were instructed how to cast their votes. Both auditing methods had the same intentional

errors and the voters were asked to report the errors they detected. The idea behind this study was not to test and compare the performance of each auditing method, but to find out which auditing method helped the voters to detect the errors. There were two kinds of intentional errors in the audit trails: vote flipping and a missing race. Since audio audits provide immediate feedback, it was easier for voters to detect vote flipping using the audio audit. On the other hand, it was much easier for the voters to detect the absence of a race on the machine that provided the audit paper trail. Knowing how the audio audit works, these results were not surprising. A voter who selects candidate X and immediately hears a message saying: "candidate Y selected", is more likely to detect this error than a voter who checks his choices at the end of the voting process. However, in the case of a missing race, a voter who selects candidate X will not hear any audio feedback and thus may not pay attention. On the other hand a voter using the paper trail is more likely to notice a missing race. The study also revealed that the majority of the voters preferred dealing with paper trails since it was simpler and provided physical evidence of their choices.

As we mentioned before, counting paper trails manually can be time consuming. The MIT study mentioned that tallying audio audit tapes can be done in a timely manner using special software. This approach might complicate the situation rather than simplify it. Having software to audit results produced by an E-voting machine might create unease among voters who already lack trust in E-voting. The concept of integrating the audit phase within the voting process can be very helpful. The audio audit mechanism provides immediate feedback to the voter via the headphones (this is a feature that most of the current machines have). Voting machines with paper audit trails provide headphones to be used by the visually impaired. Using headphones provides immediate feedback to voters regarding their selections. The only difference is that a machine with audio audit will record the audio feedback that voters hear; whereas, no tape recording happens in the DREs with paper trail. It is highly encouraged that not only visually impaired, but all voters use the headphones (Wallach, 2008). In this way, voters will be notified instantly if they selected the wrong candidate due to a screen miscalibration. Indeed, the use of headphones while voting can be an extra precautionary step for voters before checking the paper audit trail.

3. DRE and VVPRS Requirements

Equipping a voting machine with a paper audit trail is not enough. Both the DRE and the auditing tool should meet many requirements. These requirements differ slightly from one state to another. For example, the Attorney General's Office of New Jersey issued requirements for DRE machines equipped with printers (Ansari et al., 2008). These requirements include the following:

- Privacy requirements: ensuring the privacy of both voters and records.
- Security requirements: maintaining the secrecy of the whole system.
- Verification requirements: voters must be able to review their votes before they cast them.
- Functionality requirements: ensuring that the machines will operate smoothly on Election Day.

4. Our Proposed System

The system we are proposing is a hybrid of the Australian ballot and Direct Recording Electronic systems. As evidenced by the Minnesota Senate race, paper ballots have their own disadvantages. Providing pens and ballots to voters gives them more freedom than necessary. While the main purpose was to mark the oval next to the voter's candidate of choice, in Minnesota, many voters chose more than one candidate. Others circled or crossed out some of the candidates' names, used pencil instead of pen, and even signed their ballots. All these actions led to ballot rejection. A DRE might be able to reduce many of these unacceptable markings; however, DREs equipped with paper audit trails are confusing and have their own drawbacks, such as unwieldy recounts and lack of voter attention. One study shows that as many as 63% of the voters fail to detect errors on the paper records or summary screens (Everett, 2007). To ensure that voters thoroughly examine the audit records, our voting system integrates the auditing within the voting process.

In verified voting methods, votes are recorded electronically and auditing is done by counting the paper trails. However, our system treats the paper records as the primary votes, and auditing is performed electronically. We hope that this approach will increase voter confidence since the paper the voter marks is the one that is tallied.

4.1. System Components

In our system, which consists of mechanical and electronic parts, each candidate is allocated a specific spool on which his votes will be recorded.

4.1.1. Mechanical Part

This part contains several rows of compartments; each compartment can occupy one spool at most. Each candidate is assigned a spool, and each race is assigned one row of compartments. The number of occupied compartments depends on the number of races and the number of candidates in each race. For example, if a race has four candidates, then the first four compartments of that row will be used. The mechanical part is customized in a way that resembles a paper ballot. To prevent the voter from physically touching the spools, a glass shield will be used to cover the top of the mechanical part. The only way to mark the spools is by using the marker attached to the system. The marker's movement is restricted; it can only be moved along a set track. This track, which runs under all the compartments, is designed in such a way that it can reach all compartments. Depending on the election, the tracks can be configured so that the marker cannot reach unoccupied compartments. The marker, which is used to spray ink, serves the same purpose as a regular pen. However, the use of the marker will not allow voters to overvote or perform any action that compromises the integrity of the ballot. For each race, the marker will release ink only when positioned over a spool and will not spray ink for more than the allowed number of candidates.

The proposed machine will assign a specific spool to each candidate in the chosen races. Each of the spools will be divided into sections, and each section will have the name of the candidate visible to the voter. The back of the paper roll sections are also sequentially numbered. At any voting session, only one section of any spool will be visible to the voters (see figure 5).

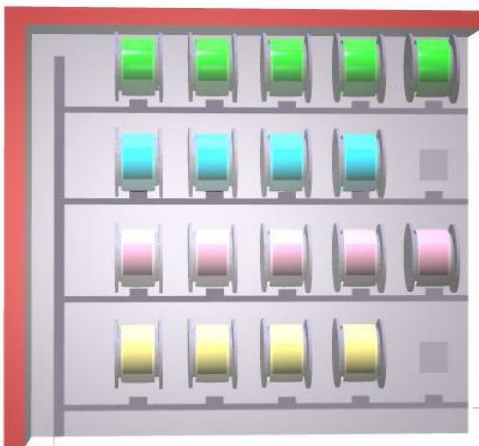


Figure 3: A partial view of the mechanical part. The top is covered with a double glass pane for illustration purposes (the voter's actual view is shown in figure 4). Notice that the figure displays four races; the first and the third race contain five candidates each; whereas, the second and fourth races contain four candidates each.

In order to read and store the chosen spool electronically, the marker will be equipped with a bar code scanner or a camera based reader. This way, the marker will notify the electronic part of the spool it is pointing at by scanning the barcode of that spool or by using the camera to read the candidate name on the spool. The latter way requires the use of digital paper to create the paper records.

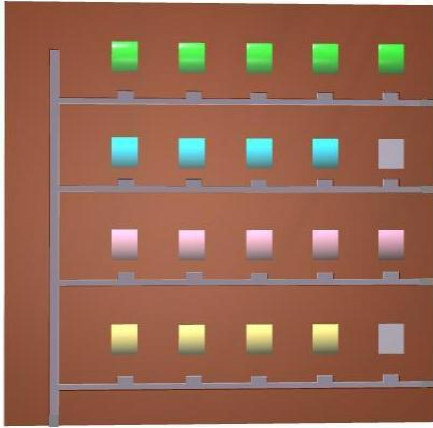


Figure 4: Shows a part of the voter's actual view. A glass pane covers the mechanical part, so the voter will not be able to touch the paper records. The voter can move the end of the marker over the track, but cannot touch the tip of the marker since it goes under the glass pane. The glass pane can be created in a way to magnify the spools. The marker (not shown) will be repositioned at the top left corner where it is refilled between the sessions. The marker will not be able to reach the empty compartments since the track will be physically blocked after the last occupied compartment.

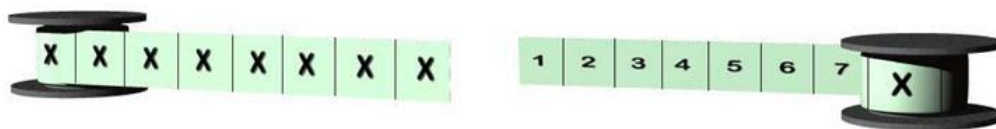


Figure 5: Left: Shows a spool for candidate X. Note that the candidate's name will be written on every section of the spool. Right: Shows the back of candidate X's spool. Election officials can find the number of votes by looking at the back of the last marked section, assuming the front of all previous sections were consecutively marked. Tallying can be achieved in a relatively short time compared to regular paper ballots.

4.1.2. Electronic Part

This part is responsible for storing the voter's selections electronically. The voter will be interacting with this part through a touch screen. For example, once the voter places the marker over a candidate spool, the screen will display a message with the candidate's name and the race he is running. Beside communicating and providing directions to the voter, the screen asks the voter to verify his selection. The electronic part also includes three colored buttons: mark, confirm and cast. The mark and confirm buttons are both used to spray the spool the marker points at. This way, the voter will be asked to confirm each selection twice before casting his vote. Requiring this additional action on the part of the voter addresses the lack of attention issue we previously

discussed. At the end of the voting session, the voter simply presses the cast button to cast his ballot. The green cast button will be located below a translucent cover so the voter will not press it by mistake.

4.2. Election Day

Once the voting session starts, the voter will move the marker towards the spool of his candidate of choice. Once the voter places the marker over a candidate's spool, the name of that candidate and the race he is participating in will appear on the electronic screen. The electronic screen will display a message asking the voter to press the mark button if he wants to mark that spool. If the voter presses the mark button, a new message will appear asking the user to confirm that he is willing to vote for that candidate by pressing a confirm button. The voter then has the choice to confirm or move the marker to another candidate's roll. If the voter confirms his action, the spool is sprayed, and the vote is counted electronically by incrementing that candidate's counter by one. Notice that the verification takes place within the voting process. By asking the voter to confirm his choices one at a time before moving on to the next race, the voter will be more likely to detect any mistakes he made or any mismatches between the paper records and the electronic records. This will eliminate the need for the voter to review his ballot at the end of the session. Not allowing the voter to change his final selections will mitigate the risk of certain malicious devices. Such devices could display everything correctly to election officials yet lie about the tallies and changes each candidate received to produce completely consistent, but erroneous results. However, since our system will take every sprayed section into consideration and none will be voided, this kind of attacks is avoided.

At the end of the voting session, the voter casts his ballot by removing the translucent cover and pressing the cast button. This will rotate all the marked spools to the next section, revealing clean spools sections for the next voter.

4.3. Tallying and Auditing

Counting the votes can be done by numbering the back of the paper rolls sequentially. After the polls close, the election officials will take the spools out of the machines. Each roll will be marked a specific number of times, each mark indicating a vote for that candidate. The number at the back of the last marked section is the number of votes the candidate has, knowing that the front of all previous sections were sprayed. For example, if a candidate's roll was marked until the 100th section, then this would mean that the candidate has 100 votes. The rest of the paper rolls can be tallied the same way. This approach allows the manual counting of ballots at a reasonable speed. The auditing can be done by comparing the number of marked sections on the candidate's paper roll with the electronic counts stored by the machine.

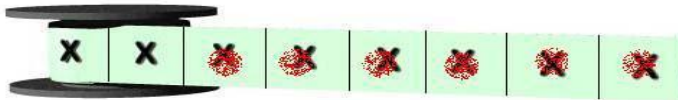


Figure 6: Shows a spool for candidate X with marked sections. The number of the red marks indicates the number of votes for candidate X.

Since the voter marked the paper records using a marker and confirmed his selections by pushing a series of buttons, we expect the process to be more memorable than it would be had he just cast his vote by a single touch screen selection. Using the proposed machine, the voter will be

more likely to detect errors on the screen before casting the ballot electronically. We assume that this method will be able to reduce the number of rejected ballots by restricting the voter's ability to perform ambiguous or distinguishing markings as were witnessed in Minnesota's Senate race.

4.4. Meeting the Requirements

As with any computational device, it is impossible to be 100% sure of the DRE's accuracy, integrity and reliability (Mercuri, 2002). This was the main reason behind producing physical audit trails. However, since the majority of voters are unlikely to notice the audit trail, its purpose is defeated. Our system provides the voter with the ability to mark the paper records, which will be used to determine the final result of an election. Allowing the voter to cast his vote using a physical record mitigates the risks of large scale manipulation.

In this system, the paper records are secured within the mechanical part and can only be replaced by election officials once notified by the system. The system will also be designed in a way to ensure that no spool will be placed in the wrong compartment. The security of the electronic audit records is ensured by implementing highly advanced encryption methods. To ensure voter anonymity, the system will mix the records using a mixing protocol before the decryption process.

In order to mark any paper roll, the voter will be asked to compare the name that appears on the screen to the name on that roll. Asking the voter to verify his selections while voting will lengthen the process slightly, but it will ensure that the votes are recorded as intended.

We also hope that our system will prevent the buying and selling of votes. Unlike DREs that generate single paper records including all voter selections, the ballot we are suggesting consists of separate paper spool records, making it harder for vote sellers to prove that and how they voted. To prevent potential theft of the spools, each spool will be scanned before being installed. The system should be able to detect and notify election officials in case of any malfunction or missing spool. Additionally, the system will be provided with a reserve battery in case of a power source failure.

4.5. Straight Ticket Option

Some US states' DREs offer a straight party option. This method allows voters to cast their votes for a specific party, in all the races listed on the ballot, in one click. The idea behind providing the straight ticket option was to allow voters with specific party preference to vote faster. For example, a voter who considers himself a Democrat can choose a straight Democratic Party ticket, and this will cast a vote for the Democratic candidate in every race. We hope that our system will allow voters to take advantage of the straight-ticket option. The straight-ticket option is supposed to provide ease for many voters; however, the poor implementation of this option on current DREs has led to a high ratio of undervoting and mass confusion.

The ambiguity of the straight-ticket option makes it a bad practice. For example, in North Carolina, the straight-ticket voting option affected every race except the presidential race. Unfortunately, the majority of the voters did not read the instructions and thus assumed that using the straight-ticket option would cast their vote in all the races when in fact, it did not. As a result, North Carolina had one of the highest presidential undervote rates in the country (North Carolina Voters, 2008). Indeed, a straight-ticket option can make the election process run smoother; however, this method must be implemented in a clear manner. We believe that our system can implement the straight ticket option efficiently. Each party that has the straight-ticket option will be assigned a specific spool. For example, in Texas the 2008 DREs provided a straight-ticket option for the Democratic, Republican and Libertarian parties (Wallach, 2008). Once the voter confirms his decision and marks one of these spools, this will cast votes for the candidates of that party in all the races they are running. After that, the voter will not be able to mark other spools leading to overvoting. Keep in mind that the voter will need to confirm his choices by following instructions on the electronic screen before marking any spool. This will ensure that the voter is fully informed of how his votes will be recorded.

5. Future Work

Our proposed system is still in its first phase and is subject to minor changes during development. While the main concept will be the same, our system can be adjusted to allow write-ins by adding a write-in spool for the races that provide this option. Once this spool is sprayed, the voter can insert the name of the candidate using the touch screen. Notice that, this way if the election officials decide that the write-in constitutes a distinguishing mark, only this race will be rejected. The machine will ensure that no spool is marked more than once and no overvoting will occur. Also we are currently studying the necessity of using a mixing protocol and other related security measures in order to ensure voter anonymity.

6. Conclusion

In this paper, we mentioned and discussed some of the problems that current US voting systems present. Until the late 1860's, the majority of the United States was against the Australian ballot system. Back then, politicians and government were not convinced that the voters' choice should be kept anonymous. Today, the Australian ballot system is still used due to its simplicity and transparency. Even though Minnesota is still unable to announce the recipient of the 2008 senate seat, as of May 2009, some data security experts still believe paper ballots are the best option. On the other hand, the idea of equipping DREs with a verified paper audit trail was introduced several years ago. However, the practical development of this idea is still questionable. The studies we pointed out show that the majority of the voters fail to detect the mismatches between their electronic ballot and the paper trail. Our proposed system would combine the transparency of the Australian ballot with the fast performance of E-voting systems.

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