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An approach to develop a methodology for functional requirements to secure an electronic voting system

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ABSTRACT

The election process is in need of a standard and secure electronic system that voters can rely on and have trust in. Currently, each state implements its own process for voting; the lack of consistency between polls results in numerous problems. Various models have been developed to address the issues of security, privacy, validation, and quality control. However, these models do not meet all of the requirements needed for a good system. Exploring electronic voting from a systems perspective can demonstrate the commonalities of the current systems and the possible solutions for the voting process.

Keywords: Electronic voting, Security, Privacy, Standards, Quality Control, Social Acceptance

I INTRODUCTION

The systems perspective looks at interrelated components that function together for some result. When looking at the "big picture" analyzers can see how each part relates to the whole system. This methodology usually results in multiple answers to problems as opposed to one correct solution. Electronic voting (e-voting) is a process that takes an immense amount of input, processes the data with the use of various technologies, and produces one output. These technologies are described later. Due to numerous current issues, e-voting is seen as a procedure that brings more problems than solutions to our society; however, e-voting is likely to be an inexpensive and less time consuming method for all users involved if a reliable and secure system is utilized.

II HISTORY

The timeline below depicts the history of voting in the United States.

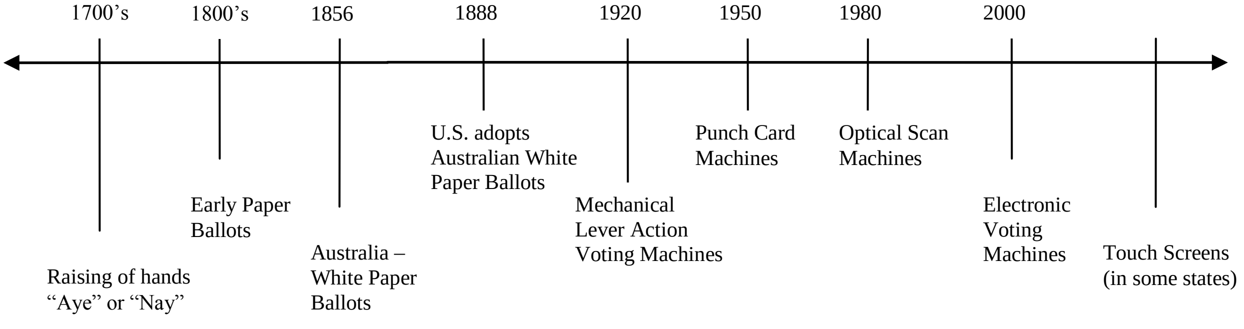

Figure 1. Timeline of Voting

2006

Our country has progressed considerably from the raising of hands to the use of machines in the voting process. The early paper ballots of the 1800s had no standardization whatsoever. Voters could add names to the ballots and because there was no method to verify the identity of the voter, could even vote at multiple locations. The United State recognized a need for a standardized ballot in 1880, yet they did not implement Australia's White Paper Ballots until 1888; Massachusetts was the first state to do so. (Saltman, 2006) Note that implementation was not nation wide. The type of machines in the voting process has evolved from a mechanical type to an electronic type, falling in line with technology advances. It is interesting to note that the mechanical lever action voting machines had no paper attached to the process. After the voter entered the poll, they would push a lever for each candidate choice. When lifting the handle to exit the poll, which opened the privacy curtain, the levers would move back to their original position causing a connected counter wheel to turn. There was no paper audit trail available to recount votes, but by this time, voters did have to verify their identity and sign their names in a book. From the 1950's on, paper is in the majority of voting processes as a means of verifying voters and as an audit trail for election results.

III AN ANALYSIS

There is strong evidence that the current e-voting systems are flawed. In analyzing the commonalities of these system failures, general characteristics for all failures will be established. The list below depicts systems' failures that have occurred beginning with the November 2000 election.

2000

- Florida - Hanging chads and butterfly ballots cause frustration at many precincts. (Mercuri, 2003)

2002

- Florida - "A faulty memory card" is cited as the cause of miscounted votes. Experts and technical staff dismissed this "cause" as implausible. (Anderson, 2006)
- Georgia - County claims e-voting machines are faulty. Because no paper trail is required, there was no method for a recount. ("E-voting", 2006)

2003

- Florida - Votes were tabulated in 644 Palm Beach precincts, but only 643 precincts exist. A court case found the same discrepancy. (Anderson, 2006)
- New Jersey - Votes were tabulated in 104 precincts, but only 102 precincts exist. ("E-voting", 2003)
- North Carolina - A programming error caused e-voting counting machines to skip several thousand votes. When fixing the error 5,500 votes were found, reversing the election results. (Anderson, 2006)
- Virginia - Machines failed when 953 voting machines called in simultaneously to report results. Fifty percent of precincts were unable to report results until the following day. Other voters complained that after indicating a candidate choice the selection would "go off." If the voters had not noticed, their

votes would have remained uncounted. It is not clear how many voters were affected by this issue. ("E-voting", 2006)

2004

- California - Non-functional voter card encoders infuriated voters from two counties. (Mercuri, 2003)
- California – An optical scanner was improperly calibrated resulting in 6,692 absentee ballot votes overlooked. (Mercuri, 2003)

2006

- Florida -Three Democratic candidates were displaying as Republican. Election officials attributed it to calibration errors in the touch screens. (Mercuri, 2003)
- Colorado - Officials asked federal judges to extend voting hours because voting machine were malfunctioning and could not handle the numbers of voters at the polls without more time. ("E-voting", 2006)
- Indiana - Seventy-five precincts failed to open on schedule because machines malfunctioned. ("E-voting", 2006)
- Pennsylvania - A programming error forced some to cast paper ballots affecting 175 precincts and resulting in extended poll hours to make up for delays. ("E-voting", 2006)
- Maryland/Ohio -Polls do not open on time as the Board of Elections failed to get "voter access cards" necessary to operate the e-voting machines. Some voters never did vote because of the delay. ("E-voting", 2006)

Reliability, security, usability, and consistency are the most prevalent downfalls in this list. The list does not include incidents of politicians demanding recounts, attributing fictitious results to faulty electronic machines. It also does not include all of the voter complaints about hard-to-use electronic machines that would not read ballots and required substantial amounts of time to use resulting in the lines shown on many evening newscasts. However, the list does not illustrate successes with e-voting systems either. Though Napa County experienced minor problems in March of 2004, they say that voters liked the touch screens and that the county saved printing costs. The officials at the poll in Napa said it only took eight seconds to tally each cartridge of votes. ("E-voting", 2006) In November 2004, Nevada had great success with e-voting machines; there were few problems. They used electronic voting machines, but also had a paper trail as a means to use for a recount if necessary. ("E-voting", 2006) These success stories demonstrate the potential for e-voting to be inexpensive and less time consuming to administer. Eventually e-voting may be a viable solution to increase voter participation in governmental elections as well. However, if not carefully designed, e-voting systems can be compromised, corrupting results with no method to verify original data, violating voters' privacy, creating queues of frustrated voters, or complete disintegration of the integrity of the system as a whole. In other words, exhibiting the same problems with reliability, security, usability, and consistency.

IV A GOOD E-VOTING SYSTEM

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The following is a description of desirable characteristics that should exist in any good system and the reason for each characteristic with respect to the voting process.

Accuracy. "A system is accurate if (1) it is not possible for a vote to be altered, (2) it is not possible for a validated vote to be eliminated from the final tally, and (3) it is not possible for an invalid vote to be counted in the final tally." (Cranor & Cytron, 1996, p.2)

Accuracy is one of the most important factors to any system. If the input is not correct, then the result will not be correct; garbage in garbage out (GIGO). Not only should the system be accurate in counting votes and maintaining the integrity of cast ballots, the system should be accurate in identifying voters. Some of the problems in Florida and New Jersey could have been prevented by checking that the number of precincts reporting matched the number of existing precincts.

Verifiability. "A system is verifiable if anyone can independently verify that all votes have been counted correctly." (Cranor & Cytron, 1996, p.2)

Currently, many experts believe that the best method to verify votes and perform recounts is with paper ballots. However, in Georgia, it was impossible to perform a recount in 2002 because some counties did not have any paper trail to audit. In addition, the voter should be able to verify that their ballot is entered correctly and allow them to adjust their vote if necessary. The process needs to verify the validity of the voter as well. Perhaps the use of a nation wide database of registered voters' information and a method of non-intrusive biometrics could identify participants. The system should also verify that the electronic system has not been compromised. This includes validation of the physical machines for consistency (quality control) and for material weaknesses.

Democracy. "A system is democratic if (1) it permits only eligible voters to vote and (2) it ensures that each eligible voter can vote only once." (Cranor & Cytron, 1996, p.2)

This characteristic can be accomplished by incorporating accuracy and verifiability. Currently, many counties require that voters vote in their own precinct so that they can sign their name in the approved voter list. Some counties have implemented a database that tracks voters. A voter must be able to show proof of their identity; the database is then updated, which prevents that voter from going to another precinct and voting again.

Privacy. "A system is private if (1) neither election authorities nor anyone else can link any ballot to the voter who cast it and (2) no voter can prove that he or she voted in a particular way." (Cranor & Cytron, 1996, p.2)

Privacy is a concern to all users of a voting system. While it is important to have an audit trail available to verify the system, aggregate data should be accessible as opposed to an individual's vote. Some voters have problems using the voting machines, this requires that a staff volunteer assists them and this can interfere with the privacy of the voter. "The second privacy factor is important for the prevention of vote buying and extortion. Voters can only sell their votes if they are able to prove to the buyer that they actually voted according to the buyer's wishes." (Cranor & Cytron, 1996, p.2)

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Convenience. "A system is convenient if it allows voters to cast their votes quickly, in one session, and with minimal equipment or special skills." (Cranor & Cytron, 1996, p.3)

The introduction of touch screens into the voting process was first used to aid the disabled population. (Bellis, 2007) This increased convenience of touch screens could lead to higher voter participation and decreased time at the polls. If the system utilizes technology that society is already comfortable using, voters will perceive the system to be more convenient.

Flexibility. "A system is flexible if it allows a variety of ballot question formats, including open ended questions. Flexibility is important for write-in candidates and some survey questions." (Cranor & Cytron, 1996, p.3)

It is probably less common now for voters to write in candidate choices; however, the system should be dynamic especially in our ever-changing fast-paced society. This means the system, if designed properly, could be used for not only national elections, but state and county elections as well. Additionally, the system should be able to accept more than one method of input to accommodate both voters at the polls and absentee ballots.

Mobility. "A system is mobile if there are no restrictions (other than logistical ones) on the location from which a voter can cast a vote." (Cranor & Cytron, 1996, p.3)

Mobility in the system could allow voters the capability of voting anywhere Internet access is available. This characteristic is better suited for an online e-voting system. However, the designs of the physical machines need to be small enough to accommodate various polling locations where space could be an issue.

While usability is definitely a concern in looking at the list of system failures, Cranor and Cytron (1996) compare this characteristic to convenience. However, some of the underlying system problems affect characteristics that are not described by Cranor and Cytron. This author proposes the following three additional characteristics needed for a good e-voting system.

Reliability. A system is reliable if it performs and maintains its functions continuously.

Reliability in the system requires that there be alternative methods should failure occur. For example, in the event of a power failure, the system should have an uninterruptible power source or an alternative paper method. Many polls did not open on time because of machines malfunctioning.

Consistency. A system is consistent if it operates efficiently at each location, in each situation, and the functions perform exactly as designed.

Each voting machine must be an exact duplicate of the other to ensure consistency and quality control. This also increases usability as the voting process does not vary between locations, especially important for our mobile society. The implementation of national standards would support the consistency requirement. Audit testing of the system would be easier because of consistency between voting locations.

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Social Acceptance. A system has social acceptance if it has favorable reception and is perceived as being an effective system by the voting population.

It can be easy to overlook the users involved in a system. Even if the system is sound, users are what make or break the system. Perception is crucial. Currently, society views the majority of e-voting as inaccurate, unusable, and not private. "We used to have a problem with giving people the wrong ballots. And if we were lucky, we'd catch it before they voted. Now if the same thing happens with a touch screen, it's a conspiracy" (Duffy et al., 2006, p. 39). The e-voting system must be perceived as being the best method available for the voting process.

Standards

In addition to these general system characteristics, the system must be implemented nation-wide and with national standards especially for national elections. Currently we have no national standards because each state and county is fiscally responsible for the purchase of the physical machines and all costs associated with the voting process. (Mercuri, 2003) If a state is seeking accreditation of their voting system, they must undergo independent qualification testing; however, only 40 states are currently participating and individual state laws vary for the actual testing. (Coggins, 2004) Standards need to be in all aspects of the system. The system should use standardized physical machines (quality control), standard procedures for verification of voters, and standardized policies and procedures for the voting process. The Institute of Electrical and Electronics Engineers (IEEE) is working on Project 1583, which is a description of standards that all voting machines should meet. The committee includes the top two vendors of electronic voting machines, ES&S and Diebold. (Grossman, 2004) All vendors of electronic voting machines would have to conform to these standards in order for their products to be utilized in governmental elections. The 2003 vote on acceptance of the current draft of standards failed. The committee continues to work on a new draft; however, the standard was not implemented for the 2006 elections and it is unclear as to when they will be finished. (Grossman, 2004) Once standards are implemented, they need to be maintained and updated.

The American National Standards Institute (ANSI) coordinates the development and use of standards in the United States. The Institute has overseen the creation, and use of thousands of standards including construction equipment, dairy and livestock production, energy distribution, and many more. ANSI is also actively engaged in accrediting programs that measure compliance to quality control and environmental standards. (Morley & Parker, 2007) There are also many national educational standards for teachers and students. The implementation of these standards, as well as the success of these standards, is in part due to the national funding that is available to help states comply. (Coggins, 2004) The IEEE is one of the world leaders in developing standards for today's leading technology. (Grossman, 2004)

Society has the available tools necessary to implement a nation wide set of standards for the e-voting system and design. ANSI and IEEE are excellent examples of organizations that have been successful in creating and distributing standards that have had direct effects on business, economics, technology, and many other areas. An independent qualification testing method could be implemented for the purpose of creating and testing the physical machines, the voting process, and compliance with national standards.

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eVACS

One such model exists where extensive independent qualification testing is used. A private Australian company has not only created a model of an e-voting system, but also implemented this system in eight polls as a pilot group. The system is called Electronic Voting and Counting System (eVACS). (Zetter, 2003) EVACS has two parts: e-voting and electronic counting. Each step of the development process for this system was verified with independent election officials. They used open source software. “We'd been watching what had happened in America (in 2000), and we were wary of using proprietary software that no one was allowed to see. We were very keen for the whole process to be transparent so that everyone -- particularly the political parties and the candidates, but also the world at large -- could be satisfied that the software was actually doing what it was meant to be doing." (Zetter, 2003, p. 1) The commission posted drafts as well as the finished software code on the Internet for the public to review. The reaction was very positive.

The voting terminals are PCs connected via a network to a single "ballot box" machine, which acts as a server for the polling place, recording votes as they are cast and providing information to the terminals when necessary. The system uses bar code readers to cast each vote and reset the PC. (Zetter, 2003) They are not connected to any external network for security, and at the end of polling, the votes are physically transported from the ballot box machine to the counting (back-end) system by duplicate zip disks. (“Electronic”, 2005)

The counting aspect of the system consists of a number of data entry workstations and the counting server. The data entry workstations are used by data entry operators to enter paper (absentee) ballots. These are recorded on the counting machine, which also receives (via zip disks) the electronic ballots. “The counting server is also used to perform some of the administrative functions needed for the system, such as generating the barcodes used for authentication.” (“Electronic”, 2005, p. 2) Each machine is an exact duplicate of the other. An audit was performed to search for material weaknessess, but found none. (Zetter, 2003)

Mercuri Method

On the other end of the spectrum is the Mercuri method. This model uses voter verified paper ballot (VVPB) extensively for actual counting of votes, but does implement machines for the process of casting votes. It also allows voters to check the accuracy of their votes. In the proposed system, a voter votes on a touch-screen machine. The system records the vote electronically and the paper ballot is displayed behind a glass or plastic panel. The voter reviews the printed ballot. If it does not represent the correct choices, the voter calls an election official who voids the ballot. The voter then votes again, and upon their approval, the ballot is dropped into a ballot box for tallying. Simple procedural controls and digital seals guard the ballot boxes. Ballots can then be optically scanned for tallying or hand-counted for verification purposes. (Mercuri, 2002) Dr. Rebecca Mercuri is a member of IEEE Project 1583.

This model supports proprietary hardware and software. Companies would have to adhere to stringent standards (IEEE Project 1583) in the building of this system. Business between companies could be affected because they no longer have any competitive edge for their machines. The physical polling booths and machines are relatively large making mobility an issue.

Table 2

Comparison of Models

eVACS	Mecuri Method
Pros/Benefits • PCs & Barcode Readers – easy to use, existing and proven technology • Server-based – security • Two discs – reliability, built in redundancy • Counting Machines – fast tabulation of votes • Duplicate Machines – quality control, supports reliability	*Pros/Benefits* • VVPB – voter verifiability, audit capability, provide for a recount, reliability, voting process can continue on paper in the event of a power failure • Touch screens – easy to use • Ballot box - security
Cons/Detriments • No paper voter receipt – no verifiability or validation • Server-based – system not available online, which might be the next trend	*Cons/Detriments* • Too large – no mobility, hard to relocate • VVPB – increased costs for paper, ink, and maintenance

The eVACS model addresses the characteristics of usability, security, reliability, accuracy, and consistency. The Mercuri Method addresses verifiability, usability, and security. A better system would incorporate the benefits of both models and attempt to resolve the detriments of each model.

V OUTLOOK FOR E-VOTING

With most everyone having access to the Internet, will e-voting move in the direction of online voting? In truth, online voting already exists. Arizona's Democratic Party held the first binding U.S. election which voters could cast their ballots online. They implemented personal identification numbers (PINs) and a series of personal questions to verify the identity of voters. In 2004, Michigan's Democratic primaries were held online. In 2005, Estonia became the first country in the world to hold an election allowing voters nationwide to vote via the web. (Parker & Morley, 2007) While many citizens would probably like to vote in the comfort of their own home, the largest problem with online voting is verifying the identification of the voter. Identity thefts are an almost everyday occurrence, social security numbers are no longer a reliable means of identification. Though an online system may be able to prevent a voter from logging on and voting more than once with one username and password, it may prove to be difficult to ensure that the same person does not have multiple usernames and passwords. Possibly, with the use of biometrics, voter identification could be verified; however, many might be opposed to this solution and the access to that type of technology could be expensive. In the future, if a public facility, such as a library or college, with online access and non-invasive biometric technology could be utilized, then e-voting online may expand. However, for now, voters are not in the comfort of their homes. The need for polls, lines, personnel, and standardized machines and processes is still necessary.

VI CONCLUSION

E-voting is used today. Developing a good system is critical to the success of the system to prevent system failures and to gain wide acceptance as the best method available. A good e-voting system requires ten characteristics. These are:

When designers analyze, design, implement, and maintain standards, they need to consider these characteristics as the foundation. The standards must be national. E-voting will be an inexpensive, and less time consuming method once a system exhibiting national standards and the above mentioned characteristics is implemented.

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