DualVote

Addressing Usability and Verifiability Issues in Electronic Voting Systems

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Abstract: *Two issues that have significantly impeded the widespread adoption and acceptance of modern e-voting solutions are the lack of an intuitive user interface and the inability to formally verify the results. This paper presents the findings of an extensive analysis of public opinion on usability and verifiability in e-voting. Based on these results it describes a novel e-voting system called DualVote, which couples the strength of electronic voting with the traditional pen and paper user interface (UI). An evaluation of the proposed system is also presented, which demonstrates a high level of usability by comparison to other E-Voting solutions.*

Keywords: e-Voting, Usability, User Interface

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Initially, this paper examines public perceptions of usability and verifiability in the context of e-voting. Usability is a metric that is commonly used to assess e-voting systems. The challenge of providing an effective and easy-to-use UI has proved to be problematic for many modern e-voting solutions. Verifiability is a topical and contentious issue in e-voting. An intrinsic challenge in e-voting systems is to ensure that: (i) All votes cast are correctly interpreted and recorded and (ii) The result is correctly tabulated. Many e-voting systems have courted controversy because they lack any mechanism for independently verifying the accuracy of the election result.

This paper presents the findings of a survey which was themed on usability and verifiability issues in e-Voting. The survey was administered to a broad section of the electorate. The findings of the survey show that a large majority of voters believe that the result produced by the e-voting system should be verifiable. In addition the results highlight that the people most vulnerable to usability problems (older age categories) believe that current e-Voting solutions do not make the voting process easier and prefer to use a pen and paper interface over alternative electronic methods.

Based on the results of this survey, the authors present a novel e-Voting system called 'Dual Vote'. In the Dual Vote system, a voter's preference is recorded concurrently on both electronic and paper media. The Dual Vote system allows a user to enter a vote using the traditional pen and

paper interface, while simultaneously interpreting and recording the vote electronically. This novel UI addresses the issues of usability and verifiability which, as outlined above, are recognized as being deficiencies in many modern e-voting systems (Goggin et al. (2007), Winckler et al. (2009)). In a recent Finnish election, usability problems were blamed for 232 out of 12,234 voters not completing their voting session during the 2008 Finnish Municipal elections. The decision by the designers to use two different screens, one for first casting the vote and another for validating it, was cited as the cause of the problem by usability experts Whitmore (2008).

In elections where casting a vote on pen and paper has been the traditional method for many years, allowing voters to cast their ballot using this method greatly simplifies the issue of usability as voters are already accustomed to the traditional pen and paper interface. The paper copy of the vote is retained. Hence, the electronic results of the Dual Vote system can be verified by comparing the paper and electronic results.

The usability of the Dual Vote system is subsequently assessed by surveying the voters who participate in a trial election. The system achieves a high usability score that compares very favorably with alternative e-voting systems. Significantly it also shows a high usability across all age categories.

The next section of this paper provides an overview of the interface aspects in e-voting. It then presents the results of the public survey, which was used to assess perceptions to verifiability and usability. The paper subsequently provides a description of the Dual Vote system. A usability evaluation of Dual Vote is then presented and finally conclusions are drawn and future directions of research are identified.

1. Related Work

Electronic voting systems present a unique challenge to interface designers as they must be usable by every citizen who has reached voting age. In a given population, the electorate base is highly diverse and their exposure to the voting interface is limited due to the fact there may be months or even years between subsequent elections. Therefore the voting machine interfaces must be immediately intuitive so that a user can accurately cast their vote. Usability of mechanical voting came to mass attention during the 2000 US presidential election with the ‘hanging chads’ controversy. A chad refers to a perforated square of paper which the voters were required to remove from the ballot paper indicating their intent for a particular candidate. There was much debate concerning what constituted a perforation and election officials were required to visually determine if a voter intended to push the chad all the way through the paper or whether an impression was accidental. As a result of these and related events, the Help America Vote Act (HAVA) was passed to allow for the widespread deployment of Direct Recording Electronic (DRE) e-voting systems. These DRE systems embodied a touch screen user interface on which the voter selected their candidates. Some later voting machines included an optical scanner so that the voter could cast their vote on paper which could then be scanned by the machine. The usability of these machines received little attention after their widespread adoption. A number of studies have highlighted usability issues with DRE’s and optical scan systems. For example Bederson et al.(2003) found that 10% of elderly voters had concerns as to the usability of the machines.

Byrne et al. (2007) proposed criteria for assessing the usability of different systems. These criteria are based on the ISO standard 9241-11 and the US National Institute for Standards and Technology (NIST) report on voting system usability (Laskowski 2004). Three metrics for gauging the usability of a system were recommended: effectiveness, efficiency and satisfaction.

Effectiveness is a measure of the accuracy of the system. In terms of electronic voting, accuracy means that the vote cast was correctly recorded for the candidate for whom the voter intended to

vote. Efficiency measures whether the voter's goal was achieved without expending an excessive amount of resources, for example, the time required for the voter took to vote. The latter metric, satisfaction is the focus of our study. Satisfaction is a subjective metric measuring a user's subjective response to interacting with the system. In many studies centered on electronic voting usability, voter satisfaction was gauged using a standardized instrument of measurement. The NIST report recommended Likert scale questions, such as the System Usability Scale described by Brook et al (1996), as a means of assessing user satisfaction. The System Usability Scale consists of ten 5 point scale questions which gauge the user's subjective response to the usability of the system.

Using the same three metrics, Conrad et al (2009) conducted a laboratory study using six different commercial electronic voting systems to better understand what particular interface features were related to certain kinds of usability problems. Conrad reported that an over complex user interface would not only reduce voter satisfaction but could potentially alter the result of an election. This could occur particularly if the usability problems stemmed from systematic errors as opposed to errors that occurred randomly. Conrad further suggested that should such errors occur among voters who hold similar political positions, such as may be the case with elderly voters; such a group may not be able to vote for their candidate and may vote in error for the opposition. In the case where the elderly voter does vote for the intended candidate, a frustrating voting experience may cause them to avoid future elections. The study also showed that there was a clear negative relationship between voter effort and voter satisfaction. The voters reported the highest levels of satisfaction with touch screen (without attached printer) and optical scan interfaces. The touch screen interface allowed for a quicker vote while the optical scan required the least amount of actions. Clearly Conrad establishes that usability is a prevalent and ongoing concern for e-voting systems

Verifiability in an e-Voting system refers to the voter's ability to verify by some means that their vote was recorded and counted as intended. Several enhancements for voting systems have been proposed by Chaum et al. (2005) and Winckler (2009) which incorporate paper mechanisms as a means of vote verification. The most prominent method termed Voter Verifiable Paper Audit Trail (VVPAT) proposed by Mercuri (2002), allows the voter to verify their vote behind a transparent screen. Even though VVPAT is present, it is not necessarily foolproof as a VVPAT receipt is also machine produced. Goggin et al (2007) determine through a field study, that significant impracticalities exists in VVPAT in the form of lengthy time delays in processing the paper spool during the tallying stage.

Our Dual Vote interface attempts to address verifiability and usability issues through one combined interface which allows the voter to cast their vote on pen and paper. In this paper we build on previous work reporting on the usability of the Dual Vote interface, MacNamara et al (2010). We are interested in how well the interface performs when assessed using the above-mentioned satisfaction metric across a broad spectrum of voters and whether a uniform level of satisfaction can be achieved across the age demographic.

2. Public Survey of E-Voting

The authors conducted a large scale survey in the Republic of Ireland to assess public perceptions on interfaces, usability and verifiability in e-voting. In total 1,015 surveys were administered via person-to-person interviews. Every effort was made to ensure that the age demographic of the respondents were representative of the actual population. We also recorded the gender and economic status of the respondents. Prior studies have reported a potential digital divide with respect to the efficiency metric showing that voters with better education took less time to vote, Byrne (2007) and Everett (2008). Currently, there has been no evidence of gender differences with

regard to e-voting machine usability. Previous work however has found a decrease in voter turnout among older people when DRE systems were used in elections, Roseman and Stephenson (2005). In this study we are interested only in the age condition and its effect on the interface aspects of the e-voting system. A comparison is made in Table 1 between our demographic data and the actual figures. While every effort was made to mirror each category to the actual population, time and budget constraints were a factor.

Table 1. Breakdown of Survey Respondents and Population

Age Group	Survey Respondents (%)	Actual Population (%)
15-24	18.7	16.1
25-44	39.8	42.1
45-64	27.5	32.0
65+	13.8	9.7

The participants were asked if having a paper audit trail in an electronic voting system was important. A total of 69% agreed that the provision of an audit trail was important. Only 8.8% of respondents disagreed with the statement and the remaining 22.2% neither agreed nor disagreed. The above-mentioned results support our view that a paper trail is an important component of e-voting systems from the public's perspective.

Respondents were also asked if e-voting was best done using: (i) Pen and Paper, (ii) Push Buttons, (iii) Touch Screens or (iv) Levers. Figure 1 depicts a breakdown of the usability results. The results are categorized based on the age of the respondents. A touch screen voting system is the most popular interface for the three younger age categories. A total of 40% of persons aged 15 to 24 and 25 to 44 favored the use of a touch screen. This figure drops to 34% for those aged between 45 and 64. Finally, touch screens make a very significant drop to 17% for those aged 65 and over. The preferred interface for persons ages 65 or over is pen and paper. This is a significant result because the majority of usability issues are encountered by persons in this demographic. Kubeck et al (1996) determined from a broad survey of varying age groups that older individuals performed consistently poorer on computer related tasks than younger adults. In addition, many e-voting usability studies have purposely over sampled elderly voters when assessing interfaces because it is within this demographic where the majority of usability problems tend to arise (Conrad et al. (2009).

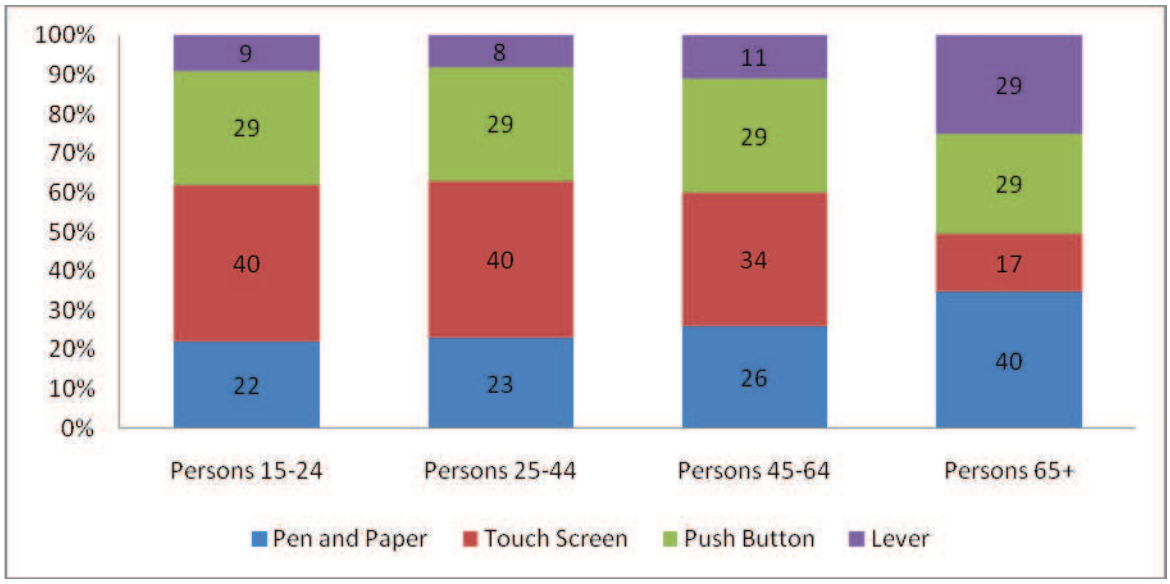

Figure 1: Usability Survey Results

The respondents were also asked if the traditional paper-based voting is easier than electronic voting. The results are again broken down into four different age categories and are depicted in Figure 2. There is a significant disparity across the age groups with older demographics agreeing that paper-based voting is easier, while the majority of the younger demographic disagree. A total of 61% of those aged 65+ and 44% of those aged 45-64 agreed that paper-based voting was easier. Respondents aged 25-44 were equally divided on the issue (34% both agreed and disagreed). Finally, only 17% of the youngest demographic, respondents aged 15-24, agreed and 51% disagreed. Again this result is significant because it emphasizes that the older age group, which are most susceptible to electronic usability problems, are more comfortable using traditional pen and paper as a voting medium.

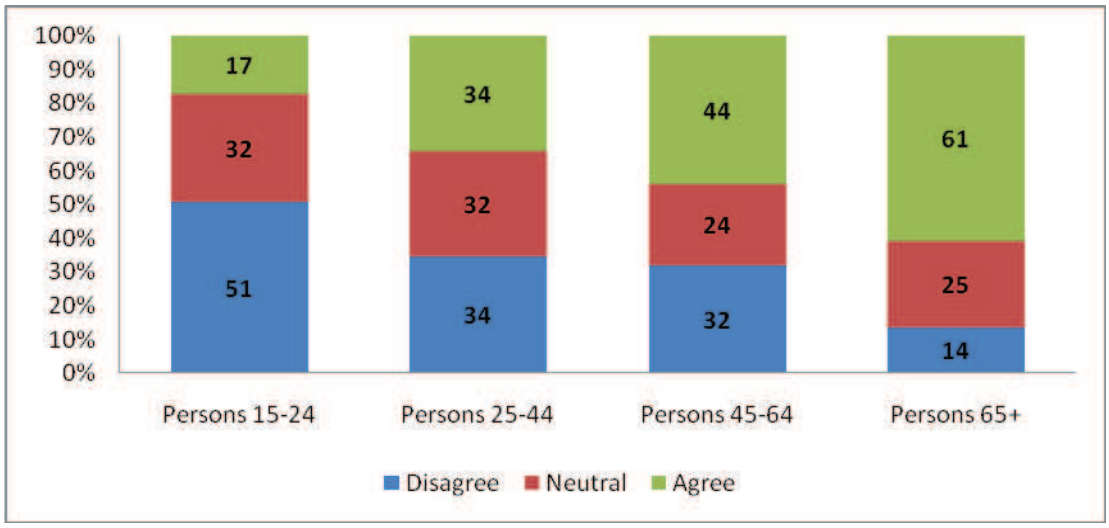

Figure 2: Paper Voting Easier Than Electronic Voting

3. Dual Vote Overview

The survey has established that the majority of respondents considered it necessary for an e-voting system to provide verifiability through the provision of an audit trail. It also highlighted that

the older age group, which are more likely to encounter usability problems with electronic systems, prefer voting using traditional pen and paper. In order to address these issues we present a novel e-voting system called Dual Vote. The system is intended for use in both professional and political elections but is at present a prototype. This system enables a voter to cast their ballot on pen and paper, while the system simultaneously interprets and records the vote electronically. Verifiability is facilitated because the voter's ballot paper is retained. Hence, the electronic results can be verified by comparing the electronic and paper results if required.

The Dual Vote interface, which is depicted in Figure 3, consists of an array of inductive sensors (Locator) and a hybrid ink / electronic pen connected to a digitizer (Interpreter). The interface works with a ballot paper which has metallic strips affixed to the underside. The properties of the metallic strips on the ballot paper change the sensor output. This change is then measured and translated to a coordinate value.

When the voter wishes to cast their vote, they place their ballot paper on the writing surface (digitizer) and simply mark their preference with the hybrid ink / electronic pen. Each ballot paper is affixed with an RFID tag: when the voter places the ballot paper into our ballot box, an RFID reader detects the ballot paper and the software ends that voting session. The system records all the pen stroke coordinates and cross references them with the coordinates generated by the Locator. By superimposing both coordinates, the system can determine where the voter has placed their mark on the ballot sheet and hence, for whom the voter has voted.

In a study of commercial e-Voting interfaces, Conrad et al. (2009) measured the activity required to vote on six different voting machines. Paper ballot / optical scan interfaces required the least number of actions. In such interfaces the voter is often required to scan their ballot using an optical scanner. The Dual Vote interface negates the need to optically scan the ballot paper when the voter has completed voting and hence reduces the number of actions required to vote. Additionally, Byrne et al found that paper ballots seem to be the most usable voting method for over the greatest range of users. Byrne found their error rate to be 1.5% which even at this percentage is lower than the comparative electronic interfaces. The interface presents a short and quick method of electronic voting based on the principle of minimizing the voter interaction with technology by adopting a pen and paper interface.

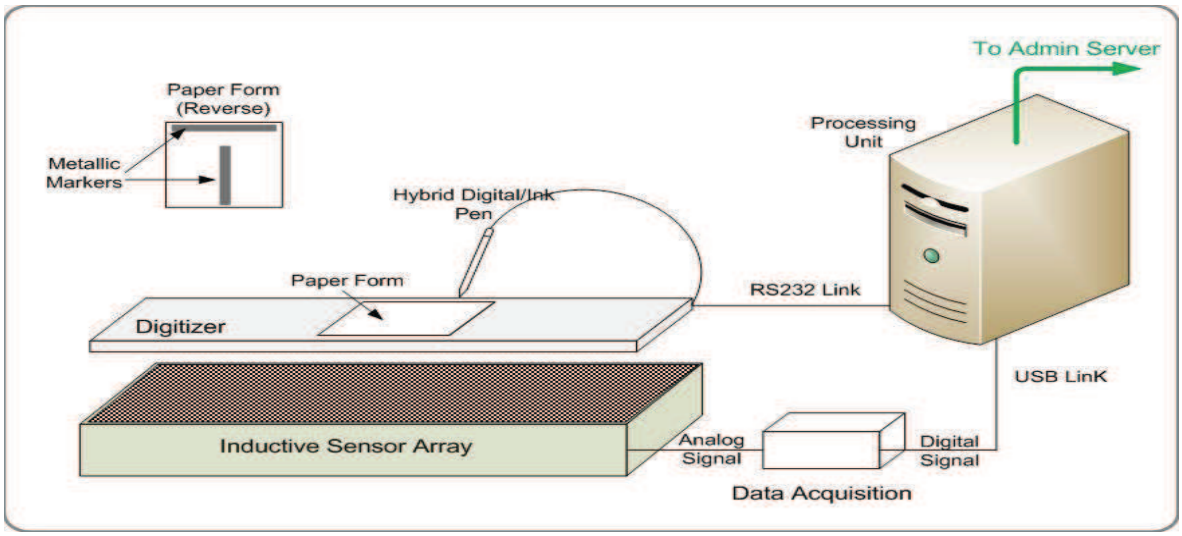

Figure 3: Overview of Dual Vote System

4. Dual Vote Usability Analysis

A field study was undertaken in order to evaluate the subjective usability of Dual Vote. In usability studies involving e-Voting interfaces, subjective usability has often been measured using the System Usability Scale (SUS) (Brooke (1996)). The SUS has been in use for many years for global assessment of systems usability and is not unique to e-Voting. SUS uses ten 5-point Likert scales to produce an overall mean usability score. A higher score denotes higher usability. Our study involved 97 respondents who cast a vote for a single candidate by placing an 'X' in a preference box. After voting each respondent completed the SUS survey. Although this was the simplest type of election, forthcoming research will show the results generalize to more complex election types. Regarding gender demographics: 72.2% of respondents were male, 27.8% were female. The age demographic was: 26.8% of respondents were aged 15-24, 50.5% were 25-44, 17.5% were 45-64 and 5.2% were 65+.

Figure 4 depicts the SUS score attained by the Dual Vote System during the trial election and those of other alternative e-Voting systems. Everett et al (2007) conducted several studies on a non-commercial DRE system called 'VoteBox'. This study compared the usability of VoteBox with paper and mechanical voting methods such as lever and punch card machines. In terms of satisfaction, the 'VoteBox' DRE scored higher than these other methods of voting.

The result of the survey was very encouraging as Dual Vote, using a traditional pen and paper interface, achieved an SUS score of 86.1, which placed it joint highest with the 'VoteBox' DRE when compared to the other traditional interfaces tested by Everret et al. (2008) and the Prêt à Voter system assed by Winkler (2009). According to observations made by Bangor et al (2008), SUS scores above 90 indicate "truly superior products". Using this scale to interpret the Dual Vote interface shows it has an acceptable score.

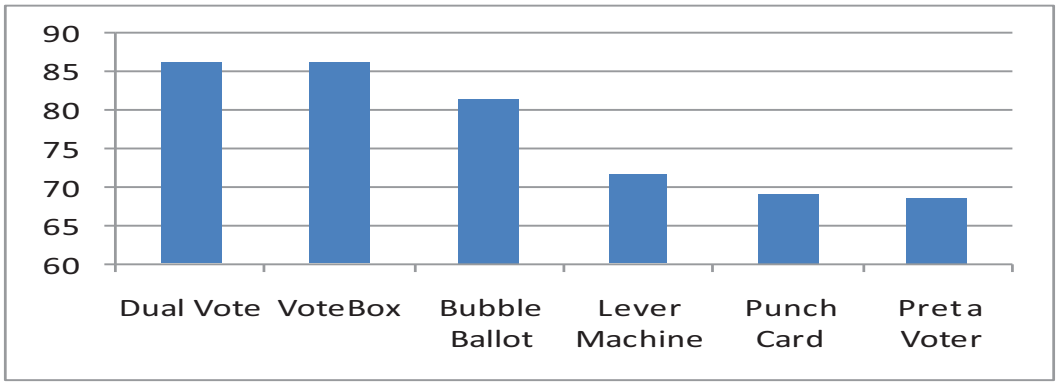

Figure 4: SUS Scores for Dual Vote and Alternative Systems

We focus on two SUS survey questions that were specifically relevant to system usability. The first of these questions asked the voter if they found the system easy to use. The respondents returned a mean result of 4.56 out of 5. The second question asked voters if they felt confident using the system. The mean result returned for this question was 4.37. While in isolation these results are very encouraging, it is important from a usability perspective to examine the experience of the older age groups, which are most sensitive to usability issues

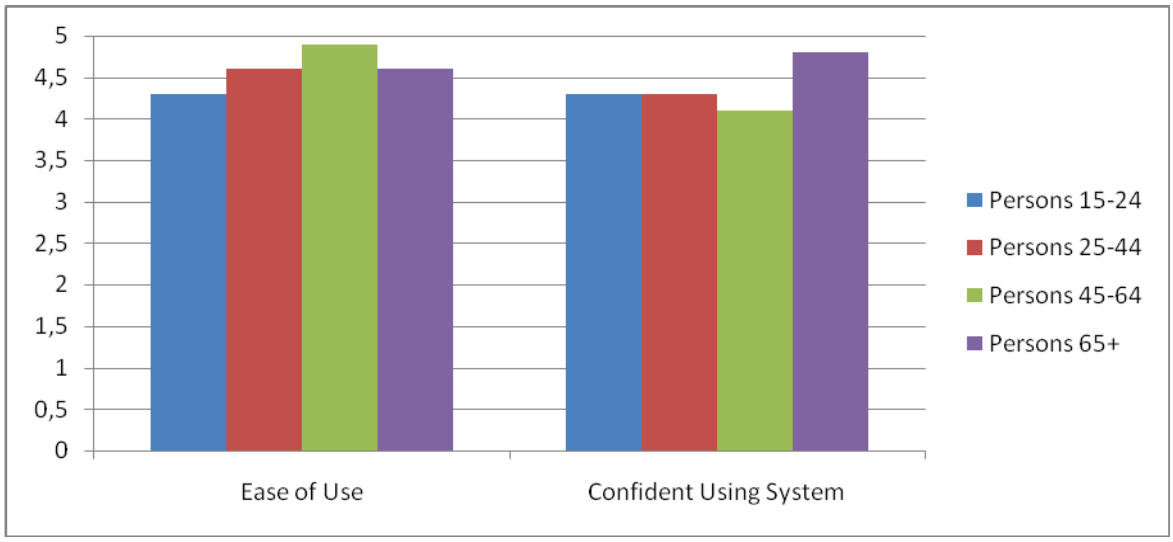

Figure 5: SUS Survey Analysis

The results obtained from the SUS questions are subdivided by age group and are presented in Figure 5. An analysis of the responses revealed near uniformity across all age groups regarding the system's ease of use.

5. Conclusion

This paper initially described the results of an extensive survey of public opinions on verifiability, interfaces and usability within e-voting. The majority of respondents favored an e-voting system that is both transparent and verifiable through the provision of an audit trail. The older demographic; which traditionally are more susceptible to encountering usability problems showed a clear preference for voting by pen and paper. To address these issues we presented the Dual Vote system, which simultaneously records a voter's preference in paper and electronic form. Because the paper form of the ballot is retained the electronic result can be fully verified. This paper also presented a usability study of Dual Vote, which showed near uniformity among all demographics regarding its subjective ease of use. Future areas of research include increasing the sample size of our SUS survey. It is also planned to supplement the current system with a GUI screen that would provide voting related information or interaction options to the user.

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