Human factors observations of the e-counting system for the scottish 2007 elections

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Human Factors Observations of the e-Counting System for the Scottish 2007 Elections

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ABSTRACT
In the recent Scottish elections, an e-counting system was employed to manage the increased complexity of the Scottish electoral system. This paper discusses some of the human factors issues observed on election night in relation to the system, and proposes some remedies.

Categories and Subject Descriptors
K.4.3 [**Computers and Society**]: Organisational Impacts, Automation.

General Terms
Human Factors, Design

Keywords
E-counting, usability, Scottish elections

1. INTRODUCTION
During the course of the 2003-2007 session of the Scottish Parliament, legislation was passed which adopted the Single Transferable Vote (STV) electoral system for the election of councillors to Scotland's 32 local authorities [1], replacing the previous system of Single Member Simple Plurality (informally known as 'first past the post').

For the variant of STV used in Scotland, elections take place in multi-member electoral wards, represented by either 3 or 4 councillors. To cast a vote in an STV election, a voter ranks candidates in order of preference (1, 2 etc). Combined with previous legislation which adopted the additional member system (for which voters are required to cast two single preference votes, one for a constituency MSP and one for the regional list) for the Scottish Parliament [3], the effect of the new electoral system was to significantly increase the complexity of running an election day operation and the subsequent count. To manage the introduction of the new electoral system, the Scottish Executive decided, in coordination with election officials, to partially automate the voting system for both the Scottish Parliamentary and local authority elections. An e-counting system was procured to scan and count paper ballots. In addition, software was procured which implements the Additional Member and the Weighted Inclusive Gregory (a variant of STV, see [2] for a description) algorithms used for electing winning candidates for the Scottish Parliament and local authorities respectively.

Partly as a consequence of the adoption of an e-counting system, several changes were made to the Scottish voting system as a whole. Changes to the voting system included ballot paper layout; security markings for ballot papers; ballot box design; scheduling of the declaration of results; distribution of counting centres; polling station operation; the election timetable; postal ballot papers; and the scale of the publicity designed to raise awareness of the changes made.

As a result of recent legislative changes [5], members of the public were eligible to register as election observers. This paper is the result of observations made by the authors during several of the system demonstrations and from the authors' experiences as observers on the night of the election. During observations, a range of human factors issues were identified with respect to the voting system, some of which have been discussed at length in the media[1]. The introduction of new systems typically results in some disruption during implementation – elections provide a particularly difficult case, since the processes are enacted only infrequently, reducing the opportunities for incremental change to the system to be tested. This paper describes the HCI-related issues identified with respect to the e-counting system itself, rather than the issues identified with the voting system as a whole.

The introduction to this paper has described the changes to electoral systems in Scotland and outlined the consequential changes for Scotland's voting system. The remainder of this paper is organised as follows: Section 2 describes the process of counting votes using the e-counting system procured by the Scottish Executive. Section 3 describes the human factors issues identified with e-counting system. Section 4 describes wider issues with regard to perceptions of the system operation during the course of the election. Finally, Section 5 proposes some remedies for the problems identified and draws some conclusions from the experience.

2. E-COUNTING SYSTEM
The counting system procured by the Scottish Executive consists of several stages, from the opening of ballot boxes to the declaration of a result, all of which require human intervention. This section describes the aspects of the counting system relevant to this paper. The hardware provided for the count consists of a central database server, a number of paper

[1] See http://www.indeedproject.ac.uk/e-counting/ for an archive of news articles.

scanning machines, a number of workstations with twin mirrored monitors; and several shelf areas used to store ballot papers at different stages of the counting process. The second monitors on workstations permitted political representatives (candidates, election agents and counting agents) and observers to view the operation of the counting system and decisions made from a public area (see Figure 1). Workstations are operated by pairs of local authority staff and scanning machines by the vendor's staff. A number of count 'marshals' are responsible for moving ballot papers between stages of the count.

Initially, a ballot box is opened and the papers transferred to a cardboard *batch box*, together with a *batch control sheet* which records the number of ballot papers that were in the batch's ballot box when the box was sealed at the polling station. Each batch box contained the contents of two ballot boxes – the parliamentary and local authority ballot papers for a polling station. Note that the parliamentary ballot paper recorded two votes (consituency and regional list), with the candidates for the two races listed in columns (see Figure 3). The batch box is then transferred to a shelf labelled "Awaiting Registration", before being transferred to a workstation. At the workstation, a bar code on the batch control sheet is scanned, which results in the workstation displaying a form for the number of ballot papers in the batch to be recorded. The batch is then transferred to a shelf labelled "Awaiting Scanning" and from there to a scanning machine.

The scanning machine is illustrated in Figure 2. First, the batch control sheet is scanned to record which batch is to be scanned. The ballot papers are then loaded into the input hopper (top left tray) and passed through the scanner. Ballot papers that are accepted by the scanner are moved to the output hopper (lower left), whilst ballot papers that can't be scanned (e.g. due to folds or tears) are moved to the reject hopper (lower right). Ballot papers that are rejected may be re-entered through the scanner, since each ballot paper is marked with a unique barcode (preventing double counting of votes). Ballot papers that are repeatedly rejected are placed into a red wallet in the batch box for later manual entry. The batch is then moved to a shelf labelled "Awaiting Verification" and from there to a workstation.

The verification process provides a check that the total number of ballot papers scanned or rejected by the scanning machine matches the number expected in the batch as recorded on the control sheet. At the workstation, the control sheet bar code is again scanned, and the number of ballot papers in the red wallet recorded. If the batch is verified, it is transferred to a shelf labeled "Storage", otherwise the batch is transferred to a shelf labelled "On Hold" for investigation by the Returning Officer (RO, the chief election official). Batches containing unscanned ballot papers (in the red wallet) are placed on a shelf labelled "Awaiting Manual Entry", from where they are transferred to a Returning Officer's workstation. The RO (or a depute [sic]) may enter a vote manually in a similar fashion to adjudication (see below).

The key correction (STV only) and adjudication process provides for human correction of the character recognition decisions made by the e-counting system; typically where a voter has not marked the ballot paper in a manner that could be confidently interpreted by the software (see Figure 3). A sizeable proportion of ballot papers were subject to this process. Electronic representations of ambiguous ballots are available for key correction and adjudication once they have been verified. The workstation operator selects a batch from an

Figure 1: Operators, political representatives and observers at the twin monitor workstations.

Figure 2: Scanning Machine

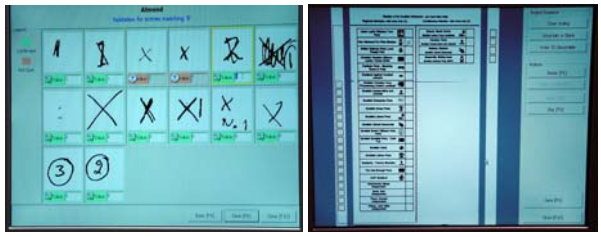

Figure 3: Key correction (Local Authority) and adjudication (Parliamentary)

available "queue" of batches listed on the user interface. For key correction (the first stage), an operator is presented with a page of glyphs which the character recognition software has determined represent a particular character. The operator can choose to accept the choice made by the software, correct it, or mark the glyph as uncertain. For standard adjudication (the second stage), the operator is presented with electronic representations of the full ballot papers. The operator can correct the vote on the ballot paper, or reject the vote. For situations where a decision still cannot be made, the ballots are placed in a special 'RO' queue for further scrutiny.

Once all batches of ballot papers have been processed, the electronic representation of votes is extracted from the central database and passed to tallying software, which computes the results of the election. The RO is presented with these results for declaration. Scanned images of ballots confidently scanned by the system are not retained, only the voting preference. The adjudicated ballots are retained for possible future examination.

3. HUMAN FACTORS ISSUES

This section discusses examples of human factors problems associated with the e-counting system observed across several counts.

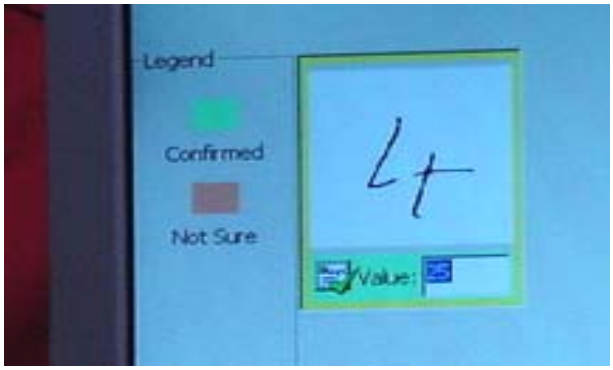

Figure 4: Software OCR during key correction

Figure 5: Reminder of the system's limitations

3.1 Ballot Paper Adjudication

The process of ballot paper adjudication raised a number of issues associated with the usability of the workstation user interface. One of the most significant causes of frustration and wasted effort was that of the adjudication queues. There was no separation of Parliamentary and Local Authority ballots in the adjudication queues; further, operators didn't have a list to tell them which were which. Initially, operators were only permitted to complete the Parliamentary count on the first night, so they had to check each queue, often, inevitably going into a local election queue by mistake, until they managed to memorise the names for the local and parliamentary areas. There was a list of areas for both elections on posters next to the declaration area as publicity within the counting halls, but the operators were unable to see these from their desks.

The adjudication system interface presented three options for rejection of a ballot paper:

- **over voting:** the most common example of which would be placing two X's on a single race.
- **void for uncertainty:** a miscellaneous category for any situation where the voters preference is not clear; an X across two lines for example
- **ID discernable:** The UK uses secret ballots, as such a vote can be spoiled by writing an identifiable mark on the ballot paper, (e.g. writing your name / address across it)

Electoral rules [4] separate "over voting" and "void for uncertainty", however as time passed these categories tended to be used interchangeably depending on which operators were working, and in some cases the ROs deputes were observed not applying the rules consistently themselves.

The software employed for character recognition (OCR) also presented usability problems. The confidence threshold of the OCR software (the level of confidence at which the software would require a human check) was deliberately lowered, (ie, the software would ask for human assistance unless it was very confident) in order to ensure system scrutiny. However, the system would always guess a number, no matter how low its probability of correctness, if that was deemed the most likely number (see Figure 4 for an example). This meant that less consideration was given to the system's choices as the count progressed, as staff lost confidence in the system's ability to aide the operator.

The amount of training received and/or knowledge retained on the system's features appeared to vary considerably across local authority staff. Some used keyboard shortcuts for example, whilst others seemed unaware of them. The software provided a zoom function for inspecting ballot papers during adjudication, but this was badly publicised. The function was accessed via the keyboard "Ctrl+Shift" key sequence. At one count, two depute ROs worked independently for a number of hours on opposite sides of a room, with one using the zoom functionality, the other not. An on-screen button would have advertised the feature; indeed this was the only substantive feature of the system not accessible via the on-screen user interface.

Initially, the rate at which adjudication per ballot paper was undertaken was relatively slow. However, as operators familiarised themselves with the system, the process was accelerated, particularly as staff learned to use keyboard shortcuts for functions. Although the operators were able to improve the efficiency of the system in this manner, a consequence was that political representatives and observers (and the operator's partner) were less able to scrutinise the adjudication decisions that were made. The time required to formulate an objection meant that the operator may have adjudicated several further ballot papers before an observer could express their concern. Although the user interface was equipped with a "back" button, this only permitted an operator to step back one ballot paper from the current adjudication – which was less useful as the operators increased their speed of operation. For example, if one ballot is adjudicated every two seconds, observing parties had a maximum of four seconds to raise an objection. In many cases by the time the observing party had turned to their associates to highlight the point, this time had passed. This limitation on the system had to be advertised to observers during the night (Figure 5).

3.2 Environmental Factors

There is evidence that the design of the system did not take into account the environment in which it would operate. Although counting machine operators were given seats, they were too low for the operators to reach the counting machine hoppers. The counting machines rarely operated for more than a few seconds at a time, with the consequence that the operators stood constantly whilst operating scanners.

There were also frequent complaints from the adjudication staff, since although they sat in a normal office style environment the system was very mouse intensive. The system forced users to move the mouse from one corner of the screen to another each time a vote was adjudicated. Key correction was worse for the staff, as they were not fully aware of the keyboard shortcuts available, forcing rapid repetitious movements. Consequently staff swapped roles every few minutes due to hand and arm pains. A better user interface layout, staff training and the provision of wrist supports could have greatly improved the working environment for staff. The

layout of the user interface suggested that the designers of the system were not aware of common user interface design principles – Fitt's law, for example.

3.3 Data Entry

Having two operators to each adjudication machine worked well in reducing the number of errors; however in many cases the main advantage was to reduce the fatigue problems relating to mouse movement rather than loss of concentration.

There were also issues relating to the manual ballot entry systems. Manual ballot entry was required when a ballot paper could not be scanned in the usual automated manner; normally due to the condition of the paper material (tears, folds, cellotape etc). Problems occurred because ballot papers for the two different votes were mixed into a single batch box for each constituency. In order to manually enter a ballot the operator first scanned the barcode on the control sheet then on the ballot paper. If the user accidentally scanned an incorrect control sheet, (there were two for each box, one parliamentary, one local) the message displayed by the system was unclear. As staff became more tired this became more frequent, in some cases leading to the RO having to deal with the problem, which was invariably caused by the staff member scanning the wrong sheet.

3.4 Usability and Security

The workstations in operation locked after a period of inactivity for security purposes. In order to log in all users were issued with bar-coded identity badges. The length of time before the screen locked however was quite long, and staff in some counting centres bypassed security by leaving their barcode identifiers on the desks next to the scanners to save time, though in nearly all cases the staff member remembered to collect the badge before they left their stations.

4. INFORMATION DISPLAYS

The perception of political representative's confidence in the e-counting system was initially high, as a number of demonstrations had been made during the procurement process. The system was equipped with large plasma-screen displays to provide real-time updates of the progress of the count (including the allocation of votes to candidates) for political representatives. However, at many counts the information provided by the plasma screen was inaccurate or out of date and was eventually switched off, leaving little information as to the progress of the count. In comparison, the previous hand count system was considerably more transparent. For hand counts, candidates appoint counting agents who are able to observe the processing of all ballot papers and the votes they record. Consequently, candidates are able to obtain an estimate of the result of an election, typically within a few percent of the final result.

This uncertainty lowered perceived confidence and some questioned the systems transparency. To compensate, a number of political representatives were observed instead undertaking the hand tally estimates of adjudicated electronic ballots. In addition, at some counts, officials provided printouts of information extracted from the database server, effectively bypassing the plasma screens to ameliorate the lack of information provided.

5. RECOMMENDATIONS FOR FUTURE ELECTIONS, AND CONCLUSIONS

Despite the problems identified with Scotland's e-counting system in this paper, our perception of the system as a whole is that it performed relatively well for the local STV vote, which could not have been realistically achieved by a hand count; considerably less so for the parliamentary vote, which proved slower than its hand count equivalent on this occasion. Although the timetable for some of the counts was delayed by almost 24 hours, results were released for the entire country the following afternoon. The introduction of new systems into existing processes is commonly fraught with difficulty and the rarity of elections as events means that implementing incremental change is difficult. Whilst the problems described in this paper contributed to the difficulties in using the e-counting system, wider systemic issues also caused disruption and contributed to delays, which we will discuss in a future paper. A number of generic points can be drawn for the development of future systems:

- User interfaces need to be both consistent and clear, as do help systems in order to support the user. In the case of this election these points were lacking.
- That training is often overlooked when it should be given greater priority. In this case the variation in the application of procedures and rules observed throughout is a clear indication of training issues.
- Working environments should be considered in more detail. The provision of higher chairs and mouse supports could have greatly improved the experience at the counts for operators.
- The provision of transparent reliable information sources for those who monitor the status of systems.

This paper has outlined the human factors related issues observed with the use of e-counting systems during the Scottish elections; provided some discussion of the causes of the problems and proposed some remedies. Our intention is not to suggest that the e-counting system failed, that the system is unusable, or should not be used for future elections. Rather, as with all new systems, observers are able to identify and propose remedies to problems not obvious to designers, thus improving the system for future use.

Note: The opinions expressed within this paper are those of the authors as observers. Due to time limitations relating to the paper deadline insufficient time has been available to verify all details with election officials.

6. ACKNOWLEDGMENTS

Our thanks go to the friendly and accommodating staff present at the counts who greatly facilitated our work as observers.

7. REFERENCES

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