Augmented Paper Applications: Initial User Tests Of A Wireless Pattern Reader

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ABSTRACT

A handheld pattern reader has been developed to read low visibility conductive patterns on paper. The patterns are formed by masking conductive paper with a non-conductive, printed lacquer. The reader was developed as part of an EU-funded project investigating methods of augmenting paper. Data read from the patterns was used to trigger events in the digital domain. Usability tests were undertaken to investigate the performance of the prototype. Results showed that at this stage of development there was significant variation in performance of the prototype from user to user. Further work is being undertaken to determine the causes of this variability.

General Terms

Algorithms, Measurement, Documentation, Performance, Design, Reliability, Experimentation, Human Factors, Standardization, Theory, Verification.

Keywords

Digitally Augmented Paper, Wireless Pattern Reader.

1. INTRODUCTION

Paper continues to be a pervasive resource throughout society. Reasons for this have been reported and include paper's mobility, portability and its facilitation of mutual access and collaboration [1]. The concept of invisible, or at least non-obtrusive, patterns as information carriers for printed documents has also been reported [2].

A review of previous work in developing relationships between digital content and paper can be found in 'The Disappearing Computer' [3].

Developments in interaction between traditional and new media allow for the versatility of paper to be maintained whilst exploiting the advantages of digital media. The PaperWorks project aims to integrate the use of paper and digital applications in a variety of ways, one of which was the development of a wireless pattern reader. The conductive-pattern reader was intended as a very low-cost item; the conductive pattern was anticipated to be mass-manufactured as part of a printed document, without specialist requirements. The costs of printing and media production were beyond the scope of this investigation, but the conductive patterns on paper are produced using established printing and paper-making materials and processing.

The solution is inherently low-cost, as opposed to optically-based systems with high-cost electronics and processing elements. The hardware approach was taken as a result of interest in the use of conductive inks on paper. Such inks have been used to create electronic circuits and discrete components. In the same way as magnetic inks were used for 'computer print' in Magnetic Ink Character Recognition (MICR) financial systems (eg. cheques), the desire was to embed information digitally in/on paper, by a low-cost method, to add to its functionality.

The wireless pattern reader, under development as part of this project, makes contact with conductive paper, reads a conductive pattern and sends data to a software application. The application used for this testing is called PaperPoint, developed by Dr Beat Signer, Prof Moira Norrie and Nadir Weibel, at ETH Zurich. It is an application that links a pointing device to PowerPoint.

The paper used for the PaperPoint demonstration is a printed PowerPoint handout, coated with a conductive layer developed by ArjoWiggins, and overlaid with a lacquer, printed by Acreo AB. The insulating lacquer defines printed patterns on the conductive surface, masking where the pattern is. The patterns are placed over an image of each PowerPoint hand-out slide, with additional patterns for navigation; forward, back, start and end. The user simply has to swipe the relevant slide or navigation icon to guide the presentation to the appropriate point.

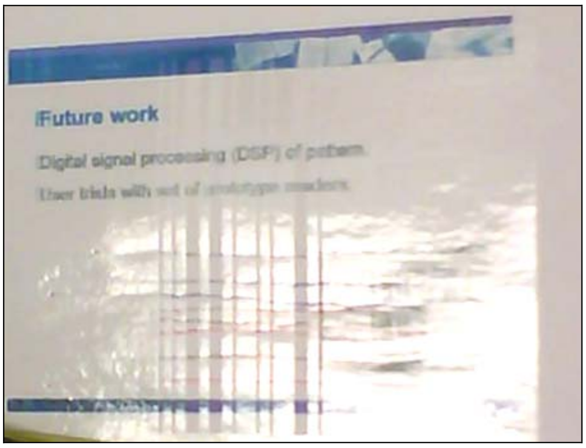

Figure 1. Image of a handout slide, showing lacquer-masked pattern.

A user test was performed that looked at the advantages and disadvantages of the prototype. A slide sorting task was selected as the problem domain. The conventional way of controlling slide sorting is with a mouse, and so this was chosen as the comparable technology.

With the resulting findings, improvements are planned for the design of the reader, with an aim to make it more intuitive, effective, efficient, easy to learn how to use, comfortable, and acceptable. The overall aim is to develop an ergonomic reader that is as inclusive as possible.

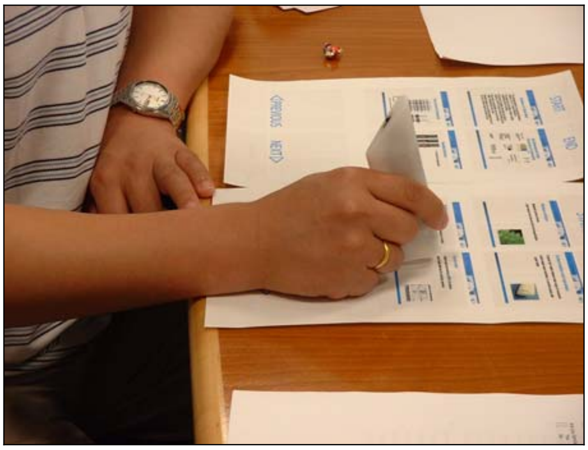

Figure 2. Pattern reader used on PaperPoint printout.

2. SUMMARY

Eight people took part in the tests conducted over two days. On the first day of testing there was an average success rate of 51%. This dropped to an average success rate of 13% on the second day. There was a total of 819 swipes across the patterns. A wide range of success was seen from user to user, varying from 0% to 96% success. Further work is necessary to determine the source of this variability.

3. DESCRIPTION OF THE TEST

The usability test was carried out on a sample user group. Data was gathered on their use of swipes to control a PowerPoint presentation.

A control was set up to compare the use of the reader to the more usual way of controlling a PowerPoint presentation with a mouse or the keyboard.

3.1 Apparatus

The user test required the prototype reader, a PowerPoint printout with low visibility barcodes, a Bluetooth-enabled laptop installed with the PaperPoint application and PowerPoint, and a desk to rest on. A camera was also needed to photograph the participants' grip of the reader and a stopwatch to record the length of time each part of the test took.

Due to the low visibility of the conductive pattern, the barcodes were stretched vertically, to fill the image boxes of the slide hand-out. This facilitated the location of the pattern, as it was contained within the defined image area of each slide box.

3.2 Procedure

The tester manually recorded the success of each swipe. The results were logged as "success" or "fail". In addition, a form was filled out by the tester, detailing how the participant used the reader, and photographs were taken of the grip used to hold the reader. Subjective user responses regarding ease, comfort, and satisfaction were also recorded at the end of each part of the task.

Participants were told: "this is a test on a new system being developed that allows a user to navigate a PowerPoint presentation by swiping low visibility barcodes printed over a PowerPoint handout." This was purposely kept brief to make sure the participants only knew as much as they needed to know to perform the task. Instructions were given on how to understand and use the printout, but not on how to hold the reader, beyond which parts needed to be touched.

3.3 Task

Each participant was asked to use the reader to swipe the barcodes to navigate through the slides one by one in a prescribed order, stepping through every part of each slide. If the slide was not brought up after five attempts, the participant was asked to move on to the next slide. The participants went through the set of slides a second time doing the same thing.

The participants were given the following instructions on how to use the reader:

- Touch the finger contact band on the reader at all times.
- Touch the border of the paper at all times.
- The reader must be in flat contact with the barcode.
- Each swipe across a barcode must start and end on the wide band of lacquer.

In addition to this task, the participants were asked to complete the same task again using a mouse and keyboard. In order to present the slides in the prescribed order, the participants were asked to sort the slides before clicking through them. Both parts of the task were timed individually.

Half of the participants were asked to do one task first, followed by the other, while the other half of the participants did the two tasks in the reverse order. This was to allow for analysis into whether doing one part of the test first helped them be more successful in the other.

3.4 Aims

The aim of the user study was to determine the capability of the contact barcode reader with regard to areas of interest as follows:

- Intuition
- Effectiveness
- Efficiency
- Learnability
- Comfort & Health
- Satisfaction

The capability of each factor was measured by one or more sets of data and the reasons for the results were analysed through comparison with various aspects of the participants' behaviour. The aim was to see if there was correlation between the results and the behaviour of the participant, to uncover which aspects control the results and hence are the areas to concentrate on for further development.

4. RESULTS

The results were gathered from the questionnaires filled out by the tester throughout the tests. The tables show the numeric data from the tests combined. Each participant had two tries at each task. The results of each task are shown in separate bar charts. The findings are divided into the categories listed in the Aims section. All of the participants were familiar with the use of PowerPoint.

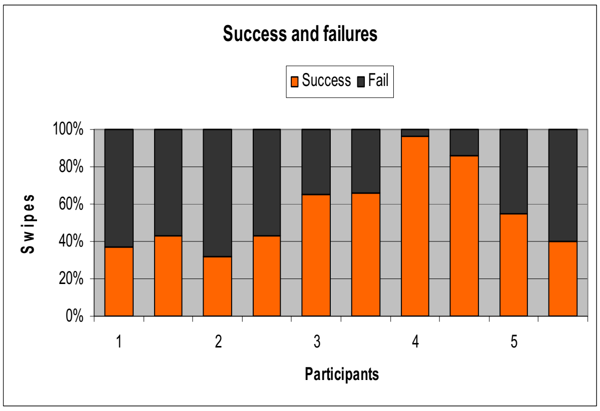

Figure 3. Percentage of successful results on 1st day.

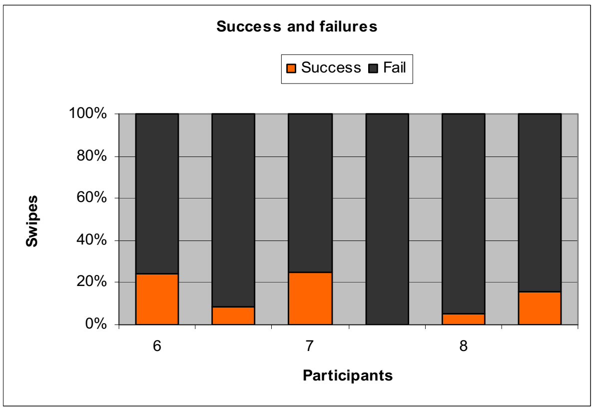

Figure 4. Percentage of successful results on 2nd day.

4.1 Intuition

The ease of the task when using the mouse or keyboard was on average rated as very easy. When the reader was used the task was rated on average as difficult.

The correct surface of the reader was used to contact the paper by all of the participants, and they all touched the finger contact band correctly. All participants held the reader in a pen grip, though each had an individual grip with variations in how much of their hand was wrapped around the reader. They all held the reader flat and did not have difficulty keeping the reader in contact with the paper.

4.2 Effectiveness

The average rate of success for the control was 95%, while for the reader it was 51% on the first day of testing and 13% on the second day. This highlights the potential of the reader to be very successful, but further studies are needed to pinpoint which factors determine success or failure.

The graphs above show fairly consistent results for the first part of the testing, which improved before dropping off for the last few participants tested on the second day. Any changes in performance between the first and second tries of each participant were minimal.

Possible reasons for reduction in success between the two days could include deterioration in the lacquer/paper interface, deterioration in the reader contact point, variations in individuals' ability, or conductivity variation in the paper brought about by humidity changes. Further work will investigate these factors.

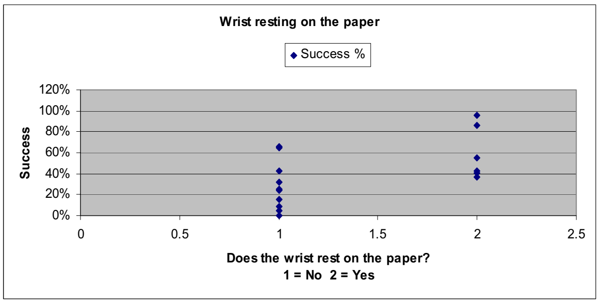

Figure 5. Wrist resting on the paper compared to success.

The previous graph shows that there is an apparent correlation between the participant's wrist resting on the paper and the success rate. There is greater success when the wrist rests on the paper, implying that the user has more control over the consistency of the swipes. Further testing would be needed to verify whether this is the case, or whether the correlation is due to natural variability.

4.3 Efficiency

The average time taken for the user to go through the slides in the control is 28 seconds, and 1 minute 12 seconds to complete the entire task including sorting the slides. The average time to complete the task using the PaperWorks pattern reader was 5 minutes 16 seconds. This was due to the time lag between swiping a barcode and seeing the result on-screen, and also the time spent on unsuccessful attempts. When the task was completed with a 96% success rate (Participant 4), this was done in 2 minutes 51 seconds.

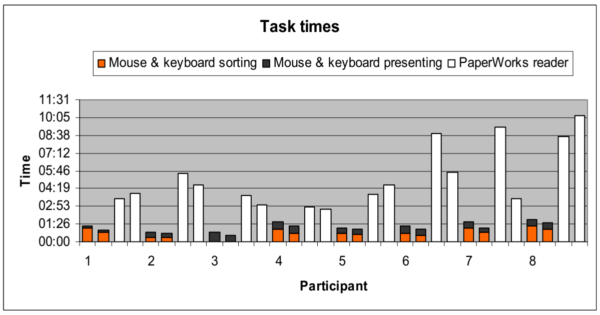

Figure 6. Task times for control and reader.

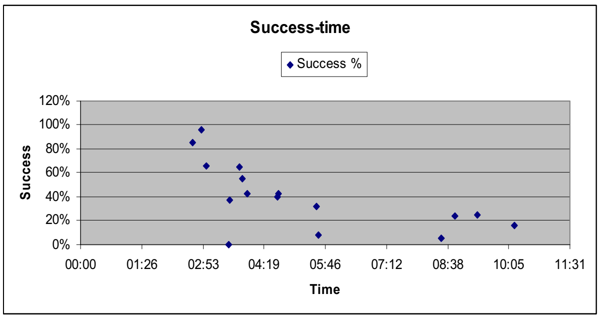

Figure 7. Time taken compared to success.

Figure 6 shows that the more successful the results were, the shorter the time the participant took to complete the task. This is due to time spent on unsuccessful swipes holding the participant back from completing the task.

4.4 Learnability

There was a 5% decrease in success between the first and second attempts of each participant to complete the task. An increase in ability was seen in participants whose first attempts were in the middle of the range of success, about 30%-40% success; and also in Participant 8 whose initial results were very low, but managed to learn how to control the outcome for a time at the beginning of the second attempt. Other reasons could be that the participants did not understand the difference between what they were doing to create success and what they were doing when they had no success, thus making them unable to learn how to improve. Successful results were hard to maintain for several of the participants.

4.5 Comfort and health

The average comfort rating for the control was comfortable, leaning slightly towards very comfortable, while for the prototype pattern reader it was rated as neither comfortable nor uncomfortable, leaning slightly towards comfortable.

All of the participants held the reader in a similar way to each other, using a pen grip. Minor differences between them are seen in different participants in each of the following areas, but there is little correlation between these differences and the comfort ratings. Participant 8 was most frequently the participant to hold the reader in a different way to the others, primarily due to being left-handed. The majority of the participants held the reader with their hand evenly spread over the reader, with fingers resting on the ridge of the reader; with a space between the thumb and index finger that was not filled by the reader, and with at least one finger wrapped around the front of the reader.

4.6 Satisfaction

The average satisfaction rating for the control was satisfied, while for the prototype pattern reader it was unsatisfied. Comments included that it tended to be better when you were more forceful with it and paused at the end of a swipe, and that it was too unpredictable.

5. CONCLUSION

The prototype reader in the hands of certain users can give repeatable high levels of success. Overall however, the performance of the reader was poor when compared with the control. Possible reasons are believed to be wear of the printed patterns, which had to be re-used between trials, and changes in ambient humidity which have been shown to affect the conductivity of the printed patterns.

Further work is required to investigate the factors contributing to the variability in performance of the overall system.

6. ACKNOWLEDGMENTS

Our thanks to the EU FP6 for funding the research project; all of our partners (King's College London, Acreo AB, Anoto AB, ArjoWiggins SAS, ETH Zurich, Malmo University, and Pearson Education and Edexel); and all of the participants of the user studies who volunteered their time.

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