BOARDTALKER: INITIAL EXPERIENCES AND OPEN PROBLEMS IN PROTOTYPING A TALKING DIGITAL WHITEBOARD TO ASSIST VISUALLY IMPAIRED STUDENTS

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ABSTRACT

BoardTalker is an assistive technology system that is designed to help visually impaired students by allowing them to hear material that is written extemporaneously on a whiteboard during class. The system uses a touch-sensitive electronic whiteboard that the teacher can write on with his or her finger. Material written by the teacher is converted to ASCII text and displayed on the surface of the board where it can be read by the fully-sighted students in the class. The visually impaired student can press a button that causes the current contents of the board to be spoken into an earpiece or small speaker. Several prototypical systems were developed by students in the author's Human Computer Interaction class; common themes, lessons learned and open problems are presented based on these prototypes.

1. INTRODUCTION AND MOTIVATION

1.1 The DEBBIE System

This paper describes initial experiences in designing an assistive technology system named BoardTalker that is designed to help visually impaired students by letting them hear material that is written extemporaneously on a whiteboard during class.

The original motivation for BoardTalker was provided by a software system named DEBBIE (DePauw Electronic Blackboard for Interactive Education, patent pending) which has been designed, implemented, and used to teach classes at DePauw University during the past several years. DEBBIE was not intended to serve as an assistive technology. Rather, the system was designed to enhance the way teachers and students share extemporaneously written material during class.

Since DEBBIE provided some of the motivation for BoardTalker, and uses some of the same technology, we continue this section with a brief description of the DEBBIE system. DEBBIE was designed to be used in a pen-based electronic classroom in which users can control the computers by writing freehand on the surface of a fifteen inch video-tablet such as a WACOM Cintiq [1] with a special electronic stylus much as one might write on a palm pilot. Additionally, the teacher can write on a large (approximately five feet wide) electronic whiteboard [2] located at the front of the room. The electronic whiteboard is touch-sensitive; therefore, the teacher can use a finger to draw directly on the surface of the board.

DEBBIE allows the students and teacher in a pen-based electronic classroom to share written information during class. For example, when using the system, the teacher can extemporaneously draw freehand sketches directly on the surface of the teacher-station’s video-tablet or electronic whiteboard. The teacher can also use a keyboard to type material, and can import material that was prepared ahead of time for use during class. All information sketched, typed, or imported by the teacher is transmitted over a network so that it appears immediately on each student’s video tablet. Each student can write freehand on his or her display to make private annotations to the teacher’s material. During class the students can submit portions of their workspace to the teacher who can then display this material for the entire class to see and discuss. The reader who is interested in more information about the DEBBIE system itself is referred to [3].

1.2 Response to DEBBIE from Low-Vision Students

Several years ago, a short segment describing the DEBBIE system was aired on a technology oriented CNN television show [4]. As an outcome of this broadcast, the author received several E-mail messages from low-vision students. These students pointed out, sometimes very dramatically, the difficulties they had in viewing blackboard material. While the students could often obtain advance copies (magnified if needed) of overhead transparencies and Power Point shows, they had real difficulty dealing with material that was extemporaneously sketched on a board during class as might be common, for example, if problems were solved on the board in a mathematics class. The students suggested that a system such as DEBBIE might allow them to see the teacher's board work, since the students had enough vision to view a video tablet located at close range, particularly if the content of that tablet could be magnified appropriately.

These E-mails, and discussions with a low-vision student who subsequently enrolled at DePauw University, motivated the design of a system named v-VIS (Viewer for Visually Impaired Students) [5]. The initial vision for v-VIS differed from DEBBIE in several ways. First, in a v-VIS classroom, we assume that only the teacher and the low-vision student have access to technology. More specifically, we assume that the teacher has an electronic whiteboard and/or video tablet that he can draw on, while the low-vision student uses a handheld computer to display the material that the teacher draws on the electronic whiteboard. The initial decision to use a handheld computer was made in order to allow the viewer to be lifted close to the low-vision student's eyes. As a second distinction between v-VIS and DEBBIE, we note that we envision v-VIS specifically as a viewer for a low-vision student. Therefore, as the teacher draws on the electronic whiteboard the material is displayed on the viewer. The low-vision student can adjust the viewer to look at different parts of the board, can zoom in and out, and can adjust color and contrast schemes. Thus v-VIS is used primarily to help the low vision student see what is on the board, as compared to DEBBIE which also supports a variety of other features such as allowing the student to exchange information with the teacher and allowing the student to save information for study after class.

Feedback from a low-vision student indicated that the v-VIS system had potential to help her during class. However, the student asked us to (a) port the system to a larger screen because the handheld was too small for her to see, (b) incorporate audio cues to let her know when to look at the screen, and where on the screen to concentrate since she could not when or where the teacher was writing on the board, and (c) convert hand-written words to typed text which could then be read to the student using a speech synthesizer.

The first two requests were incorporated into the second release of v-Vis and subsequently used by the low-vision student in a Psychology course during the fall, 2002 semester. The third request, the ability to "speak" written words, was determined to be too difficult to be implemented in time for the fall, 2002 semester. However, the author pledged to explore this idea further over the coming semesters, and this has led to the prototyping of a new assistive technology system named BoardTalker.

2. BOARDTALKER: THE VISION

The initial goals of BoardTalker are based on the understanding that students use a standard classroom board in two distinct ways. In the first style of use, students simply read the board *while* the teacher is writing in order to follow new content as it is presented. Although a visually impaired student cannot use the board in this way, compensation can be provided if the instructor orally describes material as it is written. Providing compensation for the second style of use is somewhat more challenging. In this usage pattern, a student looks at the board in order to review material that was placed there *previously*. The key here is that each student decides when she or he needs to look at the board. The following scenario illustrates this usage pattern, and demonstrates the problem this presents for visually impaired students.

> **Scenario:** A teacher in a history class spends the first few minutes of class making a list of important issues related to World War Two. The associated material, written on the board, includes dates, phrases, and short sentences. Later, the teacher asks the class: "Are there any pairs of items on the board that are related?" Some of the students glance at the board to refresh their memories and then begin offering suggestions to the teacher. Meanwhile the visually impaired student struggles to remember what items had been placed on the board.

The goal of the BoardTalker system is to provide a talking electronic whiteboard to assist a visually impaired student with scenarios such as the one described above. When using the system, the teacher will be able to write, with his finger tip, on the surface of an electronic whiteboard. Any letters or digits written by the teacher will be converted into typed ASCII text and displayed on the board where they can be viewed by the fully-sighted students in the class. Whenever the visually impaired student wishes, she can press a button located at her desk which will cause the contents of the board to be spoken into an ear piece worn in one of her ears. Revisiting the previous scenario, when the teacher asks: "Are there any pairs of items on the board that are related to each other?" Some of the fully-sighted students glance at the board to refresh their memories and then begin offering suggestions to the teacher. Meanwhile, the visually impaired student presses a button at her desk and listens while the contents of the board are spoken into an earpiece that she wears. Then she raises her hand and offers a suggestion too.

3. DEVELOPMENT ENVIRONMENT AND DETAILS

The first prototype of BoardTalker was built using equipment funded by a National Science Foundation Major Research Instrumentation (MRI) grant. Specifically, the MRI grant funded the purchase of several 61" diagonal plasma displays augmented with touch-sensitive interactive overlays that can be mounted side-by-side to form a wall-sized electronic whiteboard. Since the plasma displays and overlays are only about 6" thick, it was possible to hang them on a wall of an existing research laboratory. The BoardTalker project used three of these displays which collectively formed a fifteen foot long touch-sensitive digital wall. In order to provide a sense of scale, Figure 1 shows two of three boards that were used to drive BoardTalker. The third board extends the digital wall to the right, and could not easily fit in the photograph.

Figure 1. *Touch Sensitive Digital Wall*

During the fall, 2002 semester the author taught an upper level undergraduate course in "Human Computer Interaction" with an enrollment of thirty students. One of the goals of the course was to let the students grapple with an open-ended research problem. Toward that end the final course project required students to work in teams of three to implement prototypes of the BoardTalker system. To prepare the students for this challenge, earlier portions of the course had covered such topics as the design of graphical interfaces, issues in assistive technology, unistroke handwriting recognition algorithms, and speech synthesis using Microsoft Agent Technology. The students had also read a number of papers from conference proceedings and research journals, including some that dealt with the design and implementation of assistive technology systems.

The students were told to assume that BoardTalker would be used in a history class. Thus, they could expect that most of the material written on the board would consist of numbers, letters, words, phrases, and sentences. Specifically, the students did not have to worry about the harder issues of dealing with formulae, graphics, and other diagrams that would be common in classes from other disciplines such as mathematics. Since the students had already implemented a unistroke handwriting recognition algorithm for an earlier project in the course, they were told to assume that the teacher would use a unistroke alphabet to draw on the board. Unistroke is a style of handwriting in which every character is drawn as a single stroke consisting of a pen-down, some pen-movement, and a pen-up. The primary advantage of this style of writing is that it is considerably easier for the computer to recognize accurately. As an example, if one considers drawing an upper case "A" in the traditional way, it is clear that the letter consists of two strokes. In a typical unistroke font, however, the second stroke (the horizontal line) would simply be omitted. Most users can learn unistroke after a relatively short practice period.

The students were also told to assume that the visually impaired student would have three buttons at her desk. Whenever she pressed the left, middle, or right button, the current contents of the left-most, middle, or right-most electronic whiteboard were to be read back through an ear piece. The use of three boards concurrently has two advantages over the use of a single board. First, it provides the teacher with a larger overall writing area. Second, it allows the teacher to group related material by placing it together on the same board. For example, if the teacher is critiquing a chapter from the text book, a list of "strengths" can be placed on one board, and a list of "weaknesses" can be placed on a second board. The visually impaired student can then play back either list by pressing the appropriate button.

Finally, the students were told to support the following functionality, at a minimum, in their implementation: (a) allow the teacher to write letters and digits, (b) allow the teacher to select from at least three font sizes, and (c) allow the teacher to clear the contents of the board at any time – the material that has been cleared should no longer be read back when the visually impaired student presses a playback button. Many aspects of the assignment were intentionally left unspecified.

4. BOARD TALKER PROTOTYPES

Ten prototypes were produced by the class, one for each group of three students. As expected, the groups varied in the approaches they took. Figure 2 shows a screen dump of the system produced by one of the groups (see acknowledgement section for the names of the students). While considering the figure, keep in mind that a copy of this program would be run on each of the three electronic whiteboards, thus the teacher would see three side-by-side copies of this image spanning a total of approximately fifteen feet. As shown in the figure, the screen is organized into a grid that covers almost the entire electronic whiteboard. The teacher can draw unistroke characters directly on the grid surface, and the letter or digit that is recognized will be printed in the cell of the grid where the teacher began the stroke. The Figure shows the board after several characters and digits have been recognized.

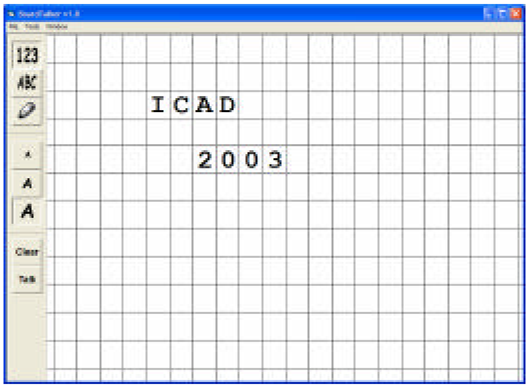

Figure 2. *A Grid Based Prototype*

When using the prototype shown in Figure 2, drawing a "back space stroke" (a vertical line drawn from right to left in a cell) erases the cell. Alternatively, the user can replace the contents of a cell with a new symbol by drawing the appropriate unistroke character on top of the existing symbol. The icons located along the left allow the teacher to, among other things, switch between writing digits and letters, and clear the board.

Figure 3 shows an approach taken by another group. This group opted to organize their screen into lines rather than into a grid. As strokes are recognized, they are adjusted in the vertical direction so that the corresponding ASCCI text is printed directly above the nearest line. However, the horizontal location of the recognized character is determined by the starting position of the unistroke. This group was also able to implement some simple editing functionality. For example, drawing a stroke in between two existing characters causes a space to open up and the new character to be inserted in the middle. Additionally, this prototype provides functionality to clear an individual line, as well as to clear the entire board surface. Finally, whereas most of the prototypes played information back in a temporal fashion, this prototype read the lines from top to bottom and left to right during playback. Thus, if the user were to write the word "ICAD" as shown in Figure 3, and then were to add the words "Welcome to" so that they appeared to the left of the word ICAD, and finally added the date "2003" to the right of the word ICAD, the speech synthesizer would read "Welcome to ICAD 2003" whereas most of the other prototypes would read "ICAD Welcome to 2003".

Figure 4 shows one additional prototype. To use this prototype, the teacher first taps the surface of the whiteboard where he wishes the recognized material to be placed. Then he draws unistroke characters in the boxes that are located along the left and right edges of the screen. The upper set of boxes is used to draw letters, and the lower set is used to draw digits. The rationale for placing the boxes on both sides of the screen was to make the system equally usable for right and left handed users. While it is possible to argue that forcing the user to write in a fixed input area is less natural than the direct input method used by the prototypes shown in Figures 2 and 3, it is also possible to argue that the prototype shown in Figure 4 has the advantage of keeping the teacher's body out of the way so that the sighted students can read what the teacher is writing.

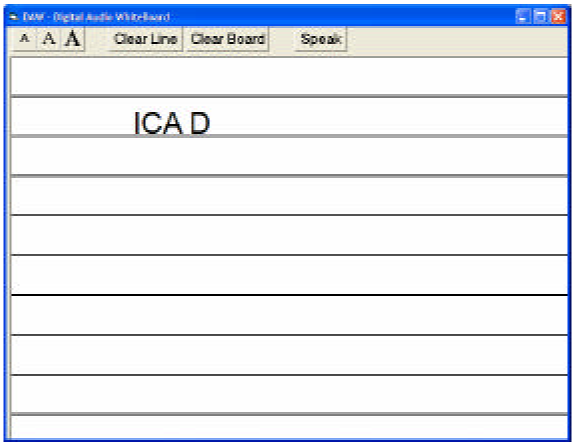

Figure 3. *A Line Based Prototype*

5. OPEN ISSUES AND FUTURE WORK

The prototypes have demonstrated that the idea of a talking digital whiteboard is worthy of further exploration. After obtaining additional feedback from students and teachers we hope to refine the prototypes into a system that can be tested in an actual class setting. Only this type of testing will allow us to determine the effectiveness of the system, for example by exposing problems that may be related to the low-vision student listening to a replay of the board, while simultaneously listing to the instructor.

Perhaps the most pressing issue to be addressed has to do with the limitation of using unistroke as the input means. Future investigation will explore whether more robust commercial handwriting recognition algorithms can be incorporated into the system. Several student groups explored the use of providing the low vision student with additional audio feedback beyond simply reading back the board contents. For example, one prototype generated chalk sounds whenever the teacher was writing. This alerted the visually impaired student that the contents of the board had changed. A variety of extensions to this approach should be considered, including the use of different sounds to provide cues as to which of the three boards is being written on.

An additional issue has to do with the ability to arrange material into logical groups. As previously noted, most of the prototypes played information back in the order it was written. The exception was the prototype shown in Figure 3, which organized material into lines, and played material back from top to bottom and left to right. This works well in some situations, but works less well in others. For example, imagine that a teacher puts two headings on the same whiteboard. The first heading is "Pros" and the second is "Cons". As the class unfolds some items are written under the "Pros" heading and others are place under the "Cons" heading with the teacher alternating between pros and cons at will. In such a case neither a temporally-based playback, nor a line-oriented playback is appropriate. Future work will investigate methods for arranging material into logical groups.

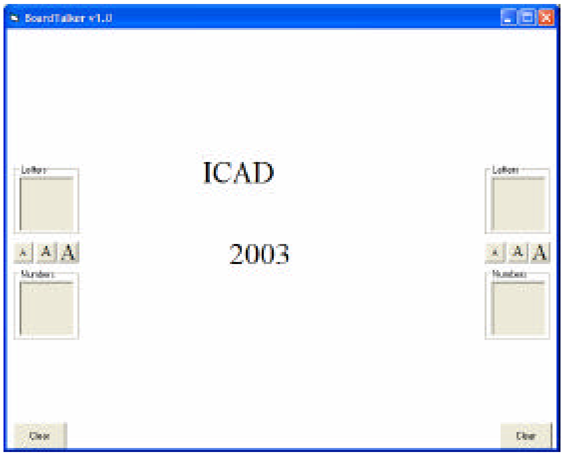

Figure 4. *A Prototype Using Fixed Input Boxes*

A final open issue relates to the problem of dealing with material that is not textual. It seems likely that BoardTalker would have to be combined with other methods of providing auditory displays in such situations.

6. ACKNOWLEDGEMENT

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7. REFERENCES

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