Development of an interactive electronic whiteboard system with multiple electronic pens for educational applications

Y. Otsuki, H. Bandoh, N. Kato & M. Nakagawa
Tokyo Univ. of Agri. & Tech.<yhoko@hands.ei.tuat.ac.jp>

Abstract

This paper describes the development of an arbitrarily large interactive electronic whiteboard system composed of multiple electronic whiteboards, which accepts simultaneous inputs to those component whiteboards. Simultaneous inputs with multiple electronic pens enable both the students and the teachers to work together with educational software employing various strategies of competition and cooperation. The device driver is the key to realize this system. It incurs little extra burden so that applications using the device driver perform smoothly even when simultaneous inputs are made with multiple electronic pens. We also describe an experimental use of this system with educational software and show that the system provides an effective and enjoyable learning environment for children.

Keywords: Interactive electronic whiteboard, Multiple simultaneous inputs, Educational applications.

1. Introduction

In recent years, personal computers (PCs) have come to play an important role in the academic curriculum of elementary schools. PCs are being actively introduced in school lessons, and class activities are being developed to take advantage of these facilities. One computer technology-based device being introduced in school is an interactive electronic whiteboard, hereafter referred as electronic whiteboard. It is about the same size as a conventional whiteboard, and the image of a connected PC screen is projected on it. There are two types of projection methods: the front projection and the rear projection. Electronic pens and erasers are employed as interactive input devices.

We have demonstrated the potential of an electronic whiteboard in school lessons, and have shown the advantages of lectures that combine the traditional chalk and blackboard environment with the information processing by a computer (Bandoh 2000). Using an electronic whiteboard, the teacher can keep the students' attention focused on his/her explanations while exploiting the power of computing to display mathematical graphs, schematics of geometry, animations of scientific simulation and so on.

However, the existing electronic whiteboards have many limitations. They are not as large as a typical blackboard used in the elementary school classes. They cannot accept simultaneous inputs from multiple electronic pens. The small size poses difficulty for multitasking of educational software, and not being able to handle multiple inputs prevents the students and the teacher from collaborating.

The ability to handle simultaneous inputs with multiple electronic pens enables both the students and the teachers to work together with educational software using various strategies of competition and cooperation. An electronic whiteboard with a wider area of drawing allows and encourages such uses.

The fact that the currently available electronic whiteboards do not accept input from multiple pens is due to the limitation of hardware. However, if we connect multiple electronic whiteboards and assume a single pen for each whiteboard, we can provide a large electronic whiteboard system with simultaneous inputs with multiple electronic pens although two or more inputs within a single board are not allowed.

This paper describes the design and development of a device driver that connects multiple electronic whiteboards to form an arbitrarily large area using the MS-Windows multiple monitor function and that accepts simultaneous inputs from multiple electronic pens. Furthermore, we presents an educational application appropriate for this extended electronic whiteboard system. We also describe an experimental use of this system by children and comment on its effectiveness.

2. Device driver for an electronic whiteboard

2.1 Hardware configuration

Multiple electronic whiteboards are arrayed to extend the area of drawing. The electronic whiteboards and the projectors for displaying the image are all connected with a single PC running the MS-Windows as shown in Fig.1.

The size of a common electronic whiteboard is 70 inches. An electronic pen and an electronic eraser are used for writing and erasing on the electronic whiteboard like writing on an electronic tablet. Although the front projection type is used in Fig. 1, the rear projection type can also be used in this configuration.

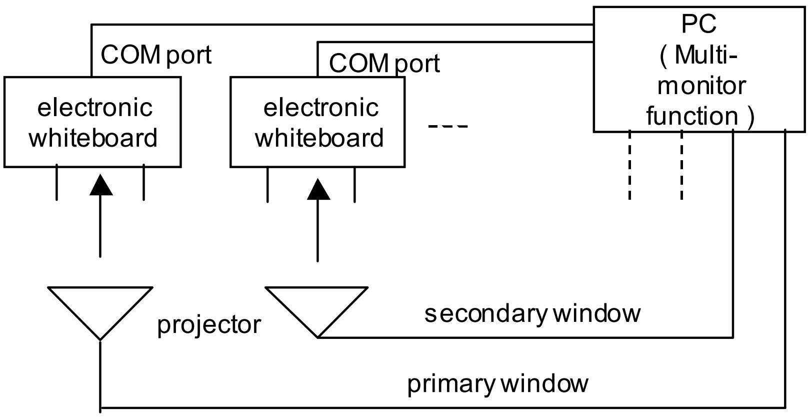

Fig. 1. Hardware configuration (employing the front projection type).

2.2 Software configuration

Figure 2 shows the data and control flow to and from the device driver installed in the host PC. It initializes all the electronic whiteboards, accepts multiple inputs simultaneously from multiple pens, and controls displays of multiple electronic whiteboard surfaces as if they form a single large board. Each electronic pen produces a sequence of coordinates along with the pen trajectory, which are sent to the device driver through a communication (COM) port. The current implementation employs two whiteboards. It is extendable, however, to three or more electronic whiteboards without any significant design modification.

2.3 Extension of the drawing area using multiple electronic whiteboards

Multiple monitor function of the MS-Windows is used for multiple electronic whiteboards to work together. The first electronic whiteboard is mapped to the primary monitor, the second whiteboard to the secondary monitor and so on. The device driver maps the pen coordinates in the n-th whiteboard to the corresponding monitor.

Another approach using a network has been implemented before (Sakurada 1999), but it restricts the applications to be executed over multiple boards.

2.4 Simultaneous inputs with multiple electronic pens

In order to process inputs from multiple electronic pens on electronic whiteboards, we employ the MS-windows standard mouse event, and extended mouse events designed for our system. First, we define the two terms. From each pen, the pen-tip coordinates and its on/off state are sampled whenever they are changed, and are sent to the device driver along with the pen trajectory from when the pen is touched until the pen is lifted. Hereafter, we call the pen-tip coordinates with on/off state as "pen datum" and a sequence of pen data from pen-down to pen-up as a "pen data stream". The following two steps are taken to process simultaneous inputs from multiple pens.

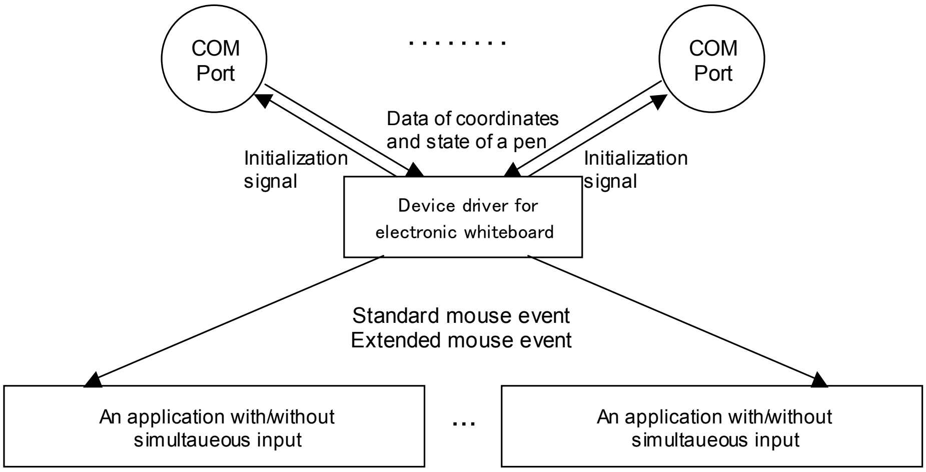

Fig. 2. Data and control flow of the device driver.

2.4.1 Conversion of pen input to mouse event

When only a single electronic pen is used, a pen datum is converted to the MS-windows standard mouse event and the succeeding pen data from the same pen are all converted to the standard mouse events. When multiple pens are used, one pen data stream is converted to the steam of the standard mouse events and other pen data streams are converted to the extended streams (2nd, 3rd ...) of mouse events. Assignment of each pen data steam to the standard or extended streams of mouse events is not very important and a new pen data stream is assigned to open (not used) stream of mouse events from the standard to the 2nd, 3rd and so on extended mouse event streams.

2.4.2 Transmission of mouse events

The device driver transmits the standard mouse event to an appropriate window using the Windows API. In the case of extended mouse events, however, the device driver first locates which window should receive them, gets its handle and send them to the appropriate window. Since a pen data stream is assumed to be input in the same window, the rest of the pen data in the stream is sent to the located window.

2.5 Controls for simultaneous inputs

In order to facilitate the development of applications that employ simultaneous inputs with electronic pens, several ActiveX controls have been developed. These controls support not only the standard mouse events but also the extend mouse events.

The control shown on the left of Fig. 3 is used as a substitute of the standard button of MS-windows, although its appearance is similar. The control shown in the middle of Fig. 3 is to accept a handwritten

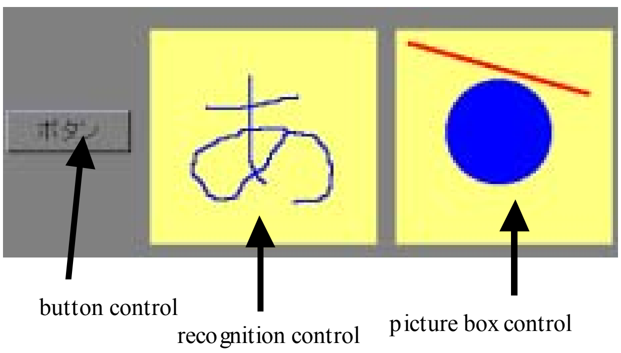

Fig. 3. The controls for simultaneous inputs with multiple electronic pens.

character and pattern recognize it. The control shown on the right is a substitute of the MS-Windows standard picture box. These controls facilitate the development of applications without requiring specialized knowledge of the device driver.

3. Evaluation of performance of the driver

3.1 Purpose

We evaluated the performance of the device driver in order to make sure that the execution of the device driver does not hinder a smooth execution of the application software.

3.2 Experimental environment

Table 1 lists equipments used in this experiment. A display-integrated tablet is used instead of an electronic whiteboard in order to evaluate the device driver in a harder condition because the display-integrated tablet used has a finer resolution so that it generates more pen data than an electronic whiteboard.

Table 1. Equipments used in performance evaluation.

Computer	DOS/V compatible machine (Pentium Pro200Mhz Memory 96M)
OS	Microsoft Windows 98SE
Tablet	MUTOH Video Tablet MVT-14

3.3 Evaluation method

We compared the effect on a higher-level application when a single tablet is used and when two tablets are used with two pens. A user draws with a pen for the single tablet case or with two pens for the two tablets case as quickly as possible to make the device driver produce a sequence or two sequences of mouse events as frequently as possible. We measured the total time for the higher-level application to capture 1,000 consecutive events in each case.

3.4 Experimental results

Fig. 4 shows the average and the standard deviation of the measured time for capturing 1,000 consecutive mouse events 20 times. The graph for "tablet 1 alone" shows the event capture time when Tablet 1 is used alone. The graph for "tablet 2 alone" shows the event capture when Tablet2 is used alone. The "mouse event" and "secondary event" graphs show the event capture times for the standard mouse events and the secondary mouse events, respectively, when both the tablets are used simultaneously. The thick bars indicate the average time for the event capture and the thin bars show the standard deviations.

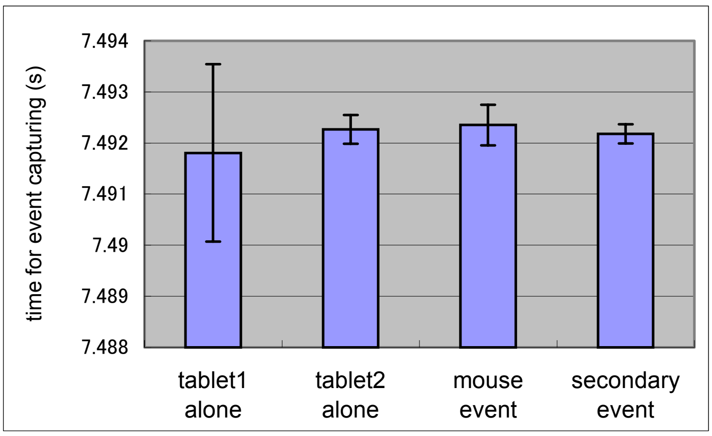

Fig. 4. The event capture times when the two tablets are used singly and when they are used together.

3.5 Discussion

Fig.4 shows that the event capture time for simultaneous multiple inputs from the device driver is almost the same as that of single inputs. The t-test for the above four measurements shows that there is no difference among them within a 5% error margin. This implies that the device driver is incurring little extra burden to capture mouse events. Therefore, higher-level applications using the device driver will perform smoothly even when handling simultaneous multiple inputs from multiple electronic pens.

4. Experimental use

4.1 Experimental environment

Using the Kanji pairing game described below, we prepared a single-player version where the user competes with a timer, and a two-players version where the players compete with each other, in order to compare how children play and learn with them. Fig. 5 shows a scene where children are playing the Kanji pairing game.

Fig. 5. A scene from the Kanji pairing game.

4.2 Experimental conditions

4.2.1 Kanji pairing game

The objective in the Kanji pairing game is to make meaningful compound words of two Chinese characters from a given Kanji character set. The players make compound words by writing them in the writing boxes with an electronic pen on an electronic whiteboard, and the system judges the answer using a handwriting recognition engine and a word dictionary. The questions are categorized into six levels based on their suitability for 1st to 6th grades of elementary school. The players can choose one of these six levels. The game is terminated when either a time limit is reached or a certain number of correct answers are given. Fig. 6 shows two windows for the two-players Kanji pairing game where 6 x 6 =36 Kanji characters can be used for forming compound words. Once a character is used for a compound, it becomes unavailable and is displayed as a white shadow. Since the two-players version stimulates children to compete, they are expected to learn Kanji characters more effectively.

4.2.2 Participants and the procedure

The participants were 28 school children from 1st to 6th grades of elementary school. All of them were familiar with using the computer with a keyboard and a mouse in their class activities and 7 children have also had some experience using an electronic whiteboard. The participants were divided into two groups, group A and group B, with the variations in ages and familiarity with computers balanced between the two groups. The children in the group A played the single-player version first and then played the two-players version, where as the group B played the two versions of the game in the opposite order, in order to cancel the order effect. Children not participating in the experiment watched the games.

4.2.3 Experimental environment

Table 2 shows the equipment used in the experiment.

Table 2. The equipment used in this experiment.

Computer	DOS/V compatible machine (Pentium3 600Mhz Memory 128M)
OS	Microsoft Windows ME
Electronic whiteboard	Hitachi Software Engineering Digital Board D-70 WACOM electronic whiteboard MS-2001

Fig. 6. Two windows for the two-players version of the Kanji pairing game.

4.3 Experimental results

Fig. 7 shows the participants response to the questionnaire about whether they preferred the single-player version or the two-players version. When a clear preference was shown to either version, a point was given to the preferred version. When no clear preference was shown, half a point was awarded to both. The figure shows for each question the averages of the groups A and B by the symbols "A" and "B", respectively.

4.4 Discussion

In Question 1, both groups showed a preference for the two-players version. Answers to the related Questions 3 and 5 also show a similar preference. Furthermore, we observed that the children in the audience gave more attention to the game when they were observing the two-players version.

The response to Question 4 showed that the children felt self-conscious when they were the only one playing in the single-player version. We have observed that children whose personalities are relatively introverted seem to be come self-conscious when answering in front of others. This is because a child playing the single-player version attracts more attention to him/her, whereas the attention is divided between both players in the two-players version, and also because the competitiveness helps to focus the players on the game and makes them less self-conscious.

On the other hand, answers to Question 2 show that the children think that the single-player version helps them more in improving their Kanji writing. This may be because they have to write characters quickly rather than neatly when they are competing with each other. For practicing neat writing Kanji characters, therefore, the single-player version seems better.

Taking all the answers into consideration, we conclude that children enjoy the two-players version more than the single-player version. However, preference to either version is not so clear. The single-player version seems better for learning how to write of Kanji characters neatly.
Although most children find learning Kanji characters boring and, painful to do daily exercises, the game like settings made it more enjoyable. As each of the single-player version and the two-players version seems to have its own advantages, we can choose either, or combine them depending on the situation and the purpose of learning. Moreover, we should also make similar experiments when there is no audience.

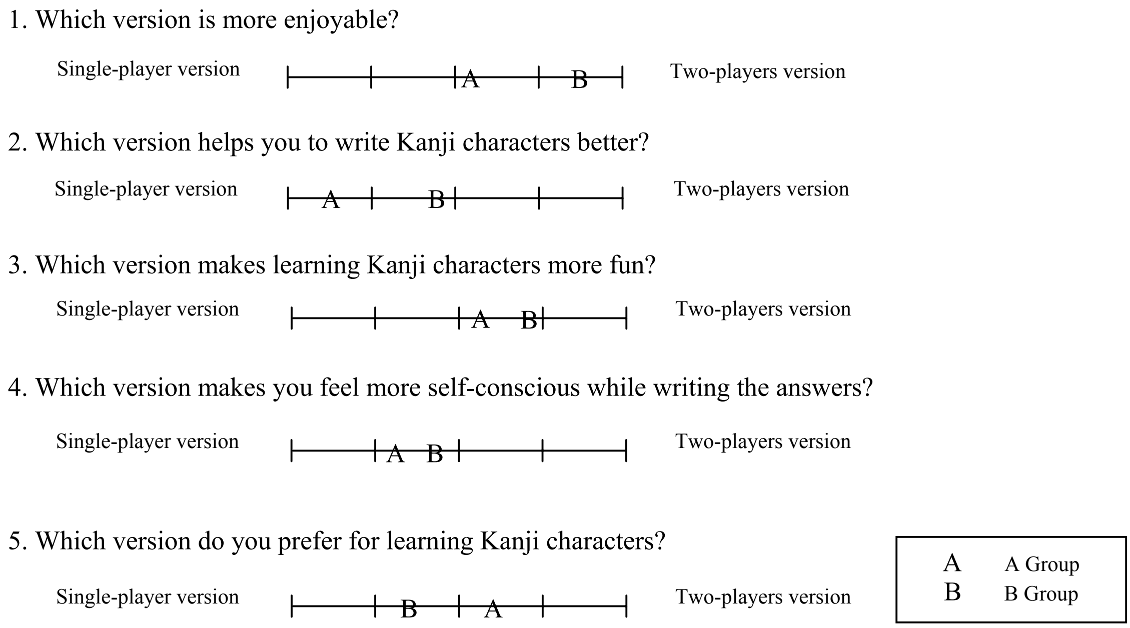

Fig. 7 Answer to the questionnaire.

5. Related research

In this section, we describe related research in this field and show how our approach is different form others.

Y. Nakada et al. developed a large single electronic whiteboard connecting two whiteboards, but their whiteboard could not accept multiple inputs by multiple electronic pens (Nakada 2000).

There exists some research related to handling multiple inputs. K. M. Inkpen developed a method to handle simultaneous inputs by two mice (Inkpen 1999). E. A. Bier et al. developed an interface architecture for a multi-device, multi-user, multi-editor system (MMM) (Bier 1991). J. Stewart developed a groupware designed for collaboration using a single display groupware (Stewart 1999). B. A. Myers developed multiple Palm Pilots as a part of the Pebbles project (Myers 1998). All these systems are based on displays, mice and keyboards but not on electronic whiteboards and pens.

Multiple tablets can be connected to a single PC, but simultaneous inputs from them result in conflicts of mouse events and disable application software from running properly. Our device driver avoids such conflicts.

The WACOM device driver for a desktop tablet has a function to support multiple inputs by multiple pens to a single tablet, but it does not work for an electronic whiteboard.

T. Sakurada et al. developed an extended electronic whiteboard and multiple inputs using local area network (LAN) (Sakurada 1999). But in this system only applications especially developed for this environment can be used, and ordinary applications are not executable.

6. Summary and conclusion

This paper described the design and development of a device driver that connects multiple electronic whiteboards to form an arbitrarily large area using the MS-Windows multiple monitor function and that accepts simultaneous inputs from multiple electronic pens. Furthermore, we presented an educational application suitable to this extended electronic whiteboard system. We also described an experimental use of the system by children and commented on its effectiveness.

We evaluated the performance of the device driver to make sure that its execution dose not hinder a smooth execution of the application software. The event capture time for simultaneous multiple inputs with the device driver is almost the same as that for the single input. Therefore, higher-level applications using the device driver are expected to perform smoothly even when simultaneous inputs are made with multiple electronic pens.

We prepared a single-player version of the Kanji pairing game in which the user competes with the timer, and a two-players version in which two players compete with each other. We evaluated both the versions of the game and compared how children play and learn with them. We observed that the children focused more attention on the game in the two-players version. However, as each version of the game has its own distinct advantages, we can choose either one or combine them depending on the situation and the purpose of learning. Moreover, we plan to make similar experiments when there is no audience except the players.

We plan to develop other educational application software to make use of the function of simultaneous inputs using multiple electronic pens, and to evaluate the performance of the whole system for education.

7. Acknowledgements

We appreciate the cooperation provided by the school children who participated in this study. Thanks are also due to Hitachi Software for supporting our research. This works is partially Grant-in-Aid for Scientific Research under the contract number 11558031.

8. References

Hirokazu Bandoh, Hidemasa Nemoto, Shinichi Sawada, Bipin Indurkhya and Masaki Nakagwa. (2000) "Development of educational software for whiteboard environment in a classroom," Proc. of IWALT 2000, 41-44.

Yasuhiro Nakada, Msayuki.Sawamura, Teruo.Nakamura, Tomohiro.Nishida, Nobuki.Tokura and Masaki Nakagawa (2000) "A Development of a whiteboard based teaching support system for all subjects," Proc. of the 60th National Convention IPSJ, vol.4, 277-278.

Kori M. Inkpen, Wai-ling Ho-Ching, Oliver Kuederle, Stacey D. Scott and Garth B. D. Shoemaker (1999) ""This is Fun! Weíre All Best Friends and Weíre All Playing." Supporting Childrenís Synchronous Collaboration," CSCL'99.

Eric A. Bier, and Steve Freeman (1991) "MMM: A user interface architecture for shared editors on a single screen," Proc. of UIST '91, 79-86.

Jason Stewart, Benjamin B. Bederson, and Allison Druin (1999) "Single display groupware: A model for co-present collaboration," Proc. of CHI 99, 286-293.

Brad A. Myers, Herb Stiel, and Robert Gargiulo (1998) "Collaboration using multiple PDAs connected to a PC," Proc. of CSCW '98, 285-294.

Takeshi Sakurada, Hirokazu Bandoh and Masaki Nakagawa (1999) "Extension of the IdeaBoard for Educational Applications," Proc..HCI International '99, Vol.1, 243-246.