The Use of a Multi-Display System in University Classroom Lectures

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ISS '16, November 06-09, 2016, Niagara Falls, ON, Canada
ACM 978-1-4503-4248-3/16/11.
http://dx.doi.org/10.1145/2992154.2996793

Abstract
We have built a display wall system with four liquid crystal displays to provide a very large visual area for university lectures. A program was developed to transform the display wall into an electronic blackboard. It has been used in a long-term classroom practice. Based on the research results, we demonstrate the benefits of the digital multi-display system for classroom learning.

Author Keywords
Multi-Display; Classroom Lecture; Electronic Blackboard

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation (e.g., HCI)]: User Interfaces—Graphical User Interfaces (GUI)

Introduction
The slide presentation is the most common form of teaching in current university classrooms. It has advantages, including the ability to structure material in advance, prepare high-quality examples and illustrations, and easily reuse material [2]. However, since the most frequently used presentation tools such as Microsoft PowerPoint and Apple Keynote currently support only one public screen, the area of visual aids dramatically decreased when moving from traditional blackboard to a single projector. Therefore, the amount

of information that can be displayed each time is limited by the screen resolution, forcing the instructors to split the related information into several parts. The information is stacked over time instead of space, which makes it difficult to understand the context and internal relationships [10]. A study [11] mentioned that the lack of history information may lead to students' "lost" of the lecture as the context was no longer available when the lecturer moved to a new slide.

Researchers try to adopt more and larger displays to regain the lost visual area and the related benefits. Different tools have been developed to make use of the increased screen space to enhance classroom learning [5, 9, 11]. These systems usually used two or more projectors to increase the public display area. The extra screens were used to display history information or other environments such as a browser window. These projects all used projectors to display lecture content since large digital displays were not even available when they were conducting their studies. Different from our approach, these systems were based on slides since the "slideware" just started getting popular at that time.

We have built a display wall system with four liquid crystal displays, providing 5.5 meters of space for classroom teaching since 2013. A canvas-based presentation system was developed to transform the screen wall into an electronic blackboard. It completely abandoned the slide metaphor. Instead, independent elements such as digital ink, texts and images can be freely placed on an infinite canvas. Lecturers from the Department of Mathematics and Computer Science in our university can use this system for their courses. Our aim is to study how teachers use the large display surfaces in real educational practices and to find out the benefits of such surfaces for classroom learning. We deployed the system in a classroom and collected students' feedback from the courses. Then we analyzed the results and discussed the benefits of such systems.

Related Work

The most convenient way to study the impact of the increased display area on learning is to use a dual-projector system. The advantages of this method are the low cost, the basic requirement of computer skills for the teachers, and easy to implement in classrooms. Therefore, numerous studies in this area are related to dual-projector systems [3, 7, 8]. The most frequently reported benefits of increased visual area include improved students' learning effectiveness [7, 8] and reduced cognitive loads [3].

However, the information can be presented in dual projection screens is still far less than a typical traditional blackboard. Other researchers adopted three or more displays as visual aids for teaching, aiming to understand the benefits of using larger displays. ModSlideShow [5] is a presentation system on which users can use a gestural interface to manipulate the flow of slides on multi-displays. It was an early study about multi-display usage for presentations and meetings. A study [4] introduced a three-projector presentation system and compared the use of it with one single projector for four weeks period lecture and concluded that the multi-display system significantly reduced the students' cognitive load and enhanced their learning effectiveness. Virtual MultiBoard [11] simulates traditional sliding blackboards with multiple digital projectors. It provides a "history" of the lecture notes for students. E-Chalk [6] was based on the chalkboard-metaphor and provided teachers with a

familiar environment. Lectures on that system were highly praised by teachers and students.

In summary, most studies we can find about multi-display (more than two) systems for classroom use were completed more than ten years ago. They are unlikely to involve large digital display walls. These studies commonly used digital projection of slides to present information. However, we believe that the traditional blackboard support many teaching techniques than slides. The combination of traditional blackboards and digital display systems may produce more suitable tools for classroom learning. We present our study and the preliminary findings of such a system.

Intellichalk

We believe that traditional blackboard has many advantages for teaching compared to slide presentations, especially in the disciplines of STEM (Science, Technology, Engineering and Mathematics) where complex reasoning and interpretations are needed. We have developed Intellichalk, an electronic blackboard teaching system.

The basic functionality of the system is to support writing. With the digital ink technology and high-quality input devices, we provide users with a smooth writing experience like writing on the paper. A variety of colors are readily available. Users can also paste images from the local disk, removable storage or the Internet. Figure 1 shows the user interface of Intellichalk.

In addition to these basic and commonly used functions, the system also provides advanced features, such as a gallery of graphic elements, handwriting recognition, and other plug-ins.

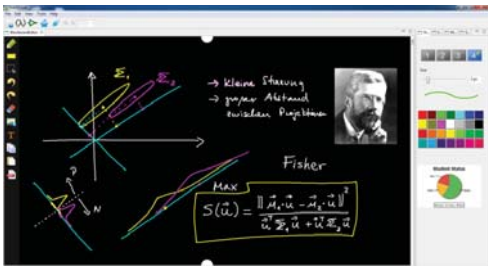


Figure 1. The user interface of the Intellichalk system.

As shown in Figure 2, an extra graphical tablet and a stylus are used as the input devices and the four screens are turned into an electronic blackboard. Figure 3 shows how we arrange the screens. The writing area extends vertically to fit the writing habits of the human. The content is mapped to the horizontally positioned four screens. The instructor can get unlimited writing space by pushing up the old contents.

According to our default settings, the fourth screen is the focus area, where new teaching contents are created. When the focus screen is full of information, the older content can be gradually pushed to the former screens. All users accepted this default setting in our study.

Figure 2. A professor was delivering a lecture with Intellichalk.

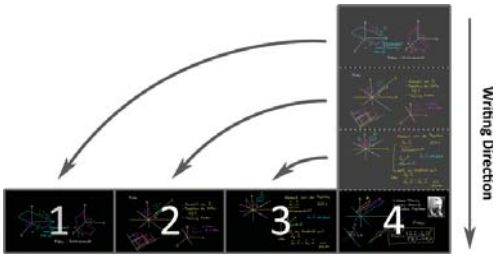


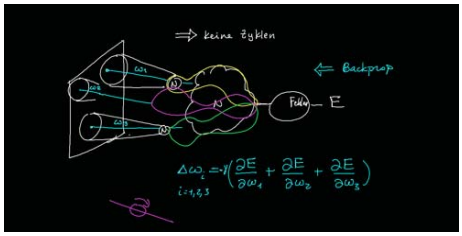
Figure 3. The arrangement of the displays.

Study

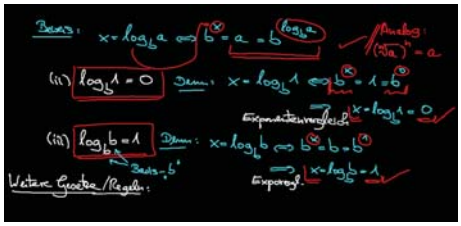
We deployed the Intellichalk system in a multimedia classroom. Three lecturers used the system for their courses for a period of one semester. At the end of each course, we sent questionnaires to investigate students' opinion towards the system.

Results

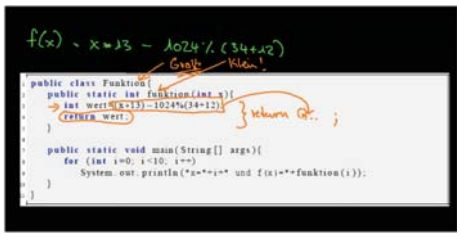
Figure 4 shows parts the screenshots of each course. The first lecturer drew lots of colorful diagrams to explain algorithms (see Figure 4 (a) for example). The second lecturer heavily used attention marks on the textual lecture content. It looks like writing on a traditional blackboard (Figure 4 (b)). The third lecturer frequently added images of code during his programming language course (Figure 4 (c)).



(a)



(b)



(c)

Figure 4. Screenshots from the three courses.

56 valid questionnaires were collected from the three courses. We list the students' evaluations about the Intellichalk system as follows (5 = strongly agree, 1 = strongly disagree):

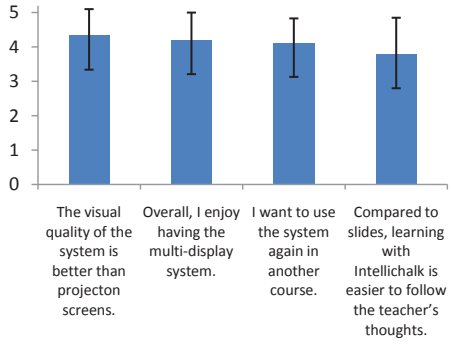


Figure 5. Students' evaluations about the Intellichalk system.

The questionnaire results (Figure 5) indicate that students thought the visual quality of the multi-display system was better than projection displays (Mean = 4.34, SD = 0.76), they enjoyed having the system in classroom (Mean = 4.21, SD = 0.79), and they showed their willingness to use the system in the future (Mean = 4.13, SD = 0.70). 38 of the 56 students (67.9%) agreed that learning with the Intellichalk system was easier to follow the teacher's thoughts compared to slide presentations (Mean = 3.80, SD = 1.05).

Discussion

We have implemented a digital multi-display system and deployed it for real classroom learning. Students' evaluations have been collected to analyze their experience with the system. Based on our study, we summarize the benefits of digital multi-display system for teaching as follows:

Better visual quality

The evaluation results show that the students were satisfied with the visual quality of the system. Actually, digital displays have many advantages over projection displays. For example, they offer higher luminance and contrast, easier to calibrate, and do not require dimming down the classroom lights. Compared with slide projection, teachers can naturally use physical gestures like when using a traditional blackboard, without the problem of casting shadows on the screen. As the display technology develops rapidly, large high-resolution displays are becoming increasingly affordable. It is highly likely that in the near future large digital displays will be used in more classrooms. We presented a vision of the digital future of the classroom.

Students' preference
Students showed very positive attitudes towards the multi-display system for both current and future use. It is possible that the results were affected by the novelty of new technology. But it is a great encourage for us to continue our study.

Support flexible ways of teaching
From the screenshots taken from three lectures, we can find that the lecturers used different visual elements for teaching. The canvas based lecturing area gives the users the flexibility to organize lecture materials according to the nature interconnection of knowledge, rather than mapping it to linear slide pages. This flexibility encourages instructors to deliver lectures in the ways which are suitable for the subjects, and the ways they like. The preliminary observation shows that the Intellichalk system may support flexible ways of teaching.

Easier to follow the lecture
Around two third of the students reported that they felt learning with Intellichalk was easier to follow the teacher's thoughts. We believe the inking process on the electronic blackboard exhibits the built up of information. It gives students chance to observe the instructor's mind, rather than showing the final results. Also, the increased display area keeps the old information available for a longer time, giving students opportunity to catch up the lecture from the short absence of mind or note-taking.

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