An Interactive Datawall for an Intelligent Classroom

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Abstract: This paper describes a low-cost, scalable, interactive datawall built by our group at Freie Universität Berlin. The datawall is a wide interactive display that can be used for for conventional chalkboard teaching, and for running modern multimedia applications. The wall is controlled by a laser pointer pen, and several Bluetooth wearable units. Using the E-Chalk system, the datawall becomes as easy to use as a traditional chalkboard. In addition to the traditional drawing functionalities, E-chalk also makes it possible to seamlessly integrate multimedia applications such as Applets or CGI-scripts. A new type of chalkboard metaphor based applications, called Chalklets, get drawings and writings as input and respond with strokes.

1 Introduction

The motivation and vision of our E-Chalk project [RKRF01] is to replace the traditional chalkboard with a modern alternative based on large computer screens. For the last few years, pen computing in the small (for example PDAs and Tablet PCs) has been evolving in parallel with pen computing in the large (contact sensitive whiteboards, plasma screens, or rear projection systems). Pen computing in the large, however, is still expensive and a stylus based input device with a display size adequate for a large lecture hall is not yet available. We want to investigate what we can offer with this new technology and what kind of teaching will be possible once the *chalkscreen* starts replacing the chalkboard. Figure 1 shows an example of a course held with our system.

2 Related Work

In the last years streamed video has gained the overhand for transmitting classes. See for example `http://webcast.berkeley.edu`.

There has been much work on electronic classrooms and the use of whiteboards for them. Some systems that come to mind are E-Class [Abo99] and Tivoli. Tivoli is a brain storming tool developed at Xerox [MvMT00] which can recognize and group notes. Scripts can be applied to provide some computational features. The E-Class system at Georgia Tech has been in use for some time, it captures slides and annotation for later display in connection with RealAudio. The Classroom Presenter developed at the University of Washington within Microsoft's Conference XP project, comes closest to our own system. The Presenter

Figure 1: Using the interactive data wall with E-Chalk for a mathematics course.

provides a whiteboard with real time *inking*, which can be annotated by local and remote users.

Current research is mainly focused on non-interactive datawalls for visualization of very high resolution data, see for example [HJS00]. The US Air Force Research Laboratory developed a portable interactive "data wall" with rear projectors and light-pen video tracking some time ago [Tec04]. Current contact sensitive commercial systems use ultrasonic pens or pens which reflect a laser beam, in order to locate the stylus. We decided to build our own datawall based on pen light tracking and could build the system at a fraction of the cost of a commercial one. A wearable device allows the user to control the system without using menus.

Interfaces for large data displays have been studied by Winograd [FJHW00] and Funkhouser [FL00].They have concentrated on collaborative ubiquitous computing environments [TW02]. Mynatt et al. [MIEL99] studied human interaction with a responsive whiteboard. Sketches drawn in specific frames could elicit different reactions, such as adding two numbers, enhancing a drawing, etc.

3   The Interactive Datawall

Figure 2 shows a photograph of our setup. The datawall is operated by two off-the-shelf PCs. A display board controls four screens with a total projection area of $1.15\,\text{m} \times 6.13\,\text{m}$ and a resolution of 4096×1024 pixels. In order to keep the depth of the datawall compartment small, and to avoid using expensive wide-angle projectors, the screen images are reflected by mirrors.

The instructor uses a special stylus to write on the board. The pen consists of a laser

Figure 2: A backstage view of the interactive datawall.

pointer with a touch sensitive tip. When the pen touches on the screen, the laser lights up. The vision system uses four regular web cams to capture a video image from the back of the datawall, in order to track the red laser spot, see Figure 3. The laser pointer's position is mapped into the coordinates of the display system which runs a Java-based client program emulating a mouse device.

We also built a small wearable Bluetooth keypad, which allows the user to interact with the E-Chalk software from any position in front of the datawall. The user can change colors, increase or decrease the size of the stroke, change to eraser mode, etc. just by pressing buttons on the wearable device. The lecturer does have to walk around to activate menus. In addition to this device we also use a regular keyboard and a special miniature keyboard called FrogPAD [1].

4   Simulating a Chalkboard

Our software, called E-Chalk [FKR02, RFKT04, FP05], transforms the screen into a black surface where one can paint using different colors and pen thicknesses. The board can be scrolled up and down vertically, providing the lecturer with an unlimited surface to write on. The user can also use an eraser to delete part of or the whole board content. During a lecture, images from the web or the local hard disk can be placed on the board. Access to CGI scripts has been implemented as a way of interfacing web services. Educational mini applications in the form of Java Applets from the Internet can also be used on the board. When strokes are drawn on the board using a reserved handwriting recognition color, the handwritten input is passed to a mathematical formula recognizer. It transforms the
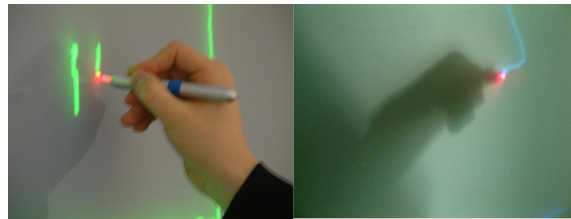
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[1] `http://www.frogpad.com`

Figure 3: The instructor writes on the board (left) and the image as seen by the camera (right).

input and passes it to other components, for example the Mathematica or Maple interface. This may be useful for presenting partial results or to annotate a plot of a certain mathematical function. Whenever the lecturer needs the result of a computation, Mathematica or Maple answers with text or an image. Another possibility to interact with third party components is what the E-Chalk systems calls Chalklets. These are applications that only interact through strokes, i.e. they are able to recognize drawings and gestures from the screen and respond by drawing their results on the board. Figure 4 shows an example of a Chalklet that simulates logic circuits [LK05].

Macros are a way to prepare lectures in advance. They are pre-recorded series of events which a lecturer may replay on the board during a lecture. The user draws the portions of the lecture which he or she wants to store in advance. During the lecture, macros are replayed either at original speed or accelerated.

When an E-Chalk lecture is closed, a PDF transcription of the board content is generated automatically. The transcription can be generated both in color and in black and white.

All events from the screen or tablet, together with the lecturer's voice and an optional video are recorded. The lecture can also be transmitted live over the Internet and can be synchronized with videoconferencing systems for student feedback. Remote users connect to the E-Chalk server to view everything as seen in the classroom. They can choose to receive the audio and optionally a small video of the teacher. The connection speed needed for a complete E-Chalk lecture with blackboard image, audio, and video is roughly 128kbit/s. Without the video stream the required connection bandwidth does not exceed 64kbit/s. The most convenient way for users to view a lecture is to use the Java based playback. In this case nothing but a Java enabled web browser is required. There is no need to manually install any plug-in or client software. Other options include to view the lecture in MPEG-2 format on a DVD, to use a Java-enabled PDA, or a third generation mobile phone using RealPlayer. When viewing archived lectures, the remote user sees a control console that enables him to regulate the content flow as done with a VCR, i.e. pausing, fast-forwarding, and rewinding.
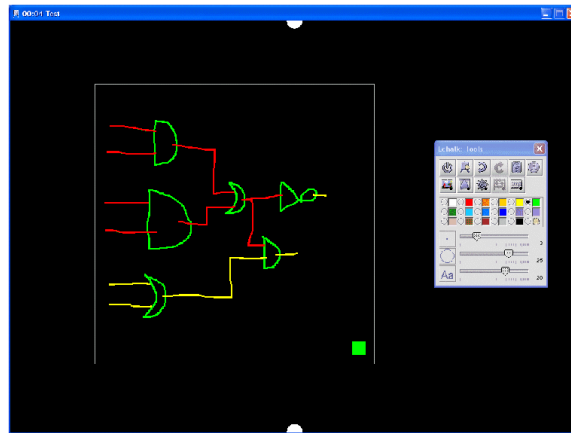
Figure 4: Simulating a hand-drawn circuit on the interactive datawall.

5   Conclusion

The datawall is in operational use at university. It can be built at a quarter of the costs of a commercial rear projection system of the same size. It is the first approximation to the intelligent blackboard of the future, which will be a partner of the teacher, responsive and always ready to perform computations, to show graphics or illustrations, to understand sketches and, in general, to assist in any imaginable way.

Our datawall shows also how a wearable device can be used to make the system easier to use, less distracting to the student, and how it can be in constant wireless contact with the main system.

In addition to drawings, E-Chalk handles a variety of multimedia applications from the Internet such as CGI-scripts and Applets, as well as embedded stroke-based applications, called Chalklets. The system records all actions of the lecturer, providing both live transmission and replay of the lecture on-demand from the web using a common Internet browser. Remote students can see the lecture unfold on their screens and listen to the recorded voice of the instructor.

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