E-Chalk

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1 Introduction

Using conventional authoring systems, the ratio of production time versus duration of the produced learning unit is typically a two to three digit number. Generally, this is not economically viable, especially as content of university lectures changes quickly. A cause for this tremendous effort is that traditional teaching know-how does not easily match contemporary authoring tools. Besides technical efforts, it requires huge amount of work to structure pedagogical content for the web. Trying to avoid these expenses, many universities use mere video capturing of their lectures. This approach does not only need technicians present during the recording to handle the camera and the audio hardware, but also standard Internet video web cast tools are inadequate for this kind of content. Writings and drawings, from slides or from a blackboard, are not encoded appropriately. State of the art video compression relies on dropping out the higher frequency parts of the images resulting in the loss of sharp edges. Either content becomes unreadable, blurry or the video stream consumes huge bandwidth.

Looking instead for established teaching techniques, one finds the chalkboard is an unmatched teaching tool for ages in many disciplines. Learners can see how ideas are developed rather than being overwhelmed with final results. This inspired the development of the described system called E-Chalk [WWW-EChalk].

A good chalkboard lecture should automatically result in a good e-learning lesson. The goal is to preserve the pedagogical advantages and the easy handling of the traditional chalkboard, while extending its reach to distance learning. The system tries to enhance teaching quality in the classroom by allowing the instructor to integrate multimedia elements. During classroom teaching the lecturer works directly on a pen-active display or uses a digitizer tablet. At the same time, the lecture is being saved and transmitted live over the Internet with negligible additional effort. The system transmits audio, video, and the animated board image of the lecture. Remote students only need a Java enabled Internet browser without additional plugin. They can also obtain a print out of the lecture, since a PDF file is generated as a static copy of the board content. For an optional postproduction of lectures, a program for editing arbitrary multimedia formats has been developed by [Friedland (2002a), Friedland (2002b)]. Among other functionalities, it allows one to change the audio track on a recorded lecture and to fix errors in the board content.

2 Methods for Lecture Recording

The following paragraphs present a small overview of systems currently used for creating distance education classes.

2.1 Video Conferencing Systems

Lecturers wanting to transmit a class often use a video conferencing solution. However, video conferencing systems have not been created for teaching explicitly. Their conception assumes a symmetric communication and relies on all participants having equivalent hardware. Great effort is spent transmitting audio and video, but convincing concepts for the transmission of teaching specific content, such as board drawings, are not available.

2.2 Internet Video Streaming Systems

Educators often rely on conventional video encoders and players, two of many examples are [WWW-Berkeley] and [WWW-iLectures]. The main scope of commercial encoders, like Windows Media Encoder, RealVideo, or Quicktime, is the transmission and archival of audio and video data. Sometimes they include the synchronized display of presentation slides. Of course, the latter requires post-production efforts. As described above, video encoding itself is not suitable for the display of slide or board writings. Using a naive recording setup these systems produce poor audio and video recordings from live lectures as their codecs assume a clean signal. In practice, one needs high quality sound equipment and technical staff to eliminate audience noise, reverberation effects, changes in illumination, etc.

2.3 CSCW Tools

Several tools for working distributedly on a shared screen are available. Many digital whiteboard hardware comes with such a computer supported collaborative work tool. They are neither designed for teaching nor for production purposes but for desktop sharing with annotations. If they support archiving, they save a static screenshot.

2.4 Lecture Recording Tools

Several applications record a presenter's desktop with annotations, audio, and video, see for example [WWW-Classroom2000, Abowd (1999)], [WWW-AOF] [WWW-Camtasia], [WWW-Lecturnity], [WWW-LecCorder], or [WWW-AOF]. Using the computer desktop as a lecture medium has severe disadvantages. The idea of the desktop metaphor is to be a virtual extension of the physical desktop, meant to be used with a mouse and a keyboard by one single person and not to be shared with an audience. The universality of this paradigm turns into a drawback in the lecturing situation. For example, technical details such as browsing through the local file system or error messages are visible to everybody. This does not only put pressure on the lecturer but is also distracting for learners.

Consequently, recording slide presentations predominate, hiding the desktop. While this approach improves the situation, the author thinks slide shows are still not adequate for domains of teaching, where complex trains of thoughts are to be developed by the instructor and followed by the students, like in science. Another difference between presentation and lecture is, that presentations have to be prepared in detail and concentrate on results. Many professional lecturers are able to simply walk to the chalkboard and start up a spontaneous talk with a high degree of interaction with the learners.

Most lecture recording tools require the remote learner to install a special receiving software[1], usually designed as a browser plugin. This introduces a psychological barrier for first time users, compare for example [Nielsen (1999)]. Moreover, remote learners often do not have the skills or even the permissions (for example on campus computers) to install such a client software.

3 The E-Chalk System

3.1 In the Lecture Room

The main objective is to present teachers with the environment they are familiar. The lecturer should be able to step into the classroom and start teaching on the board without extra effort.

Having started E-Chalk, the system's user interface metaphor changes from a computer desktop to a chalkboard. The computer screen becomes a display for more than one person. The mouse is replaced by a pen-like input device and the use of the keyboard is avoided as much as possible (for concrete hardware solutions see section 4). The software transforms the screen to a black surface[2] where one can draw using different colors and pen thicknesses. The board can be scrolled up and down vertically, providing the lecturer with a virtual unlimited surface to write on. Instead of using a desktop-style scrollbar, two *scroll points* are provided at the top and at the bottom of the screen. The user grabs the board at a scroll point with the pen and drags the board up or down.

The system allows the user to paste images from local hard drive or the Internet. Mathematical requests can be processed using an interface to computer algebra systems (such as Mathematica by Wolfram Research or Maple by Waterloo Maple, Inc), partially by using a handwriting recognition (developed by Ernesto Tapia, see [Friedland et al. (2003), Tapia and Rojas (2003b), Tapia and Rojas (2003a)]). Also any CGI script in the web delivering text or pictures can be queried.

[1] For example Lecturnity, AOF, and Camtasia require proprietary player software. LecCorder uses signed Java-Applets for replay.

[2] Actually, the system can be configured for different background colors. In practice, black is preferred because having the content shining instead of the background is less straining on the eyes.

All these actions on the board are tracked. The development of the board content can be viewed by a remote learner, both as a live transmission and as an asynchronous replay. The voice of the lecturer can also be recorded. These two data streams capture already most of the teaching substance. The distance learner is provided with a live script where teacher's side notes are not lost. Optionally, a video stream of the instructor can be used to give the remote lesson a more personal touch.

The system does not require the user to explicitely trigger a save. Everything is automatically stored for web browsers. E-Chalk can also be configured to store the lecture in a database or a learning management system[3].

Early versions of E-Chalk used the World Wide Radio system [Friedland et al. (2002), WWW-WWR] to stream and archive the voice of the lecturer. The recently integrated streaming system (see section by Gerald Friedland for details) is based on services inside an environment standardized by OSGi [WWW-OSGi]. The mechanism originally comes from the field of ubiquitous computing and specifies how to load, update, and delete software components from the Internet, while a system is running, see [OSGi (2002)]. E-Chalk uses the Oscar[4] OSGi implementation, see [Hall and Cervantes (2003)].

The entire software has been written in Java and runs on Linux, MacOS X, and MS Windows platforms.

3.2 Distance Learning

When remote students open E-Chalk's generated webpage of a given course with a browser, replay starts in the form of self synchronizing Java Applets. One Applet is started for every data stream present: board, audio, and video. Another Applet, a control panel, is provided for navigation in archived lectures. All these Applets run in a standard Java enabled browser[5], without requiring the user to download a plugin. As another advantage this solution is completely platform independent.

The audio system uses lossy compression and buffering to guarantee interruption free transmission. The required bandwidth for the transmission of audio and dynamic board content is up to 64 kbps, depending on the selected audio quality. The network traffic generated by the board content is negligible compared to the traffic needed by the audio signal, since the board uses a vector format. Using a video stream requires further 64 kbps. For the compression of the video signal a simple codec is used, based on difference images and JPEG.

A static copy of the final board image as Adobe PDF file is also included for the students to print.

[3] So far, it was experimented with an Oracle database and the learning management system Blackboard.

[4] The implementation can be found at `http://oscar-osgi.sourceforge.net`.

[5] The Applets need only Java 1.1, to avoid the requirement of a Java upgrade for the browser, and they need not be signed.

4 Use Cases

In order to use the E-Chalk Software in the classroom, one needs a pen based input device and a wide display. The display should offer good contrast, so that the visual quality can be compared to a real chalkboard, e. g. one does not want to darken the room for the lecture. Mainly, the following device configurations are in use:

- Digitizer tablets or tablet PCs with LCD projector
  The lecturer writes on a tablet while the computer screen is projected against a wall. Digitizing tablets are comparatively cheap and easy to transport. The teacher can look at the audience while writing, if a tablet with integrated display is used, which also eases hand-eye coordination.

- Digitizing whiteboards
  Several companies distribute digitizing whiteboards. These are wide, perpendicular mounted digitizing tablets (up to 80" diagonal). The screen content is displayed on the surface by an LCD projector.

- Retro projectors with pen tracking
  The advantage of using a retro projection system as wide display device is that nobody interferes with the projection beam. Contrast and luminance being much better than those of an LCD projector they are usable without darkening the room. Disadvantages are their heavy weight and the high purchase costs.

Having many students in a lecture room, a very big display surface is required. One can use a digital whiteboard or a digitizer tablet as writing surface plus an extra projector that projects the board content widely. This way, board content is even better visible than on a regular chalkboard. The Technische Universität Berlin uses this setup regularly.

For smaller seminars one can use a setup with several digitizer tablets, enabling students to interact on the board from their seats.

A handicapped professor in Arabic linguistics was glad to be able to give a chalkboard lecture while seated using a digitizer tablet for himself, instead of writing on the rear projection screen.

The Freie Universität Berlin also used E-Chalk in combination with videoconferencing systems to have audiences in different locations at the same time. The chalk content is sent parallel to the video conferencing stream. This enables students to follow remote chalkboard lectures and communicate with the instructor.

It is also possible to give a lecture at home and present it later. School teachers found this a practical feature because they can easily create classes for the students to see at home.

5 Experiences and Evaluation

Since the summer term 2001 the computer science department of the Freie Universität Berlin uses E-Chalk for courses regularly. Since the winter term 2002 the mathematics and physics departments of the Technische Universität Berlin has equipped eight lecture halls and seminar rooms with E-Chalk. In the summer term 2003, about 1100 students were taught with E-Chalk at these two universities. The author counted about 700 installations of E-Chalk world wide (as of November 2003), 50 of them are known to be used regularly. A field study has started to evaluate the use of E-Chalk and its improvement for classroom teaching, see [Schulte (2003)].

The evaluation was constructed as a field study under real life conditions. Its emphasis lies in the explorative description of leading questions, such as the usage and acceptance of the software, as well as possible effects on the students' motivation for studying. An examination has been conducted to find out effects on students' exam results. These aspects were evaluated throughout the summer term 2003 in six selected lectures[6] at both, the Technische Universität Berlin (TU Berlin) and the Freie Universität Berlin (FU Berlin).

For some of the leading questions the development of answers through the term was examined. 595 questionnaires were evaluated and 52 students were identified to have answered the questions twice, in the beginning and in the close of the term. Their responses were examined for changes in their attitudes.

To find out E-Chalk's influence on exam results, students were asked for their usage intensity for preparation. Some lecturers were selected by chance to be interviewed. One lecture used a learning management system[7] giving the evaluator statistics on the student's access on E-Chalk.

The results are summarized in [Friedland et al. (2004)].

The Berlin school department is evaluating whiteboards using E-Chalk in Berlin elementary and secondary schools. Within the project 'Computer in die Schulen!' [WWW-CidS], twelve schools were equipped with electronic boards since early 2003.

6 Summary

With the system presented here it is possible to produce distance lectures as a by-product of classroom teaching. The distance lectures are not substituting classroom teaching but supporting it. Students are helped to rework the materials with a living and active script. The remote student does not have to spend great technical effort to receive the lecture. Only a browser is used and no special software has to be installed. All substantial information in the

[6] At the Freie Universität Berlin, E-Chalk was evaluated in a computer science lecture on Neuronal Networks. At the Technische Universität Berlin E-Chalk was evaluated in the courses: Calculus II for Engineers, Introduction to Numerics, Linear Algebra for Engineers, Numerics for Engineers, and Introduction to Physics for Engineers.

[7] The FU Berlin used the learning managment system BlackBoard [WWW-BlackBoard].

form of audio and dynamic board image can be received with low bandwidth requirements.

The board is a new GUI metaphor. At the time being, the desktop is the dominating user interface. This metaphor, however, is designed for the small, personal screen that integrates in the physical writing table. Even the pen computing approaches, which have become popular recently, are considered only for personal displays. During the teaching situation, where a wide display is observed by a greater audience, the board is the proper metaphor. This way, the relation between teaching tool, teacher, and students is preserved, as it proved to be valuable for centuries. The audience can track the instructor developing the subject on the board. The technical implementation of the teaching device is formed by the pedagogical needs, instead of letting the device be purely driven by the technical development.

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