The E-Chalk Project
Electronic Chalk for the Classroom

E-Chalk is software we developed in order to enhance the classroom experience. Our guiding philosophy has been to provide the teacher with a tool which will make the lectures more dynamic and interesting. At the same time, the lectures can be stored and transmitted live over the Internet. E-Chalk is based on the chalkboard metaphor: the lecturer writes directly on an electronic board, can draw with various colors, can paste images on the board, and can even pose questions to "intelligent assistants" working in the background. One of those assistants can recognize handwriting and start a formula evaluator capable of solving arithmetic or algebraic queries and of plotting functions.

E-Chalk has been written in Java, i.e., viewers need only a conventional browser to see and hear lectures transmitted over the Internet.

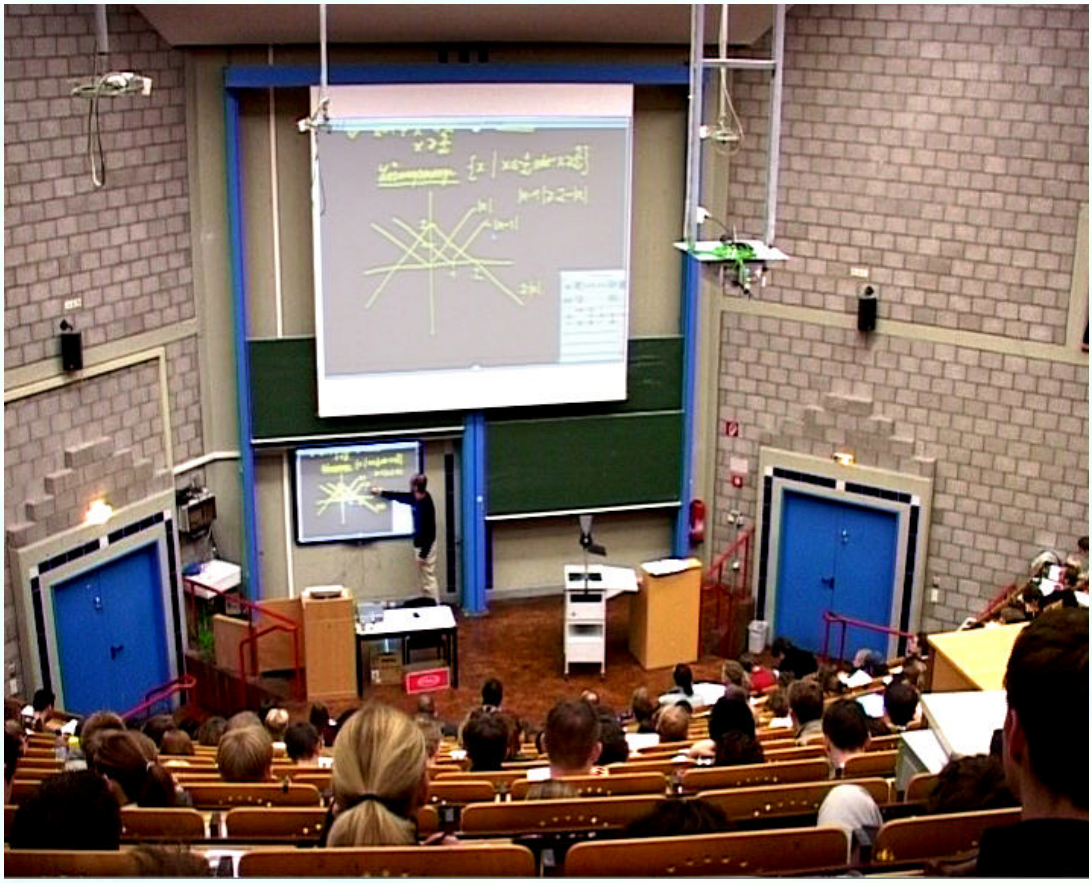


Figure 1: A professor teaching with E-Chalk at the Technical University of Berlin. The lecturer writes directly on the contact sensitive whiteboard, a large copy of the image is projected above him. More than 1500 students are being taught Mathematics for Engineers during 2003 with E-Chalk.

Beyond PowerPoint

The chalkboard is one of the earliest teaching tools in history and is still the preferred exposition medium in many scientific disciplines. Mathematics teachers, in particular, appreciate the chalkboard for its naturalness and simplicity.

Chalkboards are easy to handle and have good "imaging" features. Even when used in large lecture halls, the chalkboard has enough contrast so that its content can be easily seen from a distance of ten meters or more.

The most important pedagogical advantage of the chalkboard is that the lecturer, while writing and talking, is slowed down to a speed that better allows the audience to understand the material being presented. The teacher *thinks aloud* giving students time to absorb the main ideas. Projector slides, or computer based slide shows, are problematic for lectures that deal with rather complicated content and formulas. While systems such as PowerPoint can be useful for talks where not much time is available, they are not as useful for regular classes in the sciences.

Our motivation at the beginning of the project was, therefore, to preserve all advantages of the chalkboard, while enhancing it to allow the display of multimedia content. The chalkboard of the digital age is contact sensitive, can display information as any computer screen and is "intelligent", in the sense that it can help the teacher to access or process data. In the chalkboard of the future, the teacher is not alone while giving his or her class: help comes from programs working as assistants in the background.

Imagine a mathematics lecture in which the teacher needs the solution for a complicated integral. The teacher can look in a table of integrals or can ask the chalkboard for the solution. Imagine that a student asks about the shape of a certain function. The teacher can request the chalkboard to plot this function, and can then give a better explanation to the student. Imagine a computer science class in which the teacher writes a piece of code, which can run on the spot.

E-Chalk is a tool that allows developers to couple such applications with the chalkboard metaphor. The algebraic server, for example, is a reality. Mathematica from Wolfram Research or Maple from Waterloo Systems, can be used as mathematical assistants, always ready to solve equations or arithmetical queries.

E-Chalk transforms an electronic blackboard into a window to the world. Lectures can be transmitted live over the Internet and can be archived for later viewing. E-Chalk is primarily for the classroom but distance learning is possible with negligible additional effort.

E-Chalk: Examples of Deployment Scenarios

E-Chalk can be used with any kind of contact sensitive board or tablet.

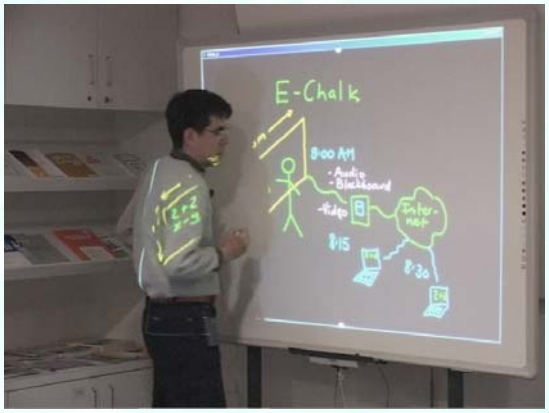


Figure 2: A whiteboard and projector.

Fig. 2 shows a system in which the computer image is projected on a whiteboard. The whiteboard is contact sensitive and the lecturer can write directly on it.

Figure 3: A rear projection system.

Fig. 3 shows a rear projection system. The projector is placed behind the contact sensitive surface. The teacher can work directly on the screen. Rear projectors are more expensive than whiteboards, but the price is falling sharply.

Fig. 4 shows a lecturer writing on a contact sensitive display. The lecturer faces the audience and the image is projected using an LCD projector on a conventional screen. This setting is specially useful in large lecture halls.

Figure 4: A pen sensitive display.

Fig. 5 is an example of an Internet transmission. The lecturer is in Stanford (the video image of the lecturer is on the screen to the right), the students are in Berlin. Both sides see and hear each other. The blackboard image from California is on the screen to the left.

Figure 5: A lecture transmitted from Stanford University to the FU Berlin.

Features of the E-Chalk System

Drawing with E-Chalk

When E-Chalk is started, the lecturer faces an empty black screen. The pen input device can be used to write on the board, as if it was a chalkboard. Different colors and different widths can be selected from a menu. An undo and redo function allow errors to be corrected. Regions of the screen can be erased with the eraser tool.

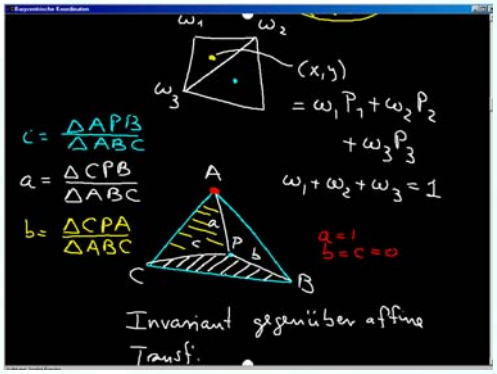


Figure 6: A screen from a real lecture (about barycentric coordinates).

Pasting Images

The user can paste images to the blackboard. The images can be selected from the hard disk or from a remote Internet location, through its URL. Normally, the lecturer prepares a set of bookmarks to the desired images before the class, and can retrieve and paste them by selecting the bookmark from the menu.

Macros

The lecturer can prepare parts of his lecture beforehand. For example, definitions or the formulation of theorems can be written and stored as elements which can be pasted later, during the lecture, on the board. These elements are then replayed, at normal, or somewhat faster speed, and allow the lecturer to save time without overburdening the audience.

Algebraic Server

The lecturer can require the algebraic server to perform a computation. Fig. 7 shows an example where the user asks Mathematica from Wolfram Research to plot the function $f(x,y) = xy$ in three dimensions. The result is pasted to the board and can be further annotated.

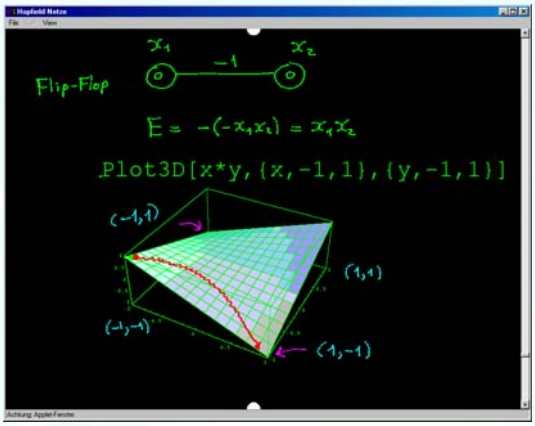


Figure 7: Plot of the function $f(x,y) = xy$. The typewritten text was entered with a wireless keyboard.

Replay of Lectures

Lectures produced with E-Chalk can be viewed over the Internet, live or time delayed. During live transmission three streams are sent over the Internet: the voice of the speaker, an optional video of his face, and the board contents, captured by the contact sensitive whiteboard. Fig. 8 shows how a viewer receives a lecture: one window shows the contents of the board, another a video of the students in the classroom. The lectures can also be replayed days or weeks after they have taken place.

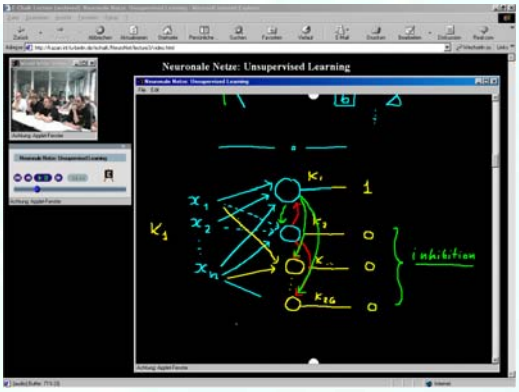


Figure 8: The neural networks class at the FU Berlin in the summer term 2002.

Transcriptions

During a class, the students do not have to copy the contents of the blackboard. In addition to the full lecture, a transcription of the board contents is stored in the Internet immediately after the class finishes and can be sent to a printer. Figure 9 shows the electronic chalkboard during a lecture about image pyramids. Figure 10 shows the transcription in PDF format. The transcription can be stored in color or black and white.

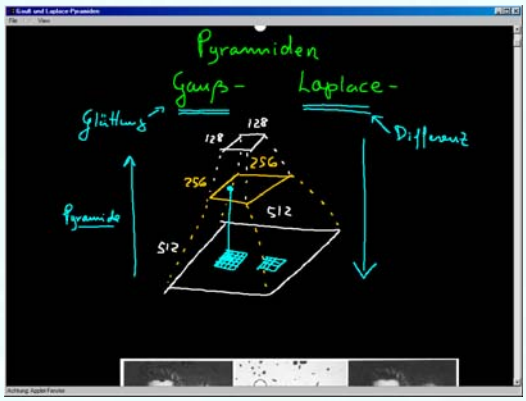


Figure 9: A lecture about image pyramids.

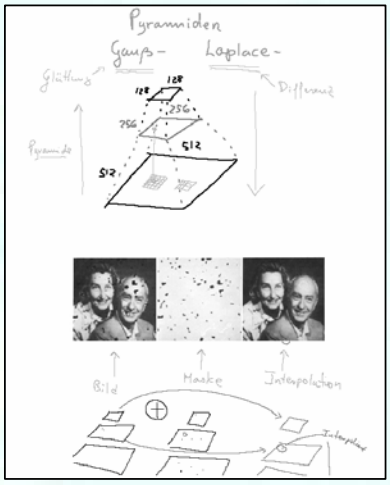


Figure 10: Transcription of the image pyramids lecture in PDF format, ready to be printed.

Handwriting recognition

E-Chalk includes a handwriting recognizer for mathematical formulas. The lecturer can write complex formulas, with subindices and powers, Greek letters and arithmetical symbols. The recognizer first interprets each symbol and then examines the layout of the formula. The recognized formula is passed to Mathe-

matica or Maple, which give back the result. Figure 11 shows a complex formula processed by the formula recognition engine. The engine can transform the formula into LaTeX code (shown on the upper right).

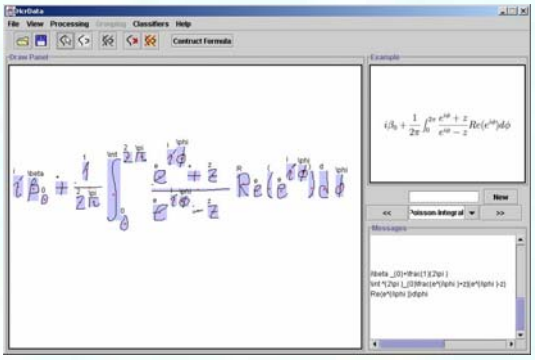


Figure 11: A complex formula processed by the handwriting recognition engine.

Animations

Since E-Chalk is written in Java, it is possible to paste Java Applets on the board and work with them. Java Applets can be interactive, for example the one shown in Fig. 11 is an example of Pythagoras Theorem. The lecturer can modify the size of the sides of the triangle by dragging the corners. The other triangles change accordingly.

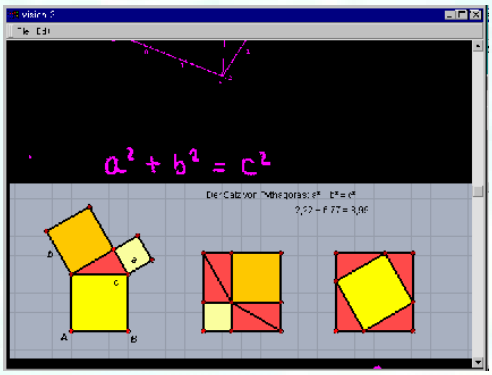


Figure 11: A Java Applet on the board.

Internet Services

E-Chalk can be coupled with Internet servers (CGI scripts). It is possible, for example, to select a service (from a list of URLs bookmarked by the lecturer previously) and ask the board to translate the word "chalk" into German. E-Chalk sends the query to an electronic dictionary in Internet and pastes the answer "Kreide" to the board. Another page can translate degrees Celcius into Farenheit, or Euros to dollars. Users can extend E-Chalk effortlessly just by setting up such Internet servers.

Exymen – the E-Chalk Editor

Lectures can be post-produced. If a lecturer made a mistake or wants to reorganize the lecture sections, the audio, video, and board tracks can be edited after the class. With Exymen, it is also possible to export E-Chalk lectures to other formats, for example for the Windows Media Player. It is also possible to add music or explanations to slide shows for the Internet.

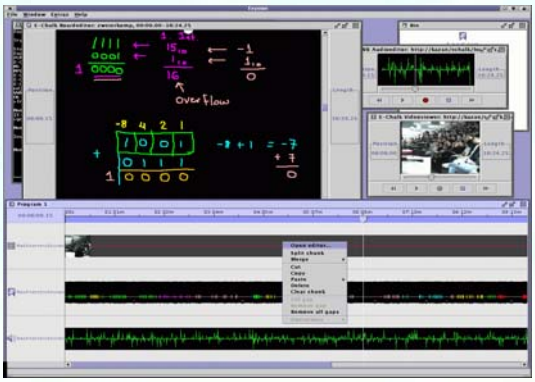
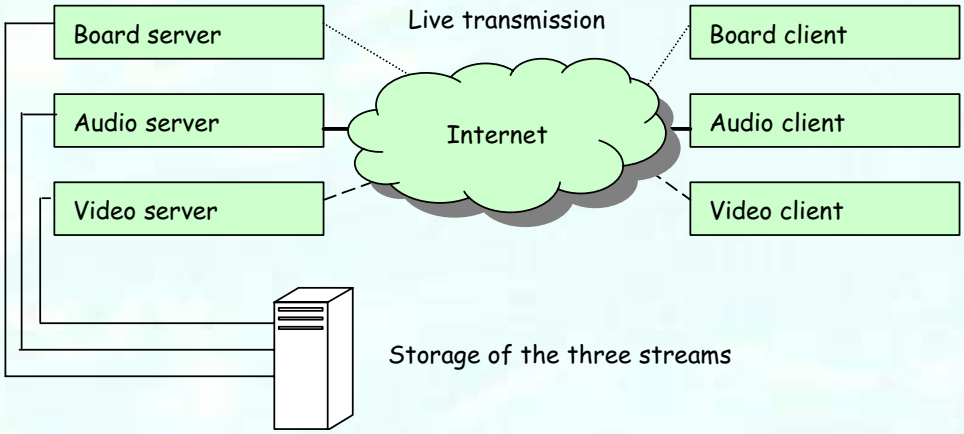


Figure 12: Editing a lecture with Exymen.

The Technology Behind E-Chalk



The E-Chalk server software currently consists of three main and several minor components. The three main components are the audio, the video, and the board server. Minor components are the database manager and the PDF converter.

The E-Chalk client system consists of a set of independent receiver Applets that synchronize themselves by communicating through our Media Applet Synchronization Interface (MASI).

E-Chalk has basically two ways of operating: on-line for live transmissions and off-line for archived transmissions. During live transmissions the audio stream, video stream, and board events are recorded from their devices, compressed, and sent, then they are received, uncompressed, and replayed in real time. While this is done, everything that is sent out is also stored in files. As a result, the E-Chalk client system has two modes, as well. In live mode, each client connects to its corresponding server, through a socket connection. In on-demand mode, clients use a http connection to receive the files and no E-Chalk server is needed.

New features

E-Chalk is being developed continuously. Features to be introduced shortly are: merging the video and board channel into a single image, intelligent audio pre-processing, support for large multiple screen systems, and many more.

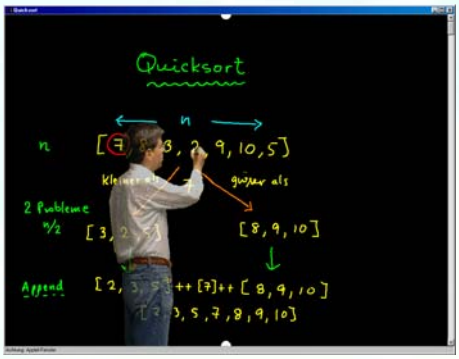


Figure 13: Coming soon, merged board and video image.

E-Chalk in the Field – Evaluations

E-Chalk has been in use at the Free and the Technical University of Berlin for several semesters. Courses have been held and are archived in the Internet. We have started a large evaluation effort which will be finished in the fall term of 2003. Several hundred students are filling in questionnaires and evaluation forms. The evaluators are independent and work under the supervision of Prof. Issing (FU Berlin).

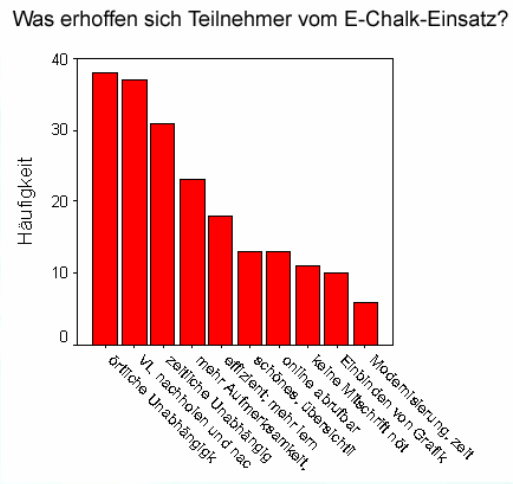


Figure 14: An evaluation histogram for a class at the TU Berlin, computed from the answers of circa 800 students.

E-Chalk in elementary schools

The government of Berlin is evaluating whiteboards and our software for wide deployment in Berlin elementary and secondary schools. Within the framework of the project "Computers in the Schools" (CIDS), teachers in selected schools have been teaching with electronic boards and our software since early 2003.

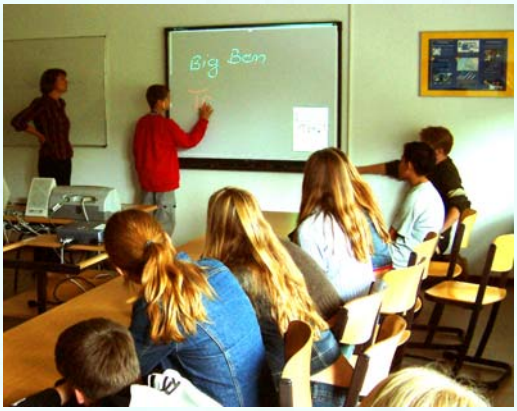


Figure 15: E-Chalk in a Berlin school.

Team

The E-Chalk project was started in 2000 by Prof. Dr. Raúl Rojas. The system was written by PhD students and undergraduates from the Free University of Berlin. Lars Knipping leads the development of the blackboard technology, Gerald Friedland the development of audio and video components, as well as the editor.
Until now, E-Chalk has been financed entirely by the FU Berlin. E-Chalk was awarded the European Academic Software Award in 2002. The thesis of Gerald Friedland (about the E-Chalk editor) was awarded the prize for the best Diploma thesis in 2002 by the Gesellschaft für Informatik.

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