The modern Chalkboard as a Teaching Support Medium for Multimedia eLearning Applications

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***Abstract* — eChalk is a software system that transforms an electronic whiteboard into a teaching tool simulating a traditional chalkboard. In addition to writing and drawings, the electronic chalkboard handles a wide range of multimedia enhancements. These may be used to enliven the lessons by visualization, allowing the system to surpass the didactic potentials of the traditional chalkboard. The system records all actions and provides both a live transmission and a replay of the lecture from the web as a by-product of regular classroom teaching. Remote students follow the lecture by watching the dynamic board content and listening to the recorded voice of the instructor. While originally created only for the use in the Western hemisphere, recent developments target the support of teaching in the Middle East. From our point of view, advantageous application in particular for teaching in different cultures is characterized. This is especially true for cultures with non-Latin scripts and regions which lack the infrastructure for high-speed Internet connections. Systematic evaluations from regular use at two universities are presented.**

***Index Terms* — eChalk, digital chalkboard, digital whiteboard, handwriting recognition, multi-cultural approach**

I. Introduction

Nowadays, it is common in university teaching to rely on the use of slideware (such as Microsoft PowerPoint) for additional motivation of students by providing a modern touch to their lectures. New teaching materials can be produced with relative ease, providing a professional, polished look, while publication is simultaneously simplified, both electronically or as hardcopies. Once created, the materials can be quickly and easily reused.

However, the employment of slideware products in teaching has also been heavily criticized [6]. These products have been developed for commercial presentation purposes. It has been argued that they are well-suited to the task of "selling" a product or idea but tend to be inadequate for presenting complex arguments [15],[16].

Also, the human brain can be easily overloaded by the sensory input that e learning and multimedia technology is capable of delivering [5]. Even though such tools can be used to give an easy-to-follow lecture when correctly employed, they do foster a tendency to overwhelm learners with an overly rapid presentation of information. Lecturers, naturally, posses a deeper understanding of the subject and often tend to proceed through the lecture at a pace too fast for their students to follow. Traditional teaching using a chalkboard imposes a natural limitation on the pace that is overcome through the use of slideware. Also, classes given with slideware tend to be far less flexible and spontaneous than more traditionally presented ones. To use the words of a university lecturer, "PowerPoint sucks the life out of a class" [2].

Some approaches try to address this situation by adding annotations to slides. Office XP now features annotation tools in PowerPoint. Classroom Presenter streams a combination of PowerPoint slides and freehand "inking" [3]. The "eClass" (later "Classroom 2000") software is an early example of recording snapshots of annotated slides and electronic whiteboard drawings for distance teaching purposes [1].

Looking instead for established teaching techniques, one finds that the old-fashioned chalkboard has been an unsurpassed teaching tool for ages. The board ensures that information stays available, providing context for further discussion. The learners can see how ideas are developed rather than being overwhelmed with final results and are supported in following the conceptual process. The teacher is slowed down to the speed of his or her handwriting, giving the students time to follow his or her train of thought.

Compared to the use of prepared slides, the "chalk and talk" approach allows for a much more flexible teaching style. Working on a chalkboard supports creative thinking, illustration, and sharing. Board drawings can be used to draw attention to details using circles, arrows, underlines, checks, groupings, etc. The inherent impreciseness and vagueness of freehand drawings holds extra information. Given these outstanding qualities for teaching, it comes as no surprise that the chalkboard is still so popular for teaching in many disciplines, especially for subjects where complex reasoning has to be taught, such as mathematics, engineering, and the natural sciences.

II. Lecture Recording

Using conventional authoring systems, creating e-learning material is a laborious process. Production costs

are estimated to range from 50 to 200 man hours for one hour of learning content. Generally, this is economically not viable unless the content is either aimed at a very large audience or can be reused many times. For the teaching at universities, the situation is particularly grave, as the contents taught tend to change very fast.

A cause for this tremendous effort lies in the fact that traditional teaching know-how does not easily match with contemporary authoring tools. Apart from technical effort it requires a huge amount of work to structure didactic content for the Web, even if presented only linearly.

Trying to avoid the expenses of standard e-learning module authoring, many universities resort to video capturing of their standard lectures. This approach has the advantage of making use of existing teaching qualifications of the lecturer, instead of requiring the lecturer to acquire new teaching skills. If the lecturer feels comfortable with being video-taped and the recordings manage to transport the feel of the lecture, they can produce high-quality teaching as a kind of by-product of traditional teaching.

However, this approach does not only requires technicians present during the recording to handle the camera and the audio hardware, but most standard Internet video web cast tools are inadequate for this kind of content. Writing and drawings, on slides or on a blackboard, are not encoded appropriately. Compression of a single video frame with off-the-shelf video encoding technology relies on dropping the higher-frequency parts from images resulting in the loss of sharp edges. Either the content becomes blurred and unreadable or, using only weak compression, the video stream requires a lot of bandwidth.

A Our Approach

These considerations inspired the development of a system called eChalk [9],[10]. During classroom teaching, the lecturer works directly on a pen-active wall display or uses a digitizer tablet. 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. While the eChalk interface is based on the metaphor of the simple chalkboard, it is enriched by a wide range of multimedia enhancements. These may be used to enliven the lessons, allowing eChalk to surpass the didactic potentials of the traditional chalkboard.

All actions on the board are tracked. The development of the board content can be viewed by a remote learner, both as a live transmission or as an asynchronous replay. The voice of the lecturer can also be recorded. The distance learner is provided with a dynamic script of the class where none of the teacher's side notes are lost. These two data streams already capture most of the substance of the lecture. Optionally, a video stream of the instructor can be added to provide a more personal touch to the remote lesson and enable the viewer to observe the lecturer's mimics and gestures.

The system is not designed to replace teaching in the classroom. The recordings should "capture the live experience" of the lecture's natural flow, as well as having the teaching style influenced by interactions with a learning audience. The approach merges classroom teaching, distance teaching, and the production of courseware into a single task.

III. The eChalk System

In the following sections the two usage tasks of eChalk are described, namely using it as a presentation and recording system during the lecture and as a replay tool for a remote viewer.

A. In the lecture hall

In order to use the eChalk software in the classroom, one needs a pen based input device and a wide display. Usually, one of the three alternative device configurations is used, a digitizer tablet or tablet PC with an LCD projector, a digitizing whiteboard or a retro projector with pen tracking.

Having started eChalk, the system's user interface metaphor changes from a computer desktop to a chalkboard. The mouse is replaced by a pen-like input device and the need of using the keyboard is avoided wherever possible. The software transforms the screen into a black surface where one can draw or write using different colors and pen widths. The board can be scrolled up and down vertically, providing the lecturer with a virtually unbounded surface to write on. Instead of using a desktop-style scrollbar, two white drag handles are provided at the top and at the bottom of the screen. The user grabs the board at a drag handle using the pen and drags the board up or down.

The lecturer may embed images from the web or the local storage devices and annotate them. As a much more sophisticated feature, computer algebra systems (such as Mathematica or Maple) working in the background can be queried for their numeric or symbolic results or even for function plots, all seamlessly integrated into the board drawings. A mathematical formula recognition allows these requests to be input conveniently in handwriting, including such complex objects as differential operators, integral symbols, vectors, and matrices [10],[14].

The lecturer can also send queries to dynamic web services (CGI scripts) returning text or pictures. Interactive Java Applets can be run on the board to provide visualizations for abstract topics and concepts. Alternatively, custom eChalk modules called Chalklets can be used. These are controlled by means of strokes of

the pen on the board and return drawing strokes themselves, preserving the board-like look and feel. For example, a logic circuit simulator [12] recognizes sketches of digital circuits and runs a simulation, color-coding the wires to indicate high or low voltages.

The system does not require the user to explicitly trigger a save. Everything is automatically and continuously stored for viewing through standard web browsers.

B. Remote Usage

When remote students open the automatically generated web page 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. An additional Applet, the control panel, is provided for navigation in archived lectures. All these Applets run in a standard Java-enabled browser, without requiring the download of a special plug-in. Audio and video is streamed using lossy compression and buffering to guarantee interruption-free transmission. A printable, static copy of the final board image is also included as an Adobe PDF file.

IV. Use in Manifold Cultures

The eChalk system relies on the audio signal captured from the lecturer combined with his or her freehand writing and drawings as board input. This does not only enable the lecturer to input complex mathematic formulae much more conveniently than using a standard formula editor, a usually rather cumbersome task. It also makes the input completely independent of the writing system and language used, whether it relies on the western alphabet or Arabic script or other sign systems, instead of forcing the learners to work with a writing system other than their native one.

Most parts of the user interface rely on icons and graphical elements. Only the recording setup uses printed information to a greater extend. However, the overall user interface of eChalk has been localized to several languages including Arabic, see Fig. 1. A translation to simplified Chinese is currently under way.

From the very beginning, eChalk transmissions were designed to impose only low technical requirements on the users. This provides an extra advantage in areas where the Internet infrastructure available does not allow requiring students to have a broadband connection. Due to the board stream using a vector representation, the bandwidth requirements are very low. The bandwidth of the board stream peaks in the range of 3 to 5 kbps when using standard pen or mouse devices, i.e. with sampling rates between 50 and 125 Hz. In fact, average bandwidth needed in real lectures turned out to be less than 1 kbps [11].

Therefore in practice, the board's bandwidth requirement is negligible compared to the bandwidth used by audio (and optional video), particularly since audio stream codecs between 24 and 256 kbps can be chosen. Again, these numbers are maximum values rarely reached and only for a few seconds. Choosing the 64 kbps codec allows remote access to a board and audio stream of sufficient quality with only a modem connection.

Fig. 1. Setup dialog for an eChalk recording in Arabic.

V. Evaluation

The development of eChalk has been guided by experience from ongoing deployment of the system in regular university teaching for several terms now. A number of field studies have been conducted in the course of university courses to evaluate the use of eChalk, its impact on teaching, and its acceptance under real-life conditions [11]. These studies were arranged by media psychologists from the Freie Universität Berlin and Technische Universität Berlin (Schulte, Issing and Hendricks). The courses included lectures and exercises on mathematics for engineers, physics for engineers, computer science as well as seminars on cartography. For computer science courses, replays with audio and PDF transcripts were provided. The cartography seminars used the system for classroom teaching only. The engineering courses provided replays without audio recordings and PDF transcripts.

During the 2003 summer term, six eChalk courses were evaluated. Data gathered included 595 full questionnaires, filled out at the beginning and end of the term, 893 short questionnaires filled out during the final exam, interviews with the six instructors, and Web access analysis for one of the courses [13]. In a second study conducted during the winter term of 2003/04, 303 questionnaires from nine eChalk courses were evaluated [8]. In the following the main findings are presented. A detailed summary of these studies can be found in [11].

A. Findings from student questionaires

Adopting eChalk in teaching did reveal neither positive nor negative effects on the students' motivation to prepare for the lecture. Didactic quality of the courses was perceived positively compared to regular courses. Students welcomed the extra flexibility in learning, both for increased independence in time and in location.

The students were asked to judge the impact of the system on their studies, whether it helped in or complicated learning. The answers showed a clearly significant tendency towards a positive impact.

About half of the students (46.8%) reported using the eChalk materials regularly for revising the classes. The average time spent revising including the "zero minutes users" was 19 minutes per week. Considering only those students who actually use eChalk for revision, the average was 40 minutes, the median 30 minutes. However, these figures should not be taken too literally, as they display a high degree of variance.

Asking students about the amount of note-taking in eChalk classes compared to regular classes yielded results differing between the two studies. The first study showed a small tendency (below statistic significance) of students reducing the amount of note-taking compared to regular courses. According to the second one, about 60% of students were taking at least as many notes in eChalk classes as in conventional classes.

The short questionnaires coupled with the exam in the summer term study were used to compare exam results and eChalk use. However, no significant correlation between exam results and eChalk use could be found. In all user categories almost the same grade has been achieved. [14] suggests further examination by forming two groups with the same external conditions differing only in the use of eChalk.

The first evaluation also examined the students' opinions on the quality of the system. The answers concerning the visual impression showed a slight tendency towards a favorable opinion, with no significant differences between classroom teaching and replay. The acoustic quality of the instructor's voice, however, received below-average ratings for the replay. This result was a major motivation to enhance the audio recording quality in eChalk by the approaches described in [7]. Despite the shortcomings in audio quality, the overall quality of the system was clearly seen as positive, both in classroom teaching and in replay. Using eChalk in the evaluated course received above-average marks from 73% of all students.

To compare eChalk with other teaching techniques, the students were asked to judge, in comparison, between eChalk-taught classes and classes using other teaching technologies. The comparison was made on courses using electronic slide presentations like MS PowerPoint, traditional chalkboard teaching, and overhead slides. eChalk was favored above all these three teaching media, with PowerPoint coming closest and overhead slides ranging last.

Students' use of eChalk-generated material was found to be uncorrelated to the bandwidth of their Internet connection and their preferred type of browser. Thus, it can be assumed that eChalk recordings are equally usable with any type of connection.

The students were asked to provide comments on the advantages of the eChalk system, on its disadvantages, and on suggestions for improvements.

The most frequently mentioned advantage was a clear, readable board image, followed by comments on remote access, revision material, enhanced visualization through the use of applets and images, the elimination of the need to copy the board content, providing the learners with more time to concentrate on the content of the lecture. A few students also noted that the lecture was easier to follow with the system.

Commonly mentioned disadvantages include complaints about the visual quality of the board image, the relative size of the board, and the bad handwriting of the instructor. A likely cause for these shortcomings is the low resolution of the displays used, forcing the instructor to write larger letters for improved readability. While the digitizer hardware describes in Sec. III.A is theoretically capable of recognizing the pen's location far beyond the accuracy of the human hand, the resolution is limited by the screen resolution of the projector and the controlling computer's graphics card. However, organic displays might solve these problems, as very wide, high-resolutions screens are expected within the next few years [4].

Almost all comments on possible improvements were requests for features which were already fully supported, but not used in the evaluated lecture.

B. Findings from instructor interviews

According to the lecturers interviews, the time needed by lecturers to get fully accustomed to the system, ranged between one and four lectures. [13] judges this as an indication for the intuitive handling of the software. The interviews also showed that most features beyond the basic writing features and use of images were rarely used.

The instructors' comments on advantages and disadvantages of the system were similar to the most frequent students' comments. In addition, they judged as positive that the teaching content of traditional classes needs no restructuring when presented with the system, enabling them to reuse their old materials. Some lecturers mentioned that they missed the small pauses introduced in traditional chalk lectures by the wiping of the board.

VI. SUMMARY

Experiences in using the system in actual teaching and systematic evaluations confirmed the potential of eChalk as a beneficial and usable system for teaching. The lecturer can easily integrate material from previous terms. Traditional chalkboard-related skills translate directly into skills for good eChalk lectures.

The system enables the user to produce electronic course materials simply as a by-product of classroom teaching. Students are supported in their revision of classes with a live and dynamic "transcript". Only a browser is needed for this and no special software has to be installed. All substantial content of the lecture including audio and dynamic board image can be received with low bandwidth requirements.

The system presented here not only tries to preserve the didactic potentials and easy handling of the traditional chalkboard. Its reach is extended to extensive use of new media and remote access, enhancing the quality of teaching in mathematics and engineering education, and fostering understanding through interaction and visualization.

Field studies conducted so far covered university teaching only in a Western setting. While the system provides the technical requirements to teach in other cultures, impacts of different learning habits still have to be researched. For example, the importance of the different content channels board, audio, and especially video might be very different in other cultures. The importance's of aesthetic writing in Far Eastern cultures, the cultural outlook on lecturers as persons of authority, or forms of etiquette are only some of the potentially influencing factors.

REFERENCES

[1] G. D. Abowd, "Classroom 2000, "An experiment with the instrumentation of a living educational environment", IBM Systems Journal, Special Issue on Pervasive Computing, vol. 38(4), pp. 508–530, October, 1999.

[2] R. Anderson, 2004, "Beyond PowerPoint: Building a new classroom presenter", Syllabus Magazine, pp. 31–33, June, 2004.

[3] R. Anderson, C. Hoyer, C. Prince, J. Su, F. Videon, and S.A. Wolfman, "Speech, ink and slides: The interaction of content channels", Proceedings of the Twelfth ACM International Conference on Multimedia, New York, pp. 796–803, October, 2004.

[4] J. N. Bardsley, International OLED technology roadmap: 2001–2010, U.S. Display Consortium.

[5] R. E. Clark, "The cognitive sciences and human performance technology", in D. Stolovitch and E. J. Keeps, Eds., Handbook of Human Performance Technology: Improving Individual and Organizational Performance Worldwide, chapter 5, ISPI/Jossey-Bass/Pfeiffer, San Francisco, second edition, March, 1999.

[6] T. Creed, "PowerPoint no! Cyberspace, yes", The National Teaching & Learning Forum (NTFL), vol. 6(4), pp. 1–4, 1997.

[7] Friedland, K. Jantz, L. Knipping, R. Rojas, "The virtual audio Technician: An automatic software enhancer for audio recording in lecture halls", Knowledge- Based Intelligent Information and Engineering Systems: 9th International Conference (KES 2005), part I, vol. 3681 of Lecture Notes in Computer Sciences, Springer, pp. 744–750, September 14-16 2005.

[8] G. Friedland, L. Knipping, R. Rojas, J. Schulte, and C. Zick, Evaluationsergebnisse zum Einsatz des E-Kreide Systems im Wintersemester 2003/2004, Technical Report B-04-06, department of mathematics and computer science, Freie Universität Berlin, June, 2004.

[9] G. Friedland, L. Knipping, J. Schulte, and E. Tapia, "E-Chalk: A lecture recording system using the chalkboard metaphor", Interactive Technology and Smart Education (ITSE), vol. 1(1), pp. 9–20, February, 2004.

[10] G. Friedland, L. Knipping, and E. Tapia, "Web based lectures produced by AI supported classroom teaching", International Journal of Artificial Intelligence Tools (IJAIT), vol. 13(2), pp. 367–382, 2004.

[11] L. Knipping, An Electronic Chalkboard for Classroom and Distance Teaching, PhD thesis, department of mathematics and computer science, Freie Universität Berlin, February 14, 2005.

[12] M. Liwicki and L. Knipping, 2005, "Recognizing and simulating sketched logic circuits", Knowledge- Based Intelligent Information and Engineering Systems: 9th International Conference (KES 2005), Proceedings, Part III, vol. 3683 of Lecture Notes in Computer Sciences, Springer, pp. 588–594, September 14-16 2005.

[13] J. Schulte, Evaluation des Einsatzes der Software E-Kreide in der universitären Lehre, Magister's thesis, Technische Universität Berlin, Institut für Sprache und Kommunikation, November, 2003.

[14] E. Tapia, Understanding Mathematics: A System for the Recognition of Online Handwritten Mathematical Expressions, PhD thesis, department of mathematics and computer science, Freie Universität Berlin, December 10, 2004.

[15] E.R. Tufte, The cognitive style of PowerPoint, Chesire (CT), May, 2003.

[16] E.R. Tufte, "Power corrupts. PowerPoint corrupts absolutely", Wired, pp. 118–119, September, 2003.