Use of ATM and Other Computer Networks in Delivery of Engineering Education - A Perspective

Patrick E. Mantey, J.J. Garcia-Luna, Craig Wittenbrink, Arul Ananthanarayanan
Baskin Center for Computer Engineering and Information Sciences
University of California, Santa Cruz

Abstract

Meeting the needs of employees in the area served by the University of California, Santa Cruz, translates into a requirement for the delivery of graduate courses to a site 30 miles from campus, a site now connected to campus by an ATM link (furnished under Pacific Bell's CalREN research project). Based on this technology we have developed the design of a "mirrored-pair" of classrooms, to support distance learning.

In conjunction with this, we have also considered requirements for support of remote or "distributed" faculty "electronic office hours", as interactive sessions over a computer network. Another dimension in this digital multimedia in the educational setting is the support for capture and storage of lectures in a digital multimedia library, which offers significant potential value for improved learning and increased faculty productivity.

For connecting the "mirrored-pair" of classrooms we have used and evaluated a variety of currently available systems and software, and have concluded that significant additional research is needed to optimally utilize remote classrooms. We currently developing those systems and software, and expect to evaluate them in the delivery of graduate courses in degree-granting programs. In this paper we discuss our objectives and our system design which exploits the available network technology.

Overview

Advances in computer and communications technology are expected to make full-motion digital video competitive with current broadcast video for use in distance learning, at least to appropriately equipped sites. Digital video provides much more flexibility than analog video (or digitally delivered NTSC video) now widely used in distance learning. Pictures at different sizes, and with different refresh rates, can be readily supported using digital video, and these can be matched to a range of communications bandwidths. Digital video, as data, can be stored and managed by computer systems, and delivered over digital networks. In conjunction with (synchronized) digitized audio streams, this digital multimedia can be used for delivering live lectures to remote students. It can also support various other forms of interactive learning and collaboration. Availability of ever-larger bandwidth internet connections, even to the home, makes possible "electronic office hours" through which interaction takes place using voice and shared white-board as well as text.

This project focuses on the applications of advanced technology to overcome distance barriers and time constraints in graduate education of students who are also employed in industry, and therefore not resident on or near the campus. The particular challenge faced by many graduate students (and a large number of potential graduate students) in computer science and engineering at the University of California, Santa Cruz, is that they are employed in Santa Clara County ("Silicon Valley"), and are simultaneously pursuing a graduate degree from UCSC. The UCSC campus, which is the UC campus geographically nearest to Santa Clara County and which has this county in its service area for University Extension, is separated from Santa Clara County by the Santa Cruz Mountains and the infamous "Highway 17". Commuting from the employee's work site to the classroom can take in the range of an hour (even if the distance is only 30 miles) and this road is subject to many accidents and closures, especially during severe winter storms.

A sizable number of our permanent faculty in CE and CS at UCSC also have their residences in Santa Clara valley. While graduate courses today at UCSC are taught primarily by permanent faculty, we appreciate the value that is brought to our curriculum by adjunct faculty that we draw from industry, as these faculty add exciting new dimensions, practical insight, and ties to the "real world" that we believe benefit our students.

Approach

To attack the distance barrier (and its corresponding time requirement when commuting "over the hill") we have designed a "mirrored pair" of classrooms, one on campus and one at our Extension facility in Santa Clara. Utilizing the latest in communications, image and workstation technology, our objective is to link these in such a way that the experience of students (and instructors) using this classroom pair closely resembles that which would result from them being in the same classroom. We expect lectures to originate at either end, and for students at either end to have the same level of involvement regardless of the site of the lecturer. While some attention is also being given to the support of remote students not in either of the connected classrooms, our (at least initial) assumption is that learning is enhanced in a group setting, and therefore that students will generally be in (one of) the classrooms of the "mirrored pair".

Technology

As part of the CalREN project at UCSC [1], sponsored in part by Pacific Bell, we have connected the "mirrored-pair" of classrooms via an ATM network operating at DS3 rates (45Mbits/sec. Using this ATM network, we have the ability to provide multiple (e.g. at 5Mbits/ sec) independent two-way digital video paths over the same ATM link.

Our current design uses two cameras in each site continuously capturing video. At the instructor's end, one video captures the instructor ("talking head" or more) and one captures the audience. Another may be used, or the instructor channel switched, to support video instructional materials. At the other site, presently one camera is for the audience overview, and one will zoom to a particular student in the case of a question or other input from a remote student.

Multiple audio channels are supported, and made as independent as possible. The instructor audio is the primary channel, and is assumed to be delivered via speakers at the remote site. Other paths from both sites would capture classroom ambient, and / or the audio from a student participant. In our design, students at workstations in the classroom have headphones and a user interface to allow them to select and control audio sources as well as video as they create their own learning environment.

An electronic "white board" is provided for instructor presentations. Support is also provided for computer-generated / stored slides, simulations, graphics, images, etc. Reciprocally, an electronic "white board" at the other site is available for students to provide input or make presentations.

To improve interaction between the students and instructors, with both scattered over at least the two counties and separated by the mountain range, we have seen a growing use of electronic mail as a form of "electronic office hours". Many faculty interact with their students, individually or as a group, in evenings and on weekends via E-mail. We are making enhancements to E-mail, to include use of voice and a shared "white board" and possibly including scanned images and video. Essentially all of our graduate students have home computers or workstations that will support, in a windowing environment, the graphics required of a white board, and a growing number are connecting to the internet at higher speeds (e.g. ISDN). Low-cost graphics pens and tablets, with the right software environment and supporting protocols, would allow creation of the desired shared "white board" environment.

Digital libraries will support the capture and delivery of the contents of lectures to enhance faculty teaching and improve faculty productivity, and for use by students for review and to make up lectures missed as live sessions. Another dimension of the evaluation of this high-technology mirrored-pair classrooms is to try and learn from students the value of, and limitations encountered, when they participate in the course asynchronously, via use of lectures from the digital library vs. their live participation in one of the mirrored-pair of classrooms. Students with home computers usually have much less bandwidth that is available between the classrooms, and may therefore either get a reduced bandwidth version of the classroom session via the electronic library, or else have to plan ahead, get it forward to themselves in compressed form, and then rebuild it at their local workstation for use later.

Research Challenges

The creation of the hardware, software and user interface to enable students to create their own optimum learning environment is a key challenge to this research, as is the evaluation of its effectiveness. The individualized environment in the shared classroom is presumed to be the ideal, and is being compared against other configurations.

Our method of approach is based on off-the-shelf hardware, public-domain software, and new or modified protocols and software environments for distance and asynchronous learning. Using off-the-shelf hardware is important, because of the continuing improvements in computer and communication technologies. Using public-domain software is based on the two premises: (a) we need to be able to make modifications to the software tools used in our experiments, and (b) many features of the tools needed for our purposes are already available or will become available soon as part of other research.

In the individualized environment, students control the size of video sources that appear in the individual's screen, choose the audio path to listen to on the headphones, control volume, and so forth. The alternative, which today is of lower cost, is to use shared displays managed by one student or by a staff person. We are developing means to compare the effectiveness of both. Tentatively, our approach is to mix the configuration in the classroom, assigning some students individual workstations (probably randomly) while others view the shared video monitors and without individual controls. We will then evaluate costs and benefits, by student performance in the course, student feedback and questionnaires, etc. For the shared video, someone in the classroom (an operator or a selected student) controls the contents of each screen and the (two) audio channels.

The activities of instructors and students in the mirrored-pair classrooms need to be coordinated, just like in a traditional class. However, the geographical separation of the classrooms and the computer technology used to disseminate information restrict the coordination among individuals. "Floor control " of the mirrored-pair classrooms is being addressed. In some cases, the instructor(s) wants full control, while in seminar formats a more free-flow scheme may be appropriate. When remote students or experts are allowed to participate in the learning process, their interactions need to be coordinated with the dynamics of the mirrored classrooms. Also, the physical separation of the mirrored classrooms limits the amount of information that can be used to orchestrate group activities (e.g., a student in one classroom cannot simply look around to make contact with another student in the other classroom, she has to use computer-based tools instead).

Our approach consists of integrating a number of available tools for multimedia collaboration and session establishment with our own software tools for floor control [2, 3]. Our goal is to be able to support a non-intrusive computer- supported way to permit turn taking [6]. We are also investigating the use of voice-activated floor control protocols (implemented in software) to eliminate echo problems in the mirrored classrooms, which aside from the computer hardware used in the experiments, will be traditional classrooms.

We plan to explore linking into the course in real-time some students or experts (e.g., a university researcher able to contribute to the class) not in either classroom. We would expect that these participants will not have the ATM bandwidth, even if they are located in the same campus of either classroom, and thus will receive much less video that those in either classroom. Support of these remote participants will require careful management and prioritization of the bandwidth available, and include use of advanced data compression and multicast dissemination protocols. A-priori, we expect that the instructor audio, white board, and other audio will be more important than any of the video streams (except when the instructor is using video materials for instruction).

The advent of applications such as shared white boards running over the Internet has demonstrated the need for reliable dissemination of multimedia information from one or multiple sources to multiple receivers. In our distance learning experiments, the instructor and students in the mirrored classrooms, or remote participants can be sources and / or destinations of information. Our recent research shows that reliable multicasting over long network distances (dictated by the bandwidth of the links and the capacity of the PCs or workstations used) can best be achieved by organizing the participants into a "shared acknowledgment tree," which is a structure over which participants can acknowledge one anothers' information efficiently. An important issue is how new protocols for concurrent reliable multicasting [4] should be integrated with type-of-service multicasting schemes [5] needed to handle information media traversing heterogeneous transmission media.

Asynchronous connection of students presents a different hardware and system challenge. These students will use previously captured audio and video streams stored in the digital library, and again access this material via bandwidths much smaller than the ATM facility. We hope to have enough remote students willing to participate in our distance learning experiments that we can evaluate the effectiveness of these asynchronous modes of participation vs. the synchronous modes supported in the mirrored-pair classrooms. Furthermore, the lectures in the mirrored classrooms will be based on on-line material, which together with the discussions elicited in class can be stored for subsequent review [7] [8].

Evaluation

We are experimenting with classes originating at either end, and with some where the instructor switches between the two sites. Evaluation plans include use of student appraisals, evaluation of student success in courses, and tracking to see what fraction of students choose to make the commute to the room where the instructor is in person vs. participating from the end which gives the easiest commute. (Since we have students whose employment and residence cover the geography around each site and the space in between, we expect to have a significant number of students making a choice of which site to go for the class.) This should provide a good start on evaluation of the effectiveness of these "mirrored pair" of classrooms. Within each classroom, we plan to experiment with different equipment configurations. Some students will view large shared monitors for video and image presentation, in a more passive mode, in that their only control will be to choose which (if any) of the monitors to watch. Similarly, their audio will be via the classroom speakers. Other students will be provided individual PC's or workstations, along with headphones, and will be able to control their own display space selecting and sizing video and image sources) and also, via a user interface provided at the workstation, select the audio channel for the earphones, control volume, etc.

Extension of this concept to multiple classrooms is a possibility, but will be considered for later work as it adds significant complexity to the already complex problem of the management of the multiple video and audio streams emanating from each site.

Conclusions

The availability of ATM networks, with their significant increase in available bandwidth, creates a new challenge in development of environments for distance learning. In this paper we have described our design of a “mirrored-pair” of classrooms, to overcome the distance and separation by employing multiple video and audio channels and other technology enhancements. Supplementing this are tools for asynchronous learning, including enhanced E-mail with video (synchronous or asynchronous, depending on available bandwidth), audio, and white-board for electronic office hours, and use of a digital library for reuse of material, to support asynchronous learning and to improve faculty productivity.

References

[1] C. Wittenbrink, A. Ananthanarayanan, J.J. Garcia-Luna and P. E. Mantey, *The Monterey Bay ATM Network*, Report UCSC-CRL-96-11, University of California, Santa Cruz, Santa Cruz, CA 95064 June 1996 http://www.cse.ucsc.edu/research/bayATMnet

[2] H.-P. Dommel and J.J. Garcia-Luna-Aceves, ``Floor Control for Multimedia Conferencing and Collaboration," to appear in the ACM Journal on Multimedia Systems, 1996.

[3] H.-P. Dommel and J.J. Garcia-Luna-Aceves, "A Reference Model for Floor Control in Multimedia Collaboration," submitted to ACM Multimedia 96.

[4] B. Levine, D. Labo, and J.J. Garcia-Luna-Aceves, "The Case for Concurrent reliable Multicasting Using Shared ACK Trees," submitted to ACM Multimedia 96.

[5] Q. Zhu, M. Parsa, and J.J. Garcia-Luna-Aceves, ``A Source-Based Algorithm for Delay-Constrained Minimum-Cost Multicasting," *Proc. IEEE INFOCOM 95*, Boston, MA, April 1995.

[6] D.C. O'Connell, S. Kowal, and E. Kaltenbacher, "Turn-Taking: A Critical Analysis of the Research Tradition," *Journal of Psycholinguistic Research*, Vol 19, No. 6, pp. 345-373, 1990.

[7] H.M. Gladney and P.E. Mantey. "Essential Issues in the Design of Shared Document/Image Libraries". *Image Communications and Workstations, SPIE Proceedings* vol. 1258, February 1990.

[8] P.E. Mantey and D.E. Levy. "Electronic Libraries and Optical Jukebox Scheduling". *Image Storage and Retrieval Systems*, SPIE Proceedings vol. 1662, February 1992.