TeleMentoring Final Report†

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ABSTRACT

Using the Asynchronous Transfer Mode (ATM) network infrastructure of the AURORA Gigabit Testbed§, we were able to carry out a trial of interactive distance learning. The trial used teleconferencing hardware which converts NTSC television and audio signals to and from ATM cells. This hardware connected the Bellcore VideoWindow(TM) with other apparatus to create a realistic two-way interaction. In our trial, the interaction was between teams of undergraduate computer science students and researchers at Bellcore, and was used to support work by these students on advanced laboratory projects for a course.

Our hypothesis was that remote "mentoring" would provide a means with which student learning could be accelerated. Further, projects could be chosen which were meaningful to industrial research goals, so that student training is coupled with gaining relevant experience.

This report summarizes the results from our TeleMentoring project. We discuss the observed strengths and limitations of TeleMentoring, and describe continuing work which is a direct result of the TeleMentoring work.

1. Introduction

Time and distance-independent education are an important role for the still-emerging National Information Infrastructure TeleMentoring [12, 11] is a research and teaching experiment, based on the observation that undergraduate computer science laboratories are taught using a ‘‘mentoring’’ model rather than a ‘‘lecturing’’ model. This suggested that the unique facilities of the AURORA Gigabit Testbed, described later, could be used to support interactive distance learning between widely separated sites, such as the University of Pennsylvania, Bell Communications Research, IBM Research, and the Massachusetts Institute of Technology.

We augmented the laboratory portion of an undergraduate computer science course through interaction with remote ‘‘mentors’’. The mentors chosen were experts in the course topic. Interaction was supported using experimental telecommunications technologies that are predecessor technologies for the NII [3]. The experimental hypothesis was that the TeleMentored students would be able to absorb more material, at a greater rate, than equivalent students who were not TeleMentored.

There were additional questions of a broader nature addressed in the work.

- First, does this idea permit us and other educational institutions to teach material which would not otherwise be available to our students?
- Second, does it allow experts in industry to participate in the process of educating students in relevant technologies and laboratory techniques?

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§ - AURORA is a now-completed joint research effort undertaken by Bell Atlantic, Bellcore, IBM Research, MIT, MCI, NYNEX, U. Arizona and and U. Penn, sponsored as part of the NSF/ARPA Sponsored Gigabit Testbed Initiative through the Corporation for National Research Initiatives, under Cooperative Agreement number NCR-8919038. AURORA work at Penn was also partially supported by Bellcore through the DAWN project, by IBM through a Faculty Development Award to Prof. Smith and equipment support, by SUN Microsystems, and by the Hewlett-Packard Company.

- Third, does it allow this learning to take place in ways (such as mentoring), and with means (such as video and manipulation of laboratory instruments), over distances which would otherwise prohibit the interactions needed for learning.

In addition, as part of the TeleMentoring research [12, 11, 13] we designed and implemented a low-cost teleconferencing technology [5] for use with ATM networks†, and in particular, direct connection to the Sunshine ATM Switch prototyped by Bell Communications Research [4]. A particular advantage of this technology (implemented as a single printed circuit board) was that a teleconferencing system could be constructed with standard technologies, such as a commercial color television and video camera. Supplemental funding allowed us to buy a commercial implementation of this same scheme, developed by Nemesys Research, Ltd. of the UK, now a subsidiary of Fore Systems, Inc of Pennsylvania.

Finally, we showed [7, 8] that telemanipulation (as would be required for virtual laboratories) was possible with ATM networks combined with an architecture for end-to-end Quality of Service (QoS)‡.

2. Telementoring Technology Base: From Bleeding Edge to Leading Edge

TeleMentoring's technologies were originally those used in the AURORA Gigabit Testbed, which focused on high-speed network interconnection of workstations [2].

The geography of the AURORA testbed as it existed is shown in **Figure 1.**

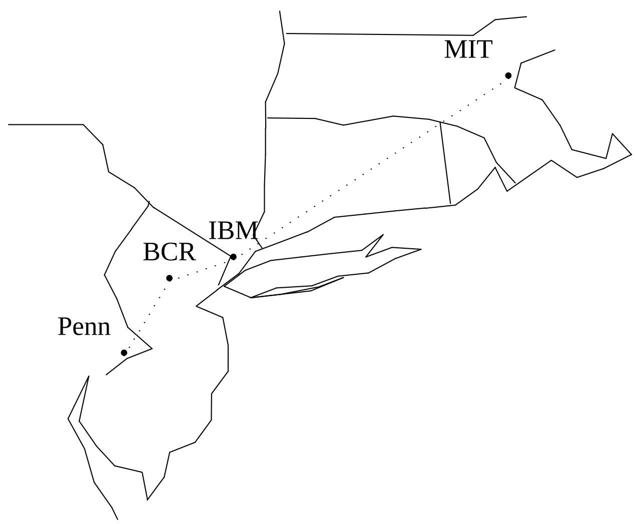

Figure 1: AURORA Geography

AURORA's transmission facilities were 2.4 billion bit per second (Gbps) Synchronous Optical Network (SONET) OC-48 links [9].

As no fast switches were available for these speeds [2], two research prototypes, Bellcore's SUNSHINE [4] ATM switch, and IBM Research's plaNET [1] switch, were built as part of the testbed research. More details of the logical topology are given in Clark, *et al.* [2] and Smith [13].

In addition, to support TeleMentoring, special switch connection hardware [6, 10] and video cards [5] were prototyped, as well as significant pieces of new software [7, 8].

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‡ Dr. Klara Nahrstedt is now on the faculty of the University of Illinois, Urbana.

2.1. AURORA Technology Achievements

In May, 1993 the first ATM cells were sent between workstations located at Penn and at Bellcore. In June 1993, a variety of video experiments were carried out, largely with low-quality video between workstations. The first Sunshine switch became operational, at Bellcore in Morristown, NJ, and was used to switch cells sent between workstations at Penn and Bellcore. The second and third Sunshine switches were deployed at Penn and MIT in Fall 1993.

The TeleMentoring ATM terminal adapter solution [5] (‘‘Cheap Video’’, later renamed AVATAR), developed in cooperation with Bellcore, connected the VideoWindow directly to a port of the Sunshine switch. We constructed [6] a SONET-compliant local distribution technology based on Hewlett-Packard’s GLINK chip set [10, 6], which allowed us to interconnect the videoconferencing facilities with low-cost media such as unshielded twisted pair.

3. Curriculum Changes

We began the first TeleMentoring evaluation in the U. Penn undergraduate course CSE371 in Spring 1994. A graduate student familiar with the high-speed networking research (Brendan Traw) served as the teaching assistant for CSE371 in order to facilitate the use of the technologies in the course.

A major curriculum change was a restructuring of the undergraduate digital design sequence, CSE370-CSE371. This course had fallen badly behind the state of the art, for a variety of reasons. In particular, the microprocessor technology employed (Intel 8085) was well over fifteen years old. While principles can be taught using any microprocessor, the use of a current technology greatly increases the relevance of the laboratory exercises, especially where that technology is used in classroom teaching.

For TeleMentoring, we emphasized classroom teaching in the first part of the course, CSE370, which is taught in the Fall. For Spring 1994, the CSE371 course had a stronger laboratory focus, with a larger-scale microprocessor project implementation in addition to a full set of lectures.

Laboratory staff were heavily involved in this effort, developing new materials, course guides and exercises. The management of course resources such as microprocessors and I/O chips was simplified by the development of kits which the students use for the whole semester. An HP16500A logic analyzer was acquired and teaching materials such as guides for use of the machine were prepared.

Using the TeleMentoring research as a basis, we received equipment support from SUN Microsystems to support undergraduate course work, four workstations with multimedia support. These workstations were also used to support a new undergraduate course developed by one of the PIs, Insup Lee, CSE 480. CSE 480, ‘‘Distributed and Real-Time Systems’’ has a major project component, which for Spring 1994 was a small-scale multimedia teleconferencing system.

4. Examples of Course Projects pursued with TeleMentoring

The projects were developed in consultation with the TeleMentors from Bell Communications Research. We attempted to size the projects so that teams of two undergraduates had a reasonable chance of success. The projects were chosen to be genuinely useful to the Bell Communications Research staff members interacting with the students. The CSE371 class at this time (1994) used Motorola 68000 processors, and thus all of the projects employ the 68000 processor.

Cell Traffic Generator: The 68000 is used to generate and write ATM cell patterns into a large Static Random Access Memory (SRAM) buffer. This buffer could be dual ported to allow a Finite-State Machine (FSM) to read the ATM cells bodies out, format their headers, and put them into SONET frames. A number of these boards could provide an inexpensive mechanism to load (and hence evaluate the performance of) a switch or workstation-based network subsystem.

Cheap Video 68K: ‘‘Cheap Video’’ is the name we have given the video adaptor we developed for TeleMentoring [5]. A clear upgrade to the initial design is to integrate a 68000 into the original all-hardware cheap video design. The 68000 could perform additional processing to allow more complicated command and status interactions between the cheap video hardware and remote nodes (e.g., at Bellcore, IBM or MIT). It would also be desirable to integrate audio capability into the design, as with ‘‘Cheap Video II’’.

Switch Status Monitor: Each input port on the Sunshine ATM switch has a serial port which could be used to obtain statistics on the operation of that port. These statistics could include: error rates, number of active connections, and utilization level. A 68000 minimal system with multiple serial ports could be used to gather statistics on the overall operation of the switch by connecting to each input port.

There were 8 students involved in the TeleMentoring evaluation this semester. Each group pursued one of these projects. Two groups of 2 students were TeleMentored, and the other two groups worked closely with the undergraduate laboratory staff member, but without TeleMentoring. This gave us a controlled experiment (to the degree possible with students!) and allowed us to draw early conclusions for dissemination to other researchers and educators. The environment for TeleMentoring at Penn was a conference room with a large table, the VideoWindow, and a whiteboard used for illustrating concepts and drawing block diagrams.

The TeleMentors met as a group of three at a table in Bill Marcus's office at Bellcore's Morristown Research and Engineering facility. Meetings were scheduled via telephone or e-mail, and were focused on a particular topic in the design and implementation of the projects.

5. Project Management

Project management was accomplished mainly via electronic mail to a mailing list, `TeleMentors@aurora.cis.upenn.edu`, over which information was distributed between the PIs and Bellcore collaborators. Another mailing list, `telementor@viper.cis.upenn.edu` was also used by the student participants, to facilitate discussion between themselves and the TeleMentors.

Our colleagues at the the industrial sites were included in this mail exploder. We had many face-to-face meetings, often including laboratory staff. The staff were involved, as they are the *de facto* agents of change. They did, in fact, offer a number of practical suggestions about course changes (for the lab courses) which we might otherwise have neglected. These range from the size, scope and implementation steps of the projects to the choice of microprocessor based on available documentation and courseware supplied by the chip manufacturers.

6. Evaluation, Conclusions and Follow-on Work

While not a clear failure, the TeleMentoring experiment as originally proposed was by no means a success:

1. The CSE371 students did not complete the projects
2. For all of the effort invested in TeleMentoring, the students did not see significant advantages compared with e-mail or local expertise.

We believe that the students did not complete the projects because the goals we set (the project scope) were too ambitious. In our first TeleMentoring trial, we saw TeleMentoring as the ''*Deus ex Machina*'' in teaching undergraduate computer science labs. Unfortunately, reality intruded and the ambitious goals were not achieved. The students involved did value the work sufficiently that they completed it later in an independent study context. We now feel that students working independently (who would otherwise be on their own, e.g., in a senior design) are better suited to TeleMentoring. They would be at a level where they could begin taking advantage of the interaction immediately, rather than only in the last month of the term. Seminars also offer an environment where distant interaction is desirable. Professor Farber has had great success distance interaction in seminars using simple speakerphones.

6.1. Conclusions

TeleMentoring resulted in a number of useful technologies, in particular the Audio-Video ATM Transmit AND Receive (AVATAR) card which allowed direct connection between analog TV equipment and the ATM components of the AURORA testbed. Interestingly, the AVATAR cards were used to help with the design of the rest of the TeleMentoring experiments - pulling the project up by its own bootstraps! The experiments included joint meetings with MIT as well as the mentoring of undergraduates. A rather unfortunate consequence of the HPCC gigabit testbed program terminating at the end of 1994 (the AURORA link to MIT was turned off Dec. 1994) was that only a small population of students were ever Telementored with the testbed setup; far too small to make a legitimate "clinical" study of its effectiveness.

TeleMentoring requires a **VERY** careful choice of educational context. It was only useful late in the semester in the CSE371 course, as the gap between the students expertise and the engineer's expectations had to be bridged before the students could specify their requests for advice appropriately. We now feel that seminars, senior theses and graduate work are more appropriate for whole-semester TeleMentoring exercises.

Much remote teaching does not require full-fidelity interaction. Prof. Farber has experimented extensively with remote speakerphone interactions in his courses, especially "Computers, Ethics and Society". We also used the speakerphone technology effectively for Ph.D. defenses, with the proviso that the student's slides had been made available to the remote person in advance. Examples include Dr. Les Vadacz at Brendan Traw's Ph.D. defense, Prof. Smith at Joe Touch's Ph.D. defense, and Dr. Paul Mockapetris at Ivan Tam's Ph.D. defense.

During the research period there has been a growth in the capability of the Internet (although full-fidelity interaction remains bandwidth- challenged). We have tried remote meetings and advising with InPerson, an SGI (Silicon Graphics) system, where a workstation is set up in the conference room where the VideoWindow resides. Other technologies such as RealAudio, WWW and MBONE are helpful, provided that the quality of interaction due to inadequate capacity does not detract from the educational experience.

Our initial experience with interaction over the NSF vBNS experimental ATM backbone supports our initial experiences with the AVATAR over AURORA; interaction is very realistic, and with the Nemesys AVA-300 ATM Camera's M-JPEG compression, we can work within bandwidth limitations of 10-15 Mbps. Initial experiments have included teleconferences with the University of Illinois at Chicago and remote conference attendance at the NSF-sponsored workshop on Data Mining at UIC.

6.2. Follow-ons to TeleMentoring

The TeleMentoring concept is getting a much larger-scale trial in the context of the DARPA-supported CADETT project, in which we are collaborating with the Franklin Institute in Philadelphia to provide interactive distance learning support technologies with the eventual target of worker retraining for better jobs. This work was directly based on TeleMentoring, and is supported by a *circa* $9M grant to an industry, museum and academia consortium to really push these ideas into the mainstream. It is notable that a major mission of the Franklin Institute as a science museum has been to train science teachers in the greater Philadelphia region.

The CADETT projects software is now being tested, and includes other facilities for advanced interaction, including support for virtual humans developed at Penn's Center for Human Modeling and Simulation. The target population is laborers wishing to be retrained to meet industrial needs (specifically, Shipyard workers), as well as adults adapting to other new job requirements. A major result of this work, which had its seeds in TeleMentoring, will be the delivery of high-quality interactive distance learning to a wider variety of learners.

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