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Synchronous Internet Distance Education: Wave of the Future or Wishful Thinking?

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e-Technologies in Engineering Education Learning Outcomes Providing Future Possibilities

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Abstract

Heralded as an important future delivery means for higher education, synchronous Internet distance education with live presenters is, to date, far less often used than its counterpart asynchronous distance education which offers materials stored on a website. The author has practiced synchronous Internet teaching since 1994 at George Mason University (GMU). This practice now is increasing, with a doubling of GMU Computer Science courses taught this way each year for the past three. This paper describes the lessons learned in finding a successful way to teach synchronous over the Internet. Technologies and class organization needed for success are described and compared. The results appear to indicate that synchronous Internet distance education may in fact become an important future delivery means for higher education.

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I. Introduction

In the late 1990s, publications such as Carswell [1] and Harris [2] heralded the advent of widespread synchronous distance education, based on widespread availability of Internet communications and inexpensive multimedia computers. Certainly, under these circumstances it is natural to consider teaching over the network. In the last five years, many institutions have begun active programs to enhance their course offerings using Internet delivery. However, most of these offerings are purely asynchronous, i.e., they consist of course materials delivered over Web servers on demand. In most cases, they simply provide easy access to course materials that formerly might have been placed in a library; however, a significant fraction of them are full courses available online. These represent a technology update of that old standby for distant students, the correspondence course. What of the more difficult *synchronous* Internet distance education? Perhaps high hopes for it are just wishful thinking.

The author's courses at GMU have been taught with synchronous Internet delivery since 1994 and now are in a third generation of delivery technology [3-7]. These courses are available in the classroom and online simultaneously. The GMU Department of Computer Science has eight courses scheduled for this form of delivery in Fall 2002. As a parallel to the comment above regarding correspondence courses, this mode might be said to represent a technology update of television course delivery. However, there are some qualitative differences that make our synchronous Internet teaching different from television:

- High-quality graphics with real-time annotation provide much better input for the visual learner than broadcast video; indeed our experience shows that "talking head" video is the least useful component of Internet distance education [8].
- Student questions can be spoken or typed over the Internet in real time, giving the medium immediacy that is not possible with broadcast television using telephone for questions.
- It is simple to capture the entire class presentation on a server and make it available for asynchronous playback, thus giving the student the ability both to space-shift (participate at a distance) and to time-shift (participate at a different time of day or week). While this also can be done with television teaching, a separate, expensive video server is needed, whereas our Internet server is an inexpensive computer workstation.

This paper will review the multimedia computer presentation, network, and software technologies available for Internet distance education, as well as the student learning styles and course organization options that apply. We will end by presenting our conclusions regarding effective implementation of synchronous Internet distance education.

II. Technology Options

A. Multimedia Computer Presentation

1) *Audio:* The spoken voice is a critical component of teaching, whether students are local or distant. Many students are auditory learners, i.e., they learn best when they hear the concepts presented verbally. For distant students, the instructor's voice needs to be delivered with clarity.

Background noise causes considerable psychological strain, as do levels too low to hear properly and levels so high the voice is distorted.

Capability for spoken student questions also is an attractive Internet capability. However, it is important for the student who does this to have a well-adjusted computer audio system. We have found that, in lecture-style classes, students seem to be satisfied with the ability to type their questions as long as the instructor notes the question quickly. In seminar-style classes, where discussion is essential, student audio input becomes much more important.

2) *Graphics:* A second critical component of engineering teaching is graphics. Drawings and problem solutions, mostly presented via projector, are fundamental to presenting technical material. We distinguish between static graphics, which are prepared in advance, and dynamic graphics, spontaneous annotations by the instructor and possibly also by students. The former impart efficiency in class delivery; the latter allow the instructor to focus student attention and provide spontaneous presentation. Both strongly support the visual learner. We find a distributed electronic whiteboard that supports both static and dynamic content, combined with audio, to provide the only media we need for most presentations. We use the term *audiographics* for this fundamental network teaching media combination. We have found it advisable to provide for instructor graphic input with an LCD graphic tablet such as those made by Wacom™.

3) *Video:* On the other hand, our experience with even high-quality video "talking heads" [8] is that they add little to the educational experience for most students. In terms of equipment and particularly of network resources, video is several times as expensive as audio. The required capability is not necessarily a great expense for students; typically, it doubles the monthly Internet Service Provider (ISP) bill. However, the aggregate network cost to the teaching organization mounts rapidly if most students receive video and even more rapidly if the video is fully synchronous rather than the delayed/buffered Web video available from products such as RealVideo™. However, some students do seem to benefit, so we conclude that video should be provided if the teaching organization can afford the cost.

In contrast, pre-recorded video can be a very powerful teaching tool. It can capture events outside the classroom and activities that are too complex or expensive to reproduce, such as scientific experiments. However, a classroom video setup is not required for delivery of pre-recorded video; typical Web video systems suffice.

4) *Text:* Plain old text may seem mundane, but we have found that a text "chat" is an excellent way to provide for student questions and comments, whether about the course material or the mechanics of the presentation (e.g., "the sound is too low").

5) *Web Links:* Clearly, a synchronous Internet course can benefit as much as any other course from supporting webpages and also from Web-based course management systems such as WebCT™. However, synchronous teaching also can use the Web as real-time support for teaching by directing the students' browsers to a URL dynamically. The URL might be a simple text webpage, a complex graphic, a streaming audio or video link, or any other multimedia Web application. When this is done, it is important for the instructor also to be able to kill the launched webpages on all student machines to maintain control of the presentation.

6) *Application Sharing:* Sophisticated conferencing services such as Microsoft NetMeeting™ allow multiple users to share the graphic interface and even control of the application so all can see and anyone can manipulate its behavior. This approach is most useful if the topic of instruction is the software itself or some topic that it illustrates, such as engineering analysis. However, network capacity required to export screen graphic for a large group exceeds even that required for video, so many teaching organizations find they cannot afford this capability, which otherwise is undeniably attractive.

7) *Recording:* It is possible to record an Internet class as it goes out over the network, simply by capturing a copy of each message sent to and from the instructor's computer. In practice, a high level of integration among the various teaching media is needed if the recording is to play back as a continuous stream with each of the media responding in playback as it did during teaching. Also, it is important for the playback capability to allow "fast forward," "reverse," and "start at" functions so the student can control the replay.

B. Network Connections

1) *Dialup*: Most potential distant students prefer to study at home and most home Internet subscribers use modem connections. Computers purchased by our students are equipped with nominal 56 kb/s modems. In general these actually support connections of 40 kb/s, forming a constraint on the multimedia traffic that may seem severe but it is feasible. Using dialup has a good side, in that the dialup portion of a modem link is not subject to congestion from other traffic. However, it is still important to ensure that the Internet path from the server-side modem to the teaching server has sufficient capacity that it never becomes congested.

2) *Enhanced Home Connections*: An increasing number of home students have available enhanced connection technologies such as ISDN, cable modem, and digital subscriber line (DSL) that support data rates from 128 kb/s to 1 Mb/s. This is sufficient to support delivery of good quality compressed video at the low end and application sharing at the high end.

3) *High Performance*: Most university facilities, and also some government and industry facilities, have high performance Internet or Next Generation Internet connections with capacity from 1.5 Mb/s to 155 Mb/s and more. Such connections are far more capable than needed for student connections, but at the lower end they may be hard-pressed to support servers for large classes. One way to circumvent limitations in the path to the Internet is to encourage student use of dialup connections that come directly to campus rather than passing through the Internet.

4) *QoS Issues*: A good network path between instructor and student is essential for synchronous distance education. Assured QoS Internet service is not offered by most ISPs. Even the highest-capacity Internet connections can at times suffer from congestion, with the result that network capacity is not adequate to support even low-demand audiographics. Moreover, congestion patterns vary during the day and week. At GMU, we insist that students planning to study by synchronous Internet distance education must try their network connection before the first class, on the day of the week and at the time of day that they plan to connect to class.

5) *Server Issues*: Multimedia applications built for Internet multicast transmission, where each packet is delivered to a whole group of computers, typically are designed for peer-to-peer operation where applications interact as equals. Those applications designed for the normal unicast Internet more customarily are designed for client-server configuration, where many student clients connect to each server. While the multicast model is a more effective one for group communication, few ISPs support multicasting, so the client-server approach is a practical necessity. At GMU, we use a hybrid approach that supports peer-to-peer software through servers that provide the network functionality of multicast.

6) *Transport Protocol*: The most appropriate Internet transport protocol for synchronous audio normally is the User Datagram Protocol (UDP), which delivers messages as quickly as possible and makes no attempt to recover lost data. The more common Transmission Control Protocol (TCP), while appropriate for text and control connections, does not always deliver data quickly because it retransmits messages as needed for reliable, ordered delivery. In the process it can cause very choppy audio. Nevertheless it is at times necessary to use TCP for audio in order to pass through Network Address Translation (NAT) units or security firewalls.

7) *Floor Control*: Where students are able to generate spoken questions or share the whiteboard, it is desirable for the instructor to have a way to control who is able to speak. A side effect of this capability is a display that shows which students are active in the class session. Floor control is not an absolute requirement; our first synchronous Internet teaching at GMU involved the MBone tools [3,4], where acces to the electronic "floor" is controlled by polite behavior. Our second generation was the now-defunct ClassWise software [6], which offered only a one-many delivery (questions were posed by text only) and so did not need floor control. In our third generation Network EducationWare (NEW, subject of a companion paper to this one), we have full floor control, which we find to be essential for seminar-style activities and very valuable for lecture-style activities, where it prevents the distant student from having to break into the class audibly to ask a question.

8) *Internet Conferencing Systems*: A number of effective Internet-based conferencing systems are available on the market today, for example Centra™ and PlaceWare™. Based on their commercial success, these clearly are meeting a need for online meetings in the commercial world. While they are sometimes used for corporate training, we observe that the capability to conference generally is somewhat different than the ability to teach over the network. Conferencing generally requires video and may not need floor control, text interfaces, or recording; whereas in teaching video is not essential but the floor control, text, and recording (with server playback) are very important. Also we find that conferencing systems, because of their value in reducing corporate travel costs, are able to command prices above those most educational institutions will consider. Our NEW system runs on inexpensive personal computers and is available at no cost to the using institution. We believe this will lead to greatly expanded use of synchronous Internet distance education.

III. Course Organization

In this section we consider factors that are more social and psychological than technical. These are related to how the student perceives the course delivery style and how the educational institution goes about making the course available to students.

A. Student Acceptance

1) *Student Situation*: Many students would prefer to attend class in person, but find themselves in situations where the

time or expense of doing so is significantly greater than the perceived disadvantage of attending online. These same students might choose asynchronous distance education or television-based courses; however, in our experience (admittedly anecdotal), they find that the higher fidelity of audiographics and the ability to ask questions, even typewritten ones, make synchronous Internet classes more attractive. Even more of this group find the ability to time-shift classes via recordings to be valuable. Many of our students are employed outside the university and must comply with work and/or travel schedules imposed by their employment. Some of these sign up for synchronous Internet classes but actually attend asynchronously; more of them attend class in person as often as they can, but time-shift classes when necessary. In general, we find that several students replay a lecture for each one who participates synchronously over the Internet.

2) *Learning Styles*: In the very first course taught by the author to distance synchronous Internet students, there was one student who did not sign up for distance delivery but switched to it after a few classes. His explanation was that he could concentrate on the class much better when alone in his office with a workstation and a direct sound feed from the instructor's clip-on microphone; noises and sights in the crowded classroom distracted him. Although we have not studied this phenomenon formally, it has been clear from interactions with students that one or two in every class fall in this category. It appears that, while most students look forward to interactions with classmates as part of the learning process, a minority are highly independent learners. Moreover, we see in online learners the same phenomenon many instructors observe in lecture: a few students are active questioners, but many prefer just to watch and listen.

3) *Educational Outcomes*: Russell has studied the effect of media on outcomes and documented the "No Significant Difference" result [9], which indicates that the medium of teaching does not make a significant difference in students' learning, all other factors being equal. Our own results, reported in [6] and since repeated in several more courses, confirm that synchronous/asynchronous Internet students' performance is not significantly different from that of those who attend class in person.

B. Scheduling and Presentation

Educational institutions have multiple options for making synchronous Internet classes available to students. In our experience, we find that it is much more effective to combine regular in-person classes with synchronous Internet delivery than to attempt to organize separate classes for distance education. Here are options we have tried, in order of increasing level of success.

1) *Separate Distance Education Classes* : We produced a pilot professional education course where the instructors taught "disk jockey" style, with no live students in the room. The instructors adapted readily to both the absence of local students and the audiographic interface, which is much like using an overhead projector. We found we had reasonable contact with the students from the questions received in real-time text format. We learned to encourage interaction by sending periodic text questions with responses to the instructor only, much as "overhead questions" might be used in a live class to gauge the students' understanding. The instructor continues with the presentation while the answers trickle back in text format. If students do seem to understand the presentation, it is easy to pause for a review before continuing. We also learned that it is important to keep a steady flow of whiteboard annotation as the instructor proceeds through each slide, in order to keep the attention of the visual learner. This is equivalent to the in-person teaching technique of pointing at the slide and proved so effective that we have adopted it for mixed in-person/distance teaching (topic 4 below).

2) *Asynchronous Recordings of Synchronous Classes*: We were unable to attract large enough student groups to continue the professional education program in Network Science. The instruction quality was rated as excellent; however, the sponsoring employers were not ready for such a large departure from traditional teaching methods. So we converted the course to asynchronous mode using recordings from the pilot and later recordings from a graduate course that followed the same format and outline. The instructor who recorded the class serves as mentor to asynchronous students, answering questions by email and also grading homework and examinations. We have had a steady trickle of students signing up for this course but on average less than one of every two enrollees completes the course. Follow-up interviews reveal that students are happy with the quality of instruction provided; however, without the fixed schedule of a regular course they tend to put off sitting through the class sessions. This is a phenomenon the author has experienced in other, non-Internet asynchronous settings; students find it is much easier to complete a course if there are scheduled sessions and assignments.

3) *Multi-Site Classrooms*: A technique widely used to deal with sparse populations is to link multiple classrooms electronically, using teleconferencing technologies that pre-date Internet teaching and conferencing. GMU tried a similar approach to multi-campus teaching in our densely populated Northern Virginia area. The approach was intended to reduce student commuting time by allowing the same class to be attended at any of three campuses. A combination of audiographics and commercial videoconferencing systems (classroom conferencing) was used. Students generally did not react well to this approach; there was a tendency for

those in distant classrooms to feel abandoned. After two years of this approach, we introduced desktop conferencing in the form of ClassWise, so students could participate either from the remote classrooms or from home and office computer desktops. Participation in the teleconferenced classrooms dropped, with most students favoring desktop conferencing. The remote classrooms were discontinued as a cost-saving measure.

4) *Mixed In-Person and Internet Attendance*: With discontinuance of the remote classrooms, we arrived at a stable point of operation where classes presented to in-person students also are transmitted as audiographics with optional video to a "NET" section of students, recorded, and made available on a server for playback. The local students see the same data format as Internet students, presented via a computer projector. This arrangement accommodates distant students at very little extra cost and also is very popular with students employed outside the university as a means of occasional time-shifting when necessitated by work. Starting with one course per semester three years ago, we have doubled the number each year. In the coming academic year, the GMU Department of Computer Science will be offering eight sections per semester with a synchronous Internet option (for details see <http://cs.gmu.edu/teaching.html>). These NET sections provide space for ten students beyond those in the classroom and often are filled to capacity. At this rate, by next year we will need to add another Internet classroom and another server for distant students. We expect to be able to do this for about US$7,500, to serve another eight courses in our "prime time" evening slots. A more serious expense will be additional supporting personnel time, which we expect will cost around US$6,000 more than non-Internet electronic classroom operations.

IV. Conclusion

We have tried a full range of technologies for synchronous Internet course delivery at GMU and have determined that this form of distance education definitely is not wishful thinking. However, it is important to use the right multimedia and network technologies, and to organize courses to achieve synergy between in-person and Internet delivery. The right multimedia technologies are audiographics with text capabilities, plus a video option if the institution is able to afford it. The right network technologies are a 56 kb/s modem capability (not delivering video) connected to the teaching server by a congestion-free path, a floor control system, and a TCP option. Uncongested, higher-capacity Internet connections may allow delivery of video in addition to audiographics and text. Internet conferencing systems typically do not have the right combination of features for teaching or low enough cost to be acceptable for higher education.

The right organization of courses in our case is in-person classes taught using a projected version of the same audiographics presented to Internet students and simultaneously recorded for delayed server delivery. This results in high-quality Internet delivery equal to that of a live class (excepting any social effects) and improves service to both local and Internet students by allowing time-shifting via the recorded sessions. Our experience shows this arrangement can be supported at little additional cost and is readily accepted by instructors and students alike.

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