PRESENTING AN ONLINE GRADUATE COMPUTER SCIENCE PROGRAM AT LOW COST USING OPEN-SOURCE SOFTWARE

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ABSTRACT

There is widespread and growing interest in distance education, conducted over the Internet. The authors have conducted courses online for several years in a mode called *simulteaching*, where the instructor presents to a group of students in the classroom simultaneously with another group online. Since 2002 they have been doing this in an expanding program in Computer Science and Information Technology that uses a system consisting of open source software components. This system, developed by Pullen, is called *Network EducationWare (NEW).* Whereas traditional synchronous online teaching can be complex and costly, the combination of simulteaching and the NEW software results in a system that is well accepted by students and faculty and also costs very little to operate. This paper describes the style of teaching, the open source software it uses, and the initial student outcomes that have been measured.

1. INTRODUCTION

The last decade has seen worldwide introduction of the Internet and with it the growth of widespread interest in distance education. The primary motivation for this form of education is accessibility: ubiquitous network access has the effect that higher education now can be delivered into homes and offices everywhere. This in turn enables a large new group of students to seek degrees online, as described by Harris 1999. At George Mason University (GMU), we were among the first to teach synchronously over the Internet (Pullen 1998; Pullen & Benson 1999), focusing on Computer Science and on Information Technology (Denning, Athale & Dabbagh *et. al.* 2001). Our synchronous online course offerings have expanded steadily so that in 2004 we presented a total of seventeen courses in Computer Science and Information Technology and now provide the student with an option to complete the Master of Science in Computer Science degree online. The central theme for this growth, which we anticipate will continue, has been accessibility.

Flexibility of access is further enhanced by asynchronous delivery. This can take two forms: (1) courses presented from programmed multimedia, mostly simple webpages (the Internet equivalent of the traditional correspondence course), and (2) recordings of synchronous class sessions, which allow time-shifting of student participation in traditional-style classes. The synchronous model, where the course is taught in real time over the Internet, is used less than the asynchronous but its use is growing (Wilson 2003). Synchronous delivery can take advantage of well-understood methods of classroom teaching that have been developed in the lecture tradition of higher education. However, as described in (Pullen 2003), such courses can be expensive to prepare and deliver if they involve custom-tailored sessions for online students and commercial Internet conferencing software. This paper describes a degree program delivered by a low-cost approach to synchronous distance education that we have pioneered at GMU, based on mixed classroom/Internet student participation and a low cost system of open source software, called Network EducationWare (NEW). The NEW system, integrated from multiple open-source components, is made available under a no-cost license to the academic community.

2. THE SIMULTEACHING MODEL

As presented persuasively by Carswell (Carswell 1998), a complete distance education system involves many functions of the university that we often take for granted, *e.g.* registration, a bookstore, and advising. However, we have found that online education can be very effective without offering such a complete system. GMU is located in the Washington, D.C. area and has many working students. NEW serves regional students who come to campus on rare occasions when they need services or to take exams. This fact is reflected in our approach to distance teaching, which we call “simulteaching.” We use the same software to teach a group of students in the classroom in addition to a number of students over the network at the same time. Classes are recorded as they are sent over the Internet and made available on a server for later playback. The students can and do switch among classroom, Internet live, and Internet playback modes from week to week. Many of the most frequent users of the online recorded classes are in fact in-person students who have missed a class.

Video can be one of the more expensive components of synchronous distance education. Until recently, synchronous distance education was delivered primarily by television. Today the Internet, combined with the personal computer, offers a means of electronic delivery that can be more effective than television, both educationally and in terms of cost to deliver. While many faculty members are conditioned by "television teaching" to assume that video plus audio is the most effective means of delivery, our experience shows that, in many cases, audiographics (the combination of audio, prepared graphics, and dynamic graphic annotation) is more effective than video. As presented by Pullen (Pullen 2001), video multiplies network costs by roughly a factor of four and yet most students find it to be of marginal educational value. We have concluded that delivering video is an option, not a requirement, for synchronous online education; providing it should be a management decision, based on resource availability. At GMU we provide a low-resolution, low-frame-rate video, which is used by less than half of the online students in a typical class. Figure 1 shows the system arrangement we use.

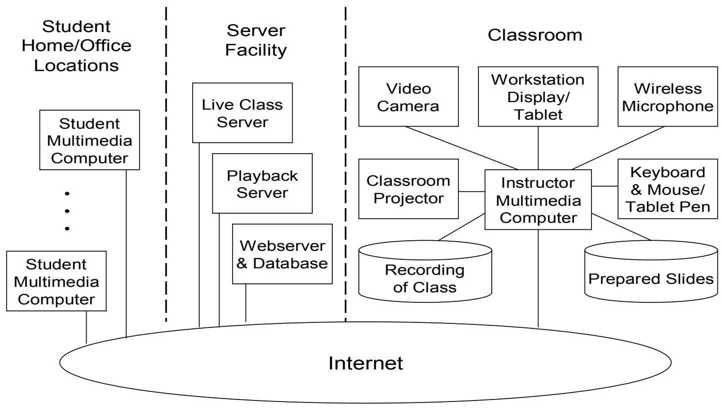

Figure 1. Simulteaching System

Because the classroom projector is driven by the same software used by online students, the simulteaching audience receives an identical audiographic presentation. It has been found that this sort of simultaneous delivery of classes on-campus and online is the most cost effective option for Internet distance education (Goodman & Bowman 2004). It builds on existing experience in live class teaching, minimizing the need to change presentation methods. Initial preparation effort is lower as there are no webpages or interactive tutorials to be created; typically, the instructor for a NEW online course will be able to use existing graphic materials. Working with an on-campus class simultaneously with online students means there is a larger student group to pay the cost of instruction and there also is a source of visual feedback to the instructor from the on-campus class. In addition, the recorded class session provides the valuable time flexibility of asynchronous delivery to the students. Under this combination of low barriers to adoption and benefits, many of our faculty members have accepted willingly the transition to teaching online.

3. OPEN SOURCE DISTANCE EDUCATION SOFTWARE

The open source movement (Lakhani & Hippel 2003) has spawned many useful software systems such as the well-known Linux operating system, the MySQL database system and the Apache webserver. NEW uses all three systems. The NEW project set out to capitalize on the ability of good quality open source Internet conferencing software developed by the multicast research community (Macedonia & Brutzman 1994). We started with an Internet telephony program, Speak Freely (SF); a whiteboard program, WBD; and an Internet video program, VIC, and customized these tools for simulteaching. We added to these our own Transport Layer Multicast server and client, providing a capability to use these best-effort multicasting tools over the reliable unicast TCP/IP network protocols. We also developed an associated Web-based course management system. This enables NEW to be used on typical home and office Windows computers with commercial Internet service or even using dialup service (without receiving video). We rounded out this system with Floor Control (FC) and Record/Playback (RP) client and server software developed at GMU, producing a complete functional distance education system.

The NEW system has continued to evolve, becoming highly robust and functional under the stimulus of 15 faculty members teaching thousands of hours in 43 courses involving over 1500 students since 2002. The overall system structure of NEW is shown in Figure 2. For author credits, documentation, demonstration, and download of source and executable code, see http://netlab.gmu.edu/NEW.

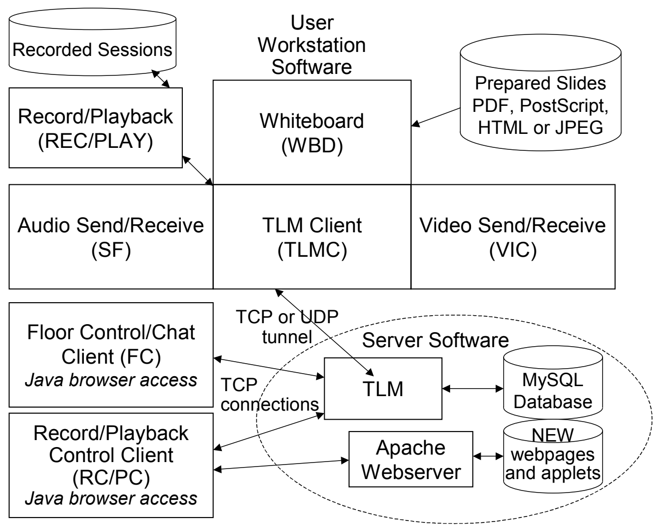

Figure 2. Software components

3.1 Server Software

Descriptions of the major components of NEW server software follow. Both executable and source code for all system components is openly available for academic purposes. The server runs on Unix or Linux systems; all components can run on a single Linux PC, serving thirty or more online students simultaneously.

The *Transport Layer Multicaster* (TLM) live class server implements the multicast paradigm over the general Internet among a group of participating workstations by accepting a data stream combining transmissions from the multicast conferencing tools from the floorholder's workstation and sending copies to all participant's workstations. It provides access control using passwords checked against the MySQL database.

The *Record* (REC) and *Playback* (PLAY) servers are used to create and play streaming recordings that capture all information sent by NEW clients over the Internet from the instructor's workstation.

The *Apache Webserver* is used to support a large fraction of all sites on the World Wide Web. We use the version that supports the PHP language needed for our webpages (see below).

The *MySQL Database System* is the same software used to support many thousands of database-centered systems in use today, under the standard Structured Query Language (SQL). The database provides a unified approach to data management and security across the NEW system. It also makes possible data access over the network that we are currently using to implement the chat room feature.

The *NEW Course Management Webpages* are the key to effective management of the mass of detail involved in supporting multiple courses. They provide teaching and learning functions, support and course management functions, authentication, and system administration functions (Pullen & McAndrews 2005). The main "Welcome to NEW" page that organizes all of these functions is shown in Figure 3. The version shown is used for instructors; students receive a page without recording and course management functions.

3.2 Client Software

Descriptions of the major components of the NEW client software follow. Both executable and source code for all system components is openly available for academic purposes. The composite user interface for all tools is shown in Figure 4.

We consider the *Speak Freely Internet Telephone* (SF) to be the most important component in the system, both because it is essential to the students' learning experience and also because conveying voice with good quality over the Internet at low data rate presents a big challenge. SF is capable of passing good voice quality over the Internet, using a standard sound interface, and requiring only 20 kilobits per second of network capacity. We have added a graphic interface that provides all needed user functions in one easy-to-use package.

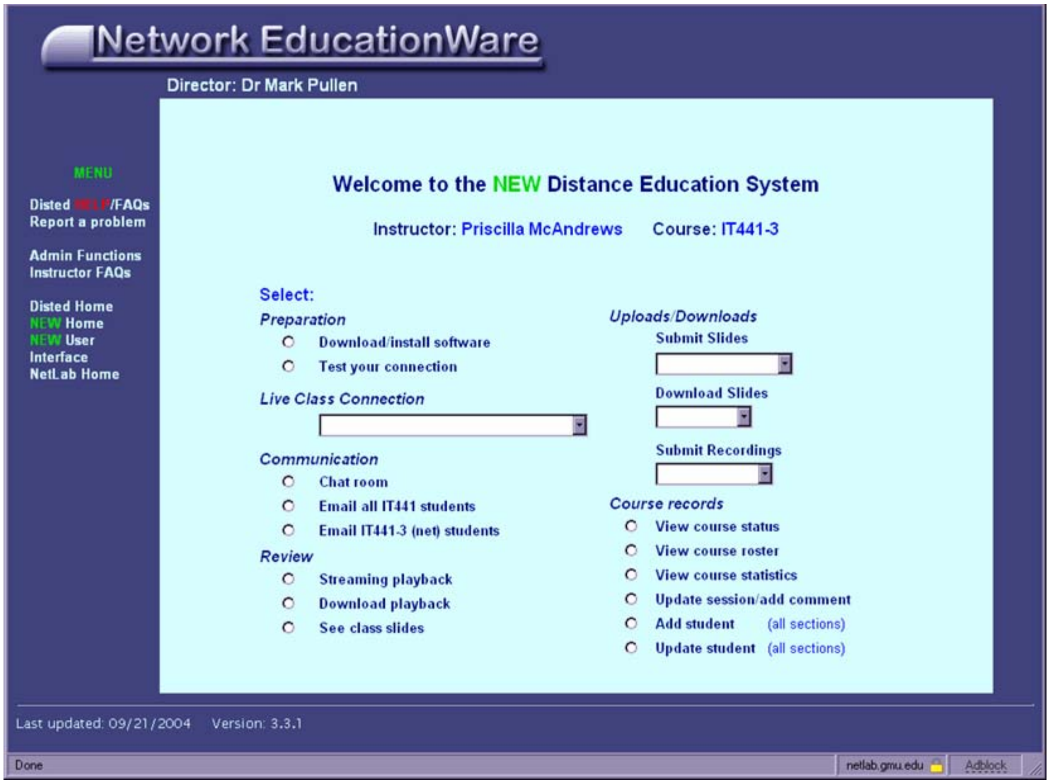

Figure 3. NEW Welcome webpage (instructor version)

The *Whiteboard* (WBD) provides the other key element for teaching online: graphics. It will display a precomposed graphic prepared in any of several open formats, including most importantly the Adobe Portable Document Format (PDF). The precomposed graphics can be annotated during class with lines, rectangles, ellipses, and text in any color, a very useful feature for maintaining the attention of the visual learner. We prefer to use the WBD with an LCD tablet interface so it becomes a surrogate chalkboard.

The optional *Video* tool (VIC) NEW is capable of multiple network formats, including standard H.323 conferencing. A typical delivery rate for NEW is two frames of 320 by 240 pixels per second, but rates up to 30 frames per second are possible. Typically, video flows only from instructor to student. While NEW can support video streams from students to the classroom, we typically do not use this feature in our courses because it would complicate system setup.

The *Transport Layer Multicast Master Client* (TLMC) encapsulates data from the multicast applications into TCP tunnels to the live class server (TLM), prioritized according to the importance of each multimedia tool (audio first, whiteboard second, video last). The combination of clients and their network configuration established by TLMC is controlled by a configuration file that normally is downloaded from the supporting webserver at the beginning of a NEW session. If software updates are indicated, TLMC also downloads and installs them.

The NEW *Floor Control* (FC) shows the participants in the session, controls access to the virtual classroom “floor,” provides for text questions to the instructor and text chat among the participants, and accepts URLs from the floor holder for browser launch on all participating client systems.

NEW Record and Playback clients (RC and PC) control REC and PLAY respectively. They feature VCR-like button icons and an elapsed time readout. The PLAY control also is capable of jumping forward and backward to the next slide in the presentation. Recordings require about 5 Megabytes of disk per hour of class.

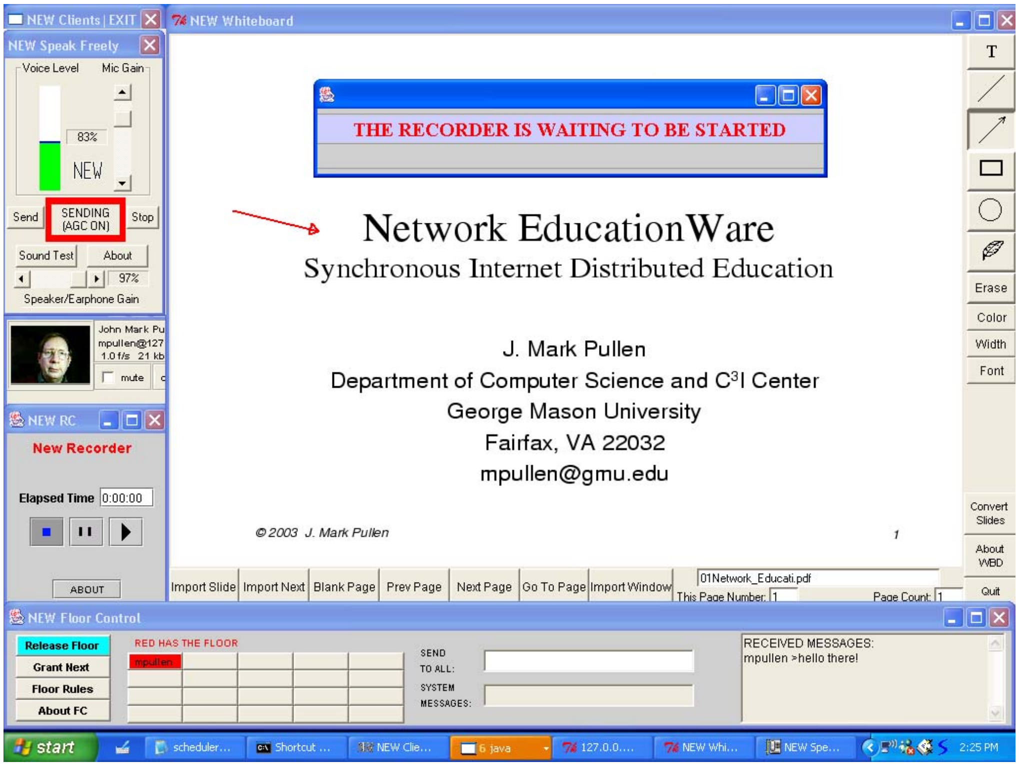

Figure 4. Composite NEW client interface (instructor version)

3.3 Costs

Using existing GMU electronic classrooms to provide the computer and projector, additional costs to offer courses via NEW currently are:

- One new Linux server computer
- A small fraction (less than ten percent) of a system administrator's time
- Two graduate student Information Technology Assistants to provide class setup, monitor outgoing session quality, post recordings, etc.
- No additional network costs have been incurred, because the extra network load was well within GMU's internal network and external Internet access capacity; however, if many GMU degree programs were to adopt our model, at some point it would become necessary to expand network facilities.

In principle, these extra costs should be offset against the reduced need for classrooms under simulteaching. However, we have not been able to obtain quantitative information on classroom cost. It seems likely to us that there is a net cost reduction under this new mode of teaching, but we can only estimate that the cost increases and decreases are roughly the same.

4. THE GMU MSCS DEGREE ONLINE

The GMU computer science department offers bachelors, masters and Ph.D. degrees in computer science. Our online teaching efforts recently have reached the point where we are able to support a regular full Master of Science in Computer Science degree. Our M.S. degree allows for concentrations in specific topic areas. At present, the M.S. degree available via NEW has a concentration in Systems and Networks. We hope to expand course offerings to include other departmental concentrations (Artificial Intelligence, Image Processing and Graphics, Parallel and Distributed Systems, and Software Engineering). Table 1 shows courses available to an online student to obtain the M.S. degree. For more information, see the GMU Computer Science catalog at http://www.cs.gmu.edu.

Course Number	Course Name	Offered at Least
CS 540	Language Processors	Annually
CS 571	Operating Systems	Annually
CS 580	Introduction to Artificial Intelligence	Annually
CS 583	Analysis of Algorithms	Annually
CS 631	Object-Oriented Design Patterns	Annually
CS 635	Foundations of Parallel Computation	Biannually
CS 640	Advanced Compilers	Biannually
CS 656	Computer Communications and Networking	Annually
IT 657	Advanced Network Science	Biannually
CS 706	Concurrent Software Systems	Biannually
CS 755	Advanced Computer Networks	Biannually
CS 756	Performance Analysis of Computer Networks	Biannually

Table 1. Online GMU MSCS Courses

5. INITIAL STUDENT OUTCOMES

Even before a sufficient set of courses for a full degree became available, initial student response to online offerings has been excellent. Course enrollment for the senior electives and graduate courses we have offered online is shown in Figure 5. The higher bar for each year represents all students in the simulteaching sections, who could (and mostly, did) use the NEW system at times; the lower bar represents the online students, who normally used NEW for every class.

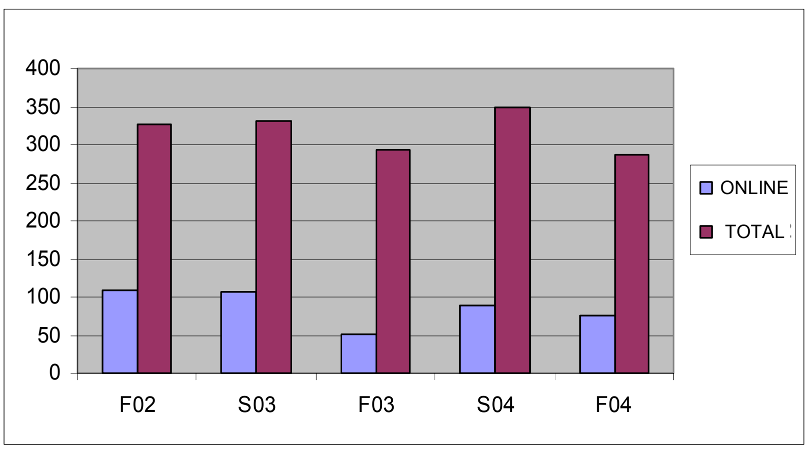

Figure 5. MSCS Online Enrollment

A summary of grades for the Spring 2003 semester is provided in Table 2. The data have been analyzed statistically and do not support the hypothesis that there is a significant difference between online and classroom students in terms of grade outcomes. This is consistent with the recent Sloan Consortium 2003 study report, which found that quality of online learning is as high as that of classroom learning. We also have examined student course-end evaluations and found they are not significantly different from GMU Computer Science evaluations for courses that did not use NEW.

Course level	Number of in-class students	Grade-point average for in-class students	Number of Internet students	Grade-point average for Internet students
Undergraduate elective	60	3.09	23	2.87
Graduate core	61	3.17	18	3.17
Graduate advanced	63	3.54	22	3.34

Table 2. Grade outcomes for simulteaching courses

6. CONCLUSIONS

We continue to be encouraged by the success of our simulteaching efforts using NEW. More importantly, our students are responding positively to the greater accessibility of our courses that are taught this way. A total of 15 regular and adjunct faculty members have taught 43 courses in Computer Science and Information Technology to over 1500 students, with good educational outcomes and student satisfaction. Using NEW, the additional costs of teaching online are small and appear to be offset by savings in classroom facilities. The system is well accepted by most faculty members because it involves relatively small changes to their normal teaching style and they continue to have visual feedback during lecture from the classroom students, in addition to full audiovisual interaction online.

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