

MSCRIBE: PILOTING AND EVALUATING AN AUTOMATED COLLEGE CLASSROOM WEB LECTURE CAPTURE SYSTEM; A FINAL REPORT ON TECHNICAL ACCOMPLISHMENTS

The University of Michigan

ATLAS Collaboratory Project

Steven Goldfarb, Jeremy Herr, Jim Irrer, Shawn McKee, Mitch McLachlan, Homer A. Neal

Center for Research on Learning and Teaching

Crisca Bierwert

Center for the Study of Higher and Postsecondary Education

Mary Antonaros, Alli Bell, Eric Dey

Introduction:

This document represents the final report of the MScribe Project. It includes a list of the technical successes achieved and the areas identified where additional focus is needed. We believe we achieved the main features of the goals originally identified in our proposal in Winter 2006. We now know that web lectures can be successfully recorded in undergraduate classrooms using a system with robotics speaker tracking, and we know from our colleagues in the School of Education and CRLT that a very rich set of pedagogical issues can be attacked using technologies of the type we have proposed.

Project goals

THE GOALS PRESENTED IN THE ORIGINAL DOCUMENT WERE:

We propose to develop, deploy, and evaluate a robust system for the automated web archiving of classroom lectures. The recordings would be accomplished through the use of techniques developed primarily at the University of Michigan that employ audio/video/slides capture devices, associated software, and robotic cameras. The web lectures would be automatically recorded and posted on class CTools websites. While we envision that this system could eventually be made available in almost all

classes at the University, and ultimately at other universities, the current proposal is to pilot this effort in a set of approximately three campus classrooms on the UM Ann Arbor Campus selected for a testbed trial period starting as early as March, 2006.

The purpose of the pilot project would be to demonstrate that a reliable web capture system can be operated over an extended period to provide high quality recordings of classroom lectures without any extraordinary efforts on the part of the instructor, and to provide a testbed for the study of pedagogical issues associated with such a new modality for delivering classroom instruction. Results from this project would be expected to have a far reaching impact.

Though other initiatives have been undertaken elsewhere to make classroom documents widely available, our proposal is, to the best of our knowledge, the first to credibly suggest that the entire classroom lecture be captured and automatically posted within the framework of a functioning CTools architecture. The technology could shift the current paradigm concerning the role of lecturing in teaching, increasing the flexibility and availability of spoken and supporting materials in order to free faculty from the traditional constraints of structured lectures, and allow them to think creatively about the use of time inside and outside of class. The intent of this pilot project is to evaluate the effects of this innovation on both faculty behavior and student learning outcomes, and also to provide a robust technology ready for large scale use.

As mentioned above, we believe these goals were attained. More details are provided in the text below.

Project scope

The approach taken in the project was to record each classroom lecture in a set of regular University of Michigan courses for which selected faculty had agreed to use our technology and to participate in the evaluation process. We posted the lectures on an accessible server as soon as possible after the class, and then monitored the use of the materials by the students of the class. Staff in the ATLAS Collaboratory Project, and participants in the Physics Department, were mainly concerned with the technical aspects of the web recording and tracking systems. Staff in the School of Education and CRLT focused primarily on the pedagogical matters, on interacting with the involved faculty and students, and in the analysis of the pedagogical results.

The information recorded in the classroom lectures included the audio, video and slides used by the instructor. It also included PowerPoint slides, tablet PC notes, photographs,

scanned book images, art, and web pages. We encountered situations where we wished to be able to record movies, but were unable to do so with our existing technology. With the recent incorporation of Flash technology, we expect to have that capability soon.

Project team

The total staff involved in the studies included individuals from the School of Education's Center for Studies of Higher and Postsecondary Education (CSHPE), the Center for Research on Learning and Teaching (CRLT), and the ATLAS Collaboratory Project (ACP). The principal participants were:

Mary Antonaros	CSHPE
Alli Bell	CSHPE
Tushar Bhatnagar	ACP
Crisca Bierwert	CRLT
Eric Dey	CSHPE
Lisa Guzman	CSHPE
Jeremy Herr	ACP
James Irrer	ACP
Christopher Jensen	CSHPE
Mitch McLachlan	ACP
Dan Merson	CSHPE
Homer Neal	ACP

The missions of the individual units are more fully explained in Appendix I.

Project execution

Classes recorded

Over the course of each semester, Fall 2006 and Winter 2007, eight entire University courses were recorded, including courses in American Culture, History of Art, Psychology, Bioinformatics, Physics, and School of Information. The list of courses is given below. In addition to the regular courses, special lectures and conferences in the CSHPE, Bioinformatics seminars, and also Saturday Morning Physics talks were recorded. Also, Statistics review sessions and a few select lectures from an Asian Studies course and an Environmental Science course were recorded. Following is a complete list of recordings.

Entire courses

- pre-pilot test, Winter 2006 - second half of PHYSICS 140: General Physics I (Dave Winn)
- Fall 2006: AMCULT 100 - Rethinking American Culture (Judy Daubenmier)
- Fall 2006: AMCULT 219 - American Folklore (Bruce Conforth)
- Fall 2006: HISTART 112 - The History of Photography (Matt Biro)
- Fall 2006: PSYCH 111 - Introduction to Psychology (Brian Malley)
- Winter 2007: AMCULT 204 - Popular Culture (Bruce Conforth)
- Winter 2007: BIOINF 526 - Introduction to Bioinformatics and computational Biology (Brian Athey)
- Winter 2007: PHYSICS 140 - General Physics I (Dave Winn)
- Winter 2007: SI 502 - Choice and Learning (Yan Chen and Jeffrey Mason)
- Fall 2007: SI 543 - Java Programming (Charles Severance)

Selected sessions of courses

- Fall 2006 and Winter 2007: STATS 350 - Introduction to Statistics and Data Analysis (Brenda Gunderson)
- Fall 2006: ENVIRON 110 - Introduction to Global Change I (Ben van der Pluijm)
- Winter 2007: ASIAN 265 - The Arts and Letters of China (David Rolston)

Other events

- School of Education CSHPE Conferences
- Various Bioinformatics Talks
- Saturday Morning Physics

Most of these courses/events were recorded using our robotic tracking system, in the following campus locations:

170 Dennison	PHYSICS 140
Angell Hall Auditorium C	ENVIRON 110
Angell Hall Auditorium D	HISTART 112, AMCULT 219, AMCULT 204, SI 502
Modern Languages Building 1200 (Auditorium 3)	PSYCH 111, STATS 350
Modern Languages Building 2011	AMCULT 100, ASIAN 265
Undergraduate Science Building 2260	BIOINF 526
Palmer Commons Building 2036	Bioinformatics talks
Rackham Graduate School 4th Floor Amphitheater	CSHPE conference
Great Lakes Room, Palmer Commons	CSHPE conference
412 West Hall (Fall 2007)	SI 543

In the remaining locations we used a professional videographer instead of the tracking system, because either higher quality video footage was needed, or bad lighting situations (sunlight, incandescent spotlights) interfered with the IR tracking system.

170 Dennison	Saturday Morning Physics
Michigan League Ballroom	CSHPE conference
School of Education Whitney Auditorium	CSHPE conference

Hardware implementation

Our implementation plan was largely realized. Four self-contained, portable, automated carts were assembled by our team and wheeled around campus to record eight University courses during the academic year 2006-2007. Each cart was outfitted with audio/video equipment, a video tracking system and a high-powered PC to record the various media feeds and control the tracking cameras. Each cart was capable of capturing audio, video, periodic still images of multiple chalkboards, and the VGA signal sent to the room's LCD projector.

Figure 1 shows one of the four MScribe recording carts built for the pilot project. Mounted on top of the cart is a metal structure holding the tracking system; beneath it are keyboard and monitor so the operator can see that everything is working properly; and underneath are the PC performing media capture and camera control, as well as assorted audio/video equipment. The entire system is controlled by simply mouse-clicking on buttons labeled START and STOP displayed on the LCD monitor.

The metal housing on top of the cart (Figure 2) houses three cameras: the bottom camera scans for the special necklace worn by the instructor, the top camera provides color video

footage based on this tracking information, and the middle camera sweeps the room every 15 seconds taking snapshots of chalkboards. Figure 3 shows a closer view of the lower portion of the cart, which holds the Linux PC with several video capture cards and serial control ports, audio equipment and VGA capture hardware and cables, and a battery backup unit so that the cart may be wheeled around campus without being rebooted.

We employed unskilled undergraduate students to record 200 hours of video in eight courses over the academic year 2006-2007. We showed thereby that we are approaching eliminating through automation the human component completely from the recording process.

After each recording, the carts were plugged into the internet and the recorded media was automatically uploaded to our archival server. Dedicated media processing servers then retrieved the media and created "Lecture Objects," an archival format described below, which were put into the Lecture Object archive for long term storage. Then RealPlayer-based Web Lectures and QuickTime video podcasts were created and uploaded to web servers. Most of this post-processing is automated, with a few remaining steps still requiring human intervention, described below.



Fig. 1. Recording cart Fig. 2. Tracking cameras Fig. 3. A/V and computer equipment

To avoid wheeling recording carts great distances across campus, we worked with LSA IT leadership to find storage closets close to the recording rooms. The carts would be stored in these rooms, plugged into the internet, and we hired work-study students to wheel them into class and operate them. When problems arose, the students would call the technical staff for help.

Our group worked with LSA IT leadership and staff to install small VGA splitters in the podiums of three classrooms: MLB 2011, Angell Aud D and MLB 1200.

As planned in the project proposal, staff from CRLT took the lead in establishing instructors and courses to be recorded, and recommended courses and venues. The technical staff then evaluated these venues for suitability. The main thing to be avoided in classrooms was sunlight and bright incandescent lamps, since these confounded the tracking system. The tracking system has since been improved to work in almost all classrooms on campus, as described below.

To keep track of the recording schedule and ensure that adequate staff were in place to cover all events, we set up Google calendars and shared them among the staff.

Software

Code developed

The following software packages were written and used during the MScribe pilot project, in the languages C, Perl, PHP JavaScript and Bash, for a total of 17,859 lines of code.

<i>software package</i>	<i>programming language</i>	<i>lines of code</i>
metadata entry	PHP	594
recording	PHP, JavaScript, BASH, C	3,700
tracking	C, Bash	7,478
formatting	Perl	4,512
web server log analysis	Perl	1,575
TOTAL		17,859

All software was submitted to a Subversion code repository so that we could easily install the various packages onto each recording cart, and so that we could track each change made in the code, who made it, and when the change was made. The Subversion code repository is accessible on the web [1] with a valid login.

Documentation

Software documentation, installation instructions, processing and recording notes and instructions were maintained in a Wiki, which is accessible on the web [2] with an authorized login. Installation instructions and further documentation were packaged with some of the software [1].

Lecture Object standard

One aspect of the MScribe archiving system that is unique, developed over the past several years by the ACP, is the use of extra processing and storage to archive each recorded talk as a Lecture Object [3], a high quality open-format data object containing high resolution and high bandwidth media along with descriptive metadata. This extra step makes the archive much more robust and long-lasting, and allows for new viewing formats to be provided as they become available.

A Lecture Object is an archival data object originally proposed by the ATLAS Collaboratory Project in 2000 at an international conference [4], designed specifically for the storage of the media and metadata associated with a typical lecture recording. It contains standardized metadata conforming to widely-used international standards such

as Dublin Core [5] and IEEE Learning Object Metadata [6], timing information, and high resolution media files encoded in open formats. The Lecture Object standard is designed with the purpose of ensuring longevity of recorded materials, flexibility in viewing formats and enabling easy sharing between multiple institutions and archives.

Although recordings could be posted more easily and quickly by encoding directly to a popular format such as RealPlayer, we have always insisted on the additional step of first creating a high quality Lecture Object. We store in the archive JPEG images of each VGA screen capture at its original resolution (up to 1600x1200), high-bandwidth MPEG-4 video at the original camera resolution (720x540) and high-quality images of any chalkboards. Our software then “transforms” the archived Lecture Object into a viewable format suitable for distribution via the Web. We can write new “transformations” or edit the existing ones to produce new Web formats, change the layout, or increase the media bandwidth. This gives the archive lasting relevance in an environment of changing user preferences and evolving media players.

The specifications for the lecture object are given on the ATLAS Collaboratory Project home page [7].

Lecture Object version 0.3 was used during the pilot project. Our experiences during the pilot project are directing the changes being made in the coming completion of version 0.4. New features will include better compatibility with Deep Blue and BlueStream’s archiving systems and support for in-class videos and animations (something that was requested repeatedly by instructors), as well as better support for additional video feeds such as chalkboards.

Work with BlueStream

We met with personnel from the BlueStream project [8] several times throughout the year to work on integration of web lectures into the BlueStream environment and investigate what benefits BlueStream had to offer for our application. A “workflow” was set up for submission of lecture object materials into BlueStream, conversion into multiple video formats, speech-to-text metadata extraction, and Optical Character Recognition (OCR) text extraction on the slides. This workflow was successfully demonstrated with several MScribe recordings, although it has not yet been automated or implemented on a large scale. Using the BlueStream system, a U-M student with proper authorization can type in any search term, such as the word “quark”, and results harvested from the slides or instructor’s speech are presented. Clicking on one of these links takes the student directly to the place in the lecture where the instructor discussed that topic. The BlueStream team made this functionality work with our existing RealPlayer viewer, so that the search results take the user to a synchronized audio/video/slides Web Lecture, instead of the default BlueStream results of just a video clip or a single slide image.

Storage and distribution of content

A web server running Red Hat Enterprise Linux 3, with 3 TB of disk storage, was maintained with the help of personnel in the Physics Department Office of Computing Services (OCS), and housed in the OCS server room. This primary web server was used to store all archived lecture objects as well as to stream the formatted web content to users. This primary web server hardware had already been in use by the ATLAS Collaboratory Project, and we continued to use it in the Fall 2006 semester to evaluate what kind of server should be purchased for MScribe recordings. Unfortunately, this old web server became susceptible to file system errors, causing an outage at the end of the Fall 2006 semester. Based on our experience in Fall 2006 we bought a much higher quality HP server and moved the archive to it in Winter 2007. No further outages occurred.

An identical web server was housed in the LSA server room and used to perform weekly data backups of the entire media archive. Weekly automated disk-to-disk backups were implemented, requiring less human intervention than tape backups, and making data recovery much easier and more reliable. The physical distance between the servers meant that the archive could survive a catastrophic event such as a fire or water damage in one location. The primary server was protected from lightning strikes and brownouts with a battery backup system.

The screenshot shows a web browser window displaying an MScribe Web Lecture. The slide content is as follows:

- Main Exam Topics: Learning about ...
- population proportion P (with handwritten \hat{P} and "estimate with" above it)
- population mean μ (with handwritten \bar{X} next to it)
- population mean difference μ_d (with handwritten \bar{d} next to it)
- difference between two population means $\mu_1 - \mu_2$ and $\bar{X}_1 - \bar{X}_2$ (both circled in blue)

The interface includes a sidebar with a video player, "PREVIEW SLIDES", "HELP", and "DONE" buttons. The main area has "GO BACK 1" and "GO AHEAD 1" buttons, a timer at "00:10:30", and "slide 008". At the bottom, there are links for "JUMP DIRECTLY TO SLIDE", "report problems", and "synchronize video with current slide".

Figure 4

Links were provided for each recording in the appropriate CTools course site for RealPlayer-based web lectures. To view these lectures, students needed any web browser and the RealPlayer plug-in. A screen shot of such a web lecture is shown in Fig. 4. In addition, QuickTime video podcasts were posted using the iTunesU tool in CTools. These video podcasts were available for automatic download and suitable to be played back either with the QuickTime player or on a video iPod. The QuickTime videos have additional features, such as the ability to play back the audio/video at a faster rate, for rapid skimming through a lecture.

CoSign authentication software [9] was installed on the primary web server, and all classroom recordings were placed in CoSign-protected directories, so that only U-M students could view the lectures. We discovered an incompatibility between CoSign and RealPlayer, such that the video would not play back in some web browsers, and on Apple computers. We provided special links in CTools so that Apple users could view the web lectures as well. In the future, however, we plan to phase out RealPlayer and switch to a Flash-based viewer. Flash is widely used, compatible with all major platforms and is plagued by none of these incompatibilities.

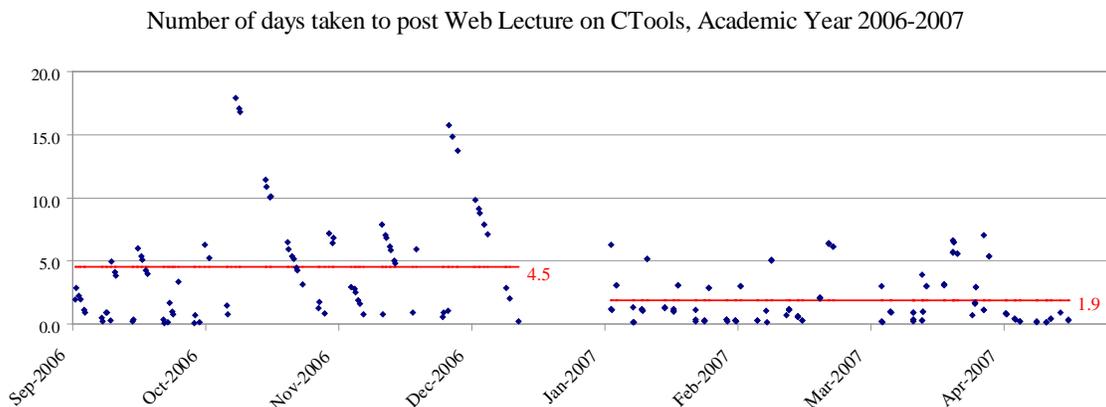


Figure 5

Figure 5 shows the number of days lag between the end of recording and final posting on CTools for every classroom lecture recorded during the Fall 2006 and Winter 2007 semesters. In our original proposal, we proposed the following goal: “The web lectures would be automatically recorded and posted on class CTools websites.” While the majority of the archiving and formatting processes were successfully automated, there were three parts that were not completed and had to be done by a human:

- metadata entry
- analysis of slide transitions
- adding links to CTools and iTunesU

Since the final web lecture could not be made available until each of these tasks had been completed, the speed of posting the lecture depended on the availability of a human to enter the metadata, check that the slides had been processed correctly, and manually add links to CTools. Lectures recorded late at night or on Friday often sat unprocessed overnight or over the weekend. During the first semester, we allocated insufficient manpower for these tasks, and the average time until posting was 4.5 days. Some of the large values occurred when insufficient allocated staff time caused long delays in getting any lectures posted. In the Winter 2007 semester, we specifically assigned the task of making sure all lectures were posted on a regular basis to a staff member, and were able to reduce the average time of posting to 1.9 days. Some lectures were posted as quickly as 2.5 hours after recording. This means that had the process been fully automated, one could expect a 2-3 hour turnaround time in the future. Since the end of the pilot project, we have been steadily making progress toward complete automation.

Of the 211 scheduled classroom lectures, 2 were not recorded because of staff scheduling errors, and 10 were not posted because of unrecoverable hardware or software failures. Software failures involved the corruption of media files, and hardware failures (accounting for most of the failures) included loose audio cables and equipment failure. Including all different types of failures, we are pleased to report an overall 94% success rate in the University's first large-scale automated web recording operation.

Unfortunately, in spite of the robustness of our data backup system, we were unprepared during Fall 2006 to deal quickly with a web server failure that occurred at the end of the semester. The file system we had been using, reiserfs, developed errors and this caused the software formatting the recordings to become corrupt and crash the server. While we investigated the problem, we kept the web server and existing recordings online as much as possible, which meant no new recordings could be posted during the critical two week period at the end of the semester. We have since resolved the problem and moved the archive to a new, higher quality web server.

Logging of usage statistics

The design of the RealPlayer lecture viewer allows for detailed information to be culled from the web server logs. This information includes IP addresses of users' computers, and timestamps indicating when any button in the viewer is pressed, including the "forward slide," "back slide" and "display thumbnails" buttons. For each time a user views a lecture, session information can be reconstructed showing how each user navigated through the lecture. All of this information was provided to the pedagogical research team. During the Fall 2006 semester, usernames were collected in the server logs along with IP addresses, but this information was not collected in Winter 2007 because of a technical misconfiguration.

Statistics showing usage of the iTunesU video podcasts were obtained from Apple directly by members of the CSHPE staff.

Using the web server log analysis software developed by the technical team, basic usage information could be graphed, as in Figure 6. From this graph, it is apparent that students used the web lectures very heavily in the 2 days before each midterm exam. Also, it is interesting to note that the usage was mostly concentrated during the week (Monday – Thursday), and not much at all on weekends, as is apparent from the regular occurring bumps in the graph. Additional analysis is provided in the Pedagogical Research section of this report.

University of Michigan Psychology 111 Fall 2006
MScribe 5-minute+ viewing sessions per day

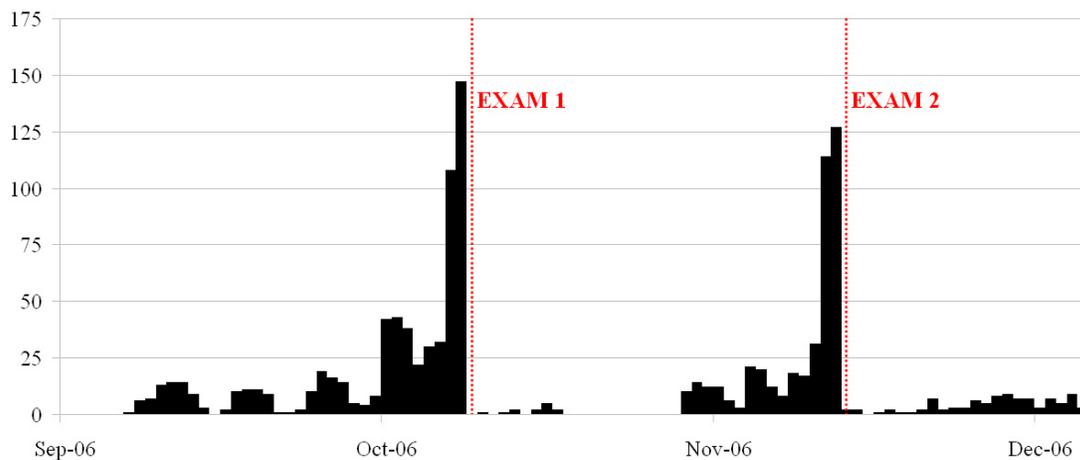


Figure 6

Novel speaker tracking system

Investigation of tracking system technologies

It has been clear to us for several years that total automation is the only way to make recording technology useful on a large scale, and we have sought to extend this automation even to the operation of the video camera. Our group received an NSF grant in 2003 to explore the possibility of automating the video camera. On this grant we investigated several tracking technologies including radio-frequency, ultra-wide-band, ultrasound and infrared based systems. Most of these were ruled out because they failed to meet one or more of the following criteria:

- Portable
- Accurate
- Robust
- Affordable

- Runs without expert intervention
- Minimal setup or calibration

The current system

At the start of the MWrite pilot project, we had already settled on an infrared (IR) based tracking system as the most promising technology for classroom use, and had built a rough prototype. During the Project, we developed a production-ready version of this system, consisting of a special necklace that is worn by the instructor, and a pair of pan-tilt-zoom video cameras to follow his/her movement. The necklace consists of a chain of about 30 IR LEDs that are constantly lit, and are powered by a battery pack that fits on the instructor's belt. For simplicity, we used two identical models of off-the-shelf Pan-Tilt-Zoom (PTZ) video cameras. One camera is equipped with the appropriate IR filters so that it sees only the necklace, and follows it around the room. Based on this position information, the second camera is pointed appropriately at the instructor to provide color video footage.

Figure 7a shows a picture of the necklace in regular light, and Figure 7b shows the exact same scene as the IR camera sees it. In normal light the LEDs do not appear to be shining, but in the IR spectrum their presence is dramatic and easily discernible. The system design is simple and therefore robust. It requires no setup or calibration, works independent of the lighting or geometry of the venue, and is affordable and easy to repair since it uses off-the-shelf products. It provides accuracy to within inches, and can be mounted on a portable cart. The principal drawback to this system is its inability to function in the presence of bad background noise, in the form of direct sunlight, incandescent lights and IR communication ports found on laptops and assisted listening systems. However, we have made substantial improvements in these areas since April 2007, which are described below.

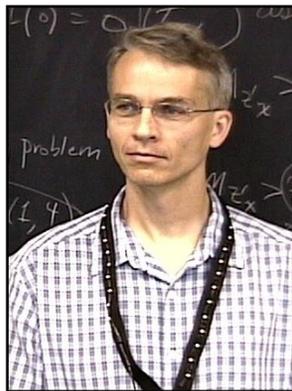


Figure 7a. the necklace
(color view)



Figure 7b. the necklace
(IR view)

Although the IR system we developed works reasonably well and has many nice features, it is inherently limited in certain ways by the basic physics of its construction. It can only

provide 2-dimensional tracking information, and can only track one necklace in the room at a time. And it is susceptible to distraction by a significant competing IR source, such as the newer assisted listening LED beacons being installed in newer rooms on campus. In concurrence with our work developing and debugging the IR system, we investigated other promising tracking technologies as well.

Position sensitive detector

The first technology we investigated was also IR-based, using a special light-sensitive chip called a Position Sensitive Detector (PSD) to detect the light from the necklace instead of a CCD camera. This is a square silicon chip specially made so that when a spot of light falls on it, it gives a 2-coordinate readout showing the position of the light very precisely. A very promising feature of the PSD, in addition to its precision, is its capability to process the incoming signals extremely quickly. We planned to pulse the IR necklace at a high frequency, making it possible to pick its signal out from the background by using electronic filtering. Using the same IR necklace in our existing system and attaching it to a pulsing circuit, we set up a lens assembly to focus the incoming IR light onto the PSD. However, our tests showed that the PSD only works at short distances and the signal-to-noise ratio is much too small at distances of 30 feet, a typical distance that the instructor might be.

IR quad detector

The second technology we investigated was also IR-based, again with the idea of pulsing the necklace LEDs, this time using a quad detector. The quad detector is a very simple and inexpensive array of four IR light sensors that report which “quadrant” the light source is in: up, down, left or right. This quad detector can be mounted on a pan-tilt (PT) platform and moved appropriately until it points directly at the necklace. When the necklace moves again, the quad detector senses the change and is again moved by the PT platform until it centers on the new location. Again pulsing the necklace, we successfully got a high-quality signal with this system at 80 feet. This technology looks very promising, although the design inherently requires that a PT platform be used, introducing more moving parts and limiting the speed that the system can track. We suspended working on this system in favor of another promising technology, ultrasound, described below.

Ultrasound

During Fall 2007, we presented a challenge to a U-M engineering class in the form of a class project. Multiple teams of students were instructed to design a tracking system that met with a list of requirements we specified suitable for classroom recordings. The most promising of these was an ultrasound-based system. We investigated this system and built a rough prototype during the summer of 2007, and although no production-ready

system has been built, we are hopeful that this method could work even better than the current infrared one. Its advantages are as follows.

- There is no significant competing noise we know of in the 40kHz audio range in classrooms.
- It is just as mobile as the infrared system and promises to be easier to miniaturize.
- This system will allow switching between multiple targets, so that e.g. a panel of speakers could be recorded automatically.
- Coupled with an RF pulse, the audio information can be used to establish the necklace position in 3D, making more sophisticated and humanlike videographer algorithms possible.
- It should be possible to build the tracking part of the system with no moving parts.

It is similar to the existing infrared system in that the instructor is given a necklace to wear and a small laptop-operated station at the back of the room can track its position with no special setup. However, instead of IR LEDs, the necklace has a couple ultrasonic emitters sending out an audio pulse many times per second, and instead of a CCD camera, the tracking station has an array of ultrasonic receivers that measure the times of arrival of the audio pulse and use the differences between them to calculate the angle to the emitter.

Documentation, reports, meetings

The technical staff met weekly to report on the recording schedule, hardware and software problems, and ongoing development.

Google spreadsheets were created and shared among several staff to track the status of every recording made and its associated archiving and formatting.

The advisory committee met twice to discuss the overall activities of the project and form longer term plans.

Software documentation, processing and recording notes and instructions as well as some meeting notes were maintained in a Wiki [2].

Presentations on MScribe and related activities of the ATLAS Collaboratory Project were given at CHEP 2006 [10] and [11], CHEP 2007 [12], and for an AT Commons meeting [13].

A web page [14] was set up for MScribe with some basic information and a demonstration web lecture.

Developments since April 2007

Since the end of classroom recordings in April 2007, the development team has been able to re-direct their time from debugging problems with the system in daily use to making improvements and innovations in several aspects of the technology.

New Flash-based viewer

A Flash-based lecture viewer has been developed to replace the RealPlayer viewer. Flash has none of the CoSign compatibility problems that RealPlayer has, which means the viewer can be used in any web browser on any OS and content can be protected using CoSign. It also logs all user events and can generate the same and even more detailed information about student usage, for future pedagogical studies.

Recording and archiving systems

The recording and tracking systems have been separated, and the recording system alone has been successfully installed on a laptop. The ATLAS Collaboratory Project team has used this portable laptop-based system with a professional firewire camera to record 187 talks for the ATLAS Collaboration since March 2007 (including at Univ. of Glasgow, CERN, Stanford, and U of Michigan Physics).

A metadata entry form has been added to the recording application, so that the person wheeling the cart into the room can enter a few descriptive terms at the time of the recording, eliminating the need for human intervention later in the process. This takes the whole system one step closer to complete automation and faster posting times.

Tracking system

Improvements in the tracking system have been made so that it works in less-than-ideal environments. This was mainly accomplished through the extensive tweaking of camera settings and purchasing better IR filters so that the camera could be made to see the necklace against the background in less-than-ideal environments. This was tested dramatically in USB 2260, a large auditorium with an entire wall of windows, with direct sunlight streaming into the room. Using the new settings and filters, the system can track the necklace even in this direct sunlight. Previously we could only record in this room with all the blackout shades drawn.

The motion of the color video camera has been made smoother. This was accomplished by a thorough audit of the tracking code and improvements to the videographer algorithm. We have also implemented extensive position recording routines so that the movements of the camera can be recorded in great detail and mathematically analyzed

later, to improve our understanding of how instructors move and the increase the quality of the tracking algorithm.

Designing effective LED necklaces has been challenging for several reasons. They must be completely fabricated by us in the lab, consisting of many small parts that must be soldered together and subjected to rough use by a variety of instructors. The necklaces must be visible even when the wearer turns in every direction and covers up parts of it with hands or papers. And since they are worn by the instructor, the necklaces must be powered by as few batteries as possible while also being as bright as possible. The first necklaces have had a battery life of between 1 and 3 hours, and generally lasted a couple months before daily use wears out the solder joints. We attempted to build newer necklaces that are tougher and more flexible (using different kinds of wire), less obtrusive while still providing adequate coverage of the instructor's upper torso (using fewer, brighter LEDs and a more intelligent layout), and are visible in every direction (using wide-angle LEDs).

The necklaces built and used in the pilot project year consisted of a chain of around 30 wide-angle LED's and powered by 2 AA batteries, with no special circuitry involved. After much searching, brighter wide-angle IR LEDs were found and built into a new necklace, using special circuits to squeeze as much current as possible out of 4 AA batteries and create a much brighter necklace, with fewer LEDs. This necklace only has battery life of one hour but is detectable from farther away and in more adverse conditions.

We have continued to work on development of the most promising technology to date, the ultrasound system described above. It has been slow to implement because all components must be custom fabricated. We will keep pursuing this technology until we are able to successfully implement it or until we determine that it will not work.

Pedagogical research

As we noted in our original proposal,

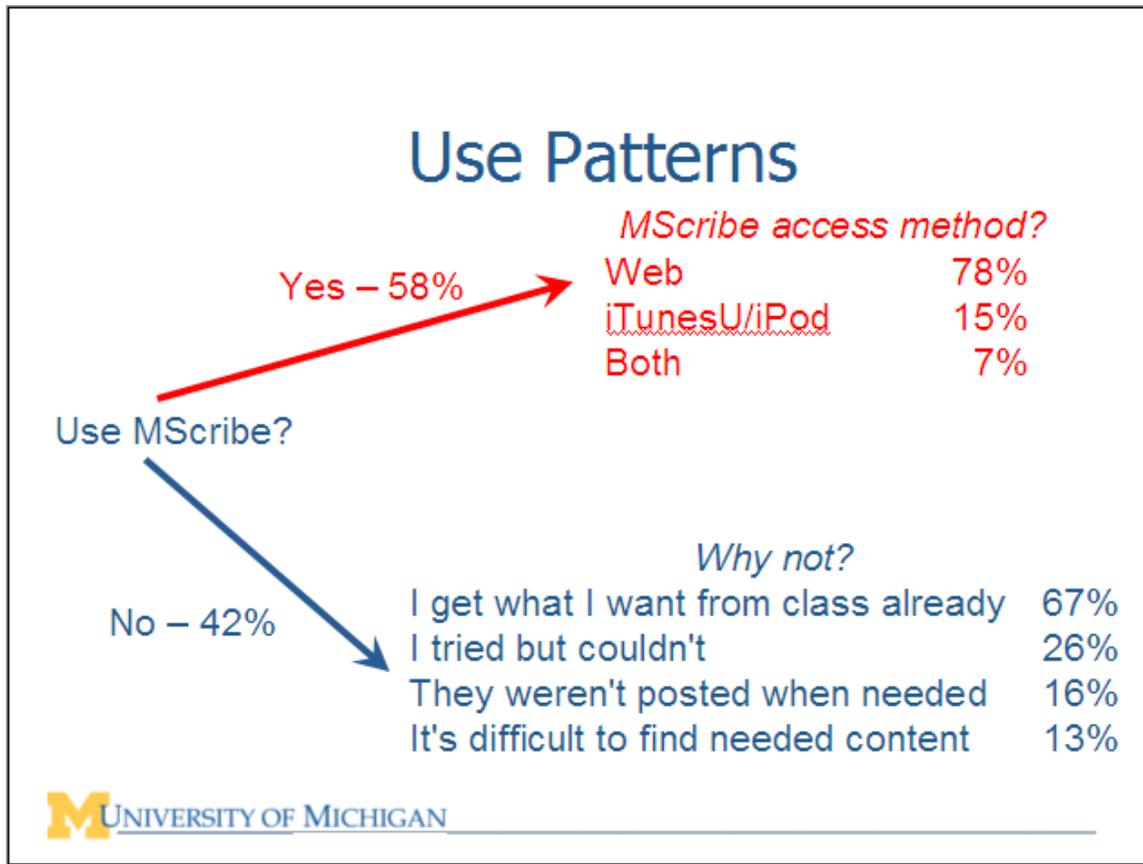
“The ability to deploy an automated system for capturing classroom lectures for distribution via the web is based primarily on the experience and technologies associated with the Web Lecture Archive Project (WLAP; <http://www.wlap.org>). WLAP is a joint venture between the UM-ATLAS Collaboratory Project, the University of Michigan Media Union, and the European Organization for Nuclear Research (CERN), and its goal is the implementation of an electronic archival system for slide-based presentations on the Internet. WLAP has recorded over 700 content-rich lectures and published them via servers at the University of Michigan and at CERN. This archive comprises a variety of lecture types, including general interest, class instruction, historical events and specialized hands-on software tutorials. We have monitored recorded lecture use patterns

and continued to improve capture and publishing techniques based on user feedback. The utility of such archives as a training vehicle for high level software developers has been firmly established by this group. Further work has been funded by the National Science Foundation to study the issues involved with the recording of lectures in environments where multiple sessions must be recorded simultaneously. This desire to execute a larger scale operation with minimal manpower has driven our team toward the automation of as many of the aspects of the recording, processing and archiving as possible. Findings from this work now make it feasible for us to contemplate deployment in classroom settings as proposed herein.

The impact on student learning and attitudes of advanced information technology usage in college instruction is still a matter that requires substantial study, preferably in existing educational settings with a level of support that is realistic. By piloting and evaluating a testbed system for capturing lectures, this project will not only ensure the robustness of the technologies, but also provide a natural experiment to test the effects of a technological innovation related to teaching and learning. Researchers from the School of Education will work with CRLT as well as participating faculty to study and evaluate their use of the technologies and the resulting student learning. This will be accomplished using both quantitative and qualitative measurement approaches. Comparing practices and outcomes across disciplines and fields could be an effective way of sorting out how student learning can be enhanced by online educational approaches. Likewise, an expansion of the effort to examine faculty involvement in this project, and collateral improvements in their presentations and teaching would be possible, and feed directly into general campus imperatives to improve all educational efforts. Finally, in collecting data from faculty and students involved in this pilot we will be able to evaluate the activities from a programmatic perspective, while also providing some infrastructure and data useful to the University's campus assessment activities. “

Results – student use and reactions

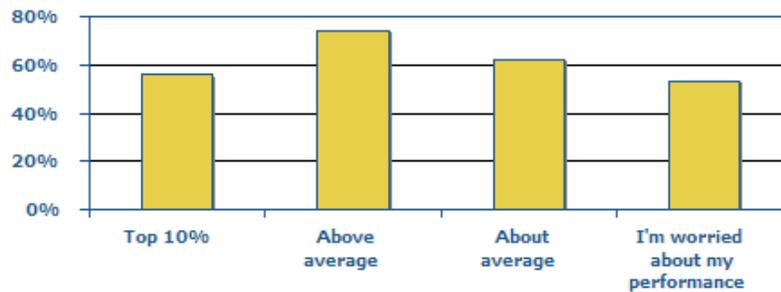
Over one-half of the students enrolled in the pilot project classes reported using MScribe on a regular basis (49 percent of Fall 2006 survey respondents and 66 percent of the Winter 2007 respondents), while the web server log data reveals that nearly all the eligible students explored the use of the system by at least one or two visits. Among those not accessing the video archives, about two-thirds reported that they were already getting what they needed from class, which made the archives unnecessary. However, a substantial proportion reported technical problems, delayed postings, and inefficient navigation and view options as reasons for non-use.



Student characteristics show some relationship to tendency to use the MScibe system. Students who indicate that the faculty teaching the pilot course in which they are enrolled have expectations that are in perfect alignment with their learning preferences are substantially more likely to be regular users of MScibe (85 percent versus 61 – 65 percent for those with less than perfect alignment). Asked to compare their expected performance relative to other enrolled students, those who rated themselves as “better than most” or “about average” had the highest viewing rates (74 and 63 percent, respectively), versus those in the “top 10-percent” (56 percent) or those who had significant performance concerns (53 percent). One of the biggest differences in use likelihood is associated with being a non-native speaker of English, with 84 percent of those whose first language was not English reporting regular use versus 52 percent for native speakers.

Which students use MScribe?

- Self-assessed performance level:



- Students whose learning styles are “perfectly aligned” with faculty expectations
- Students for whom English is not their first language



Of the regular visitors, two-thirds accessed the recorded videos exclusively via the web portal, about a quarter used the portable iPod videos, with the balance using a combination of both methods. The Fall 2006 data showed that 57 percent of users accessed the MScribe lectures from a laptop in a public place, 39 percent of students accessed the lectures from a home computer, with the balance using campus computing facilities.

MScribe users generally browsed around the MScribe lectures (two-thirds), while about one-half reported going to specific points in the lecture to review. These figures are closely followed by students who re-watched certain segments based on their notes (48 percent) and those who watched large chunks of the videos looking for information (44 percent). Only one-quarter watched the entire video from start to finish. These results are consistent with preliminary findings from qualitative pilot data, where students said that they mostly used MScribe to study for exams, to add to the richness of their class notes, and to review material that they may have missed in class.

Three-quarters of MScribe viewers used the archives as an exam study tool, followed by using it to fill in gaps in their notes, as a study supplement, and as a replacement for the live lectures. Only 12 percent of students accessed the MScribe lectures to work on class assignments, and 3 percent used it as a study group resource.

Results – student engagement

Turning now to outcomes, we found that about 40 percent of MScribe users agree strongly or somewhat that having access to the MScribe lectures helps them to pay attention to the instructor during class. These results are consistent with preliminary qualitative findings, where students mentioned that knowing that they could access the MScribe lectures reduced their anxiety of taking meticulous notes in class and allowed them to listen more closely to the instructor so that they could absorb information. Likewise, a similar proportion of users reported that taking extensive notes in class slightly decreased since MScribe became available to them.

The majority of MScribe users reported that their reading and preparation for class, class attendance, and note-taking activity remained unchanged after using MScribe. Further, 44 percent reported that review lecture content and/or notes from lecture slightly increased, and 43 percent reported that studying for exams also slightly increased. Writing papers, working on class projects and asking the instructor questions outside of class remained unchanged. These results make sense based on related findings, as students typically use MScribe for intensive and/or time sensitive purposes (such as studying for exams and filling in class notes) more often than for class-related activities that involve course texts and instructors for reference.

Future R&D initiatives

Ongoing research and development is required to fully realize the vision of ubiquitous and reliable web recording systems. We believe that, with our years of experience in this area, we are well positioned to help contribute to advancing this goal. Specifically, we wish to focus our efforts on the following items.

1. We have performed an initial investigation of an ultrasound-based tracking system and believe it is a promising technology. In fact, we believe that it promises to be at least as effective as the current IR tracking system, and have none of its weaknesses. This technology should be further tested and developed, so that a compact, portable, robust system can be developed and used in any room anywhere.
2. We now have many hundreds of hours of recorded video in our archives. Using this and the new logging capability built into newer versions of our tracking system, we will be able to developing smarter speaker tracking algorithms that more closely mimic a human videographer.
3. The Flash viewer described above provides platform- and browser-independent functionality equivalent to the current RealPlayer viewer without the CoSign incompatibilities. But even more exciting is the fact that Flash contains the ActionScript programming language, which means that any feature we can conceive of can be added to the viewer, which would not have been possible using RealPlayer. Display of multiple video streams simultaneously (e.g. to display in-class video segments and animations,

close-ups of science experiments or artifacts), and the ability for instructors and students to collaboratively annotate web lecture material are just a couple useful features that could be added to the functionality of the Flash viewer.

4. The Lecture Object standard has been a central theme in the activities of the ATLAS Collaboratory Project since 1999. The MScribe pilot project has informed the ongoing development of this standard, and will help to make it a more complete and useful tool in the archiving of lectures. We are in ongoing discussion with colleagues at Deep Blue and CERN to help make this a more useful standard that will integrate well with other archives and promote the dissemination of valuable multimedia presentation material among educational institutions and to the general public.

5. A key development that will make lecture capture ubiquitous will be miniaturizing the hardware of our lecture capture system, so that what used to fit on a rather bulky cart can be reduced to the size of a large laptop.

6. In terms of pedagogical research on students, current and planned work is focused on connecting access data from web access logs with student performance data. This information has the advantage of being statistically unbiased as it represents population (not survey sample) data, as well as directly addressing the question of impact.

7. Research on faculty use of these kinds of lecture capture technologies is also planned, as it represents one avenue faculty (and their employing institutions) can use to improve teaching and student learning.

Plans are underway in the ATLAS Collaboratory Project to work in the technical areas, while the Center for the Study of Higher and Postsecondary Education and the Center for Research on Learning and Teaching are pursuing the pedagogical topics. A final push toward completion of these activities may require a significant pulse of funding from an agency or Foundation, or collaboration with an industrial concern.

Recommended campus actions

The MScribe Project has demonstrated that classroom lectures can be recorded and posted in a CTools environment, that such materials can be of use to students and faculty, that web lecture recordings with student performance links provide a rich set of topics for pedagogical research, and that we are on the brink of making web lecture recordings scalable. We recommend that the campus take the next steps to build on what has been learned in this Project. Namely, we recommend:

That the campus publicly declare its intention to develop and exploit opportunities for web based classroom teaching and learning.

That the campus take action to create a center devoted to evaluating how web based teaching and learning can be best employed, what techniques work and which ones do not, and what types of recording systems are best suited for classroom deployment. Within this center would be a focused r/d unit directed exclusively to supporting the center's pedagogical work.

That a major component of such a center be focused on how students learn using web lecture technologies, and how such technologies impact student achievement.

That the campus give priority to extending web lecture capture options across all of its activities, from departmental colloquia and seminars to university-wide events, for internal uses as well as outreach.

That the campus provide guidelines on what materials and human interactions are acceptable for capture, what procedures must be followed, what permissions may be maintained, and what materials may be made public.

That the campus should give priority to funding a number of web lecture r/d activities, drawing upon the broad expertise already within the university. An environment should be established that would encourage collaboration, while not prohibiting standalone efforts.

University of Michigan contributors

The entire project was made possible by contributions from a number of University of Michigan units. The list includes:

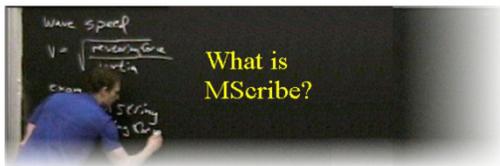
- College of Literature, Science and the Arts
- College of Engineering
- School of Medicine
- Bioinformatics Program
- School of Education
- M-GRID
- BlueStream
- Center for Research on Learning and Teaching
- Center for the Study of Higher and Postsecondary Education
- Department of Physics

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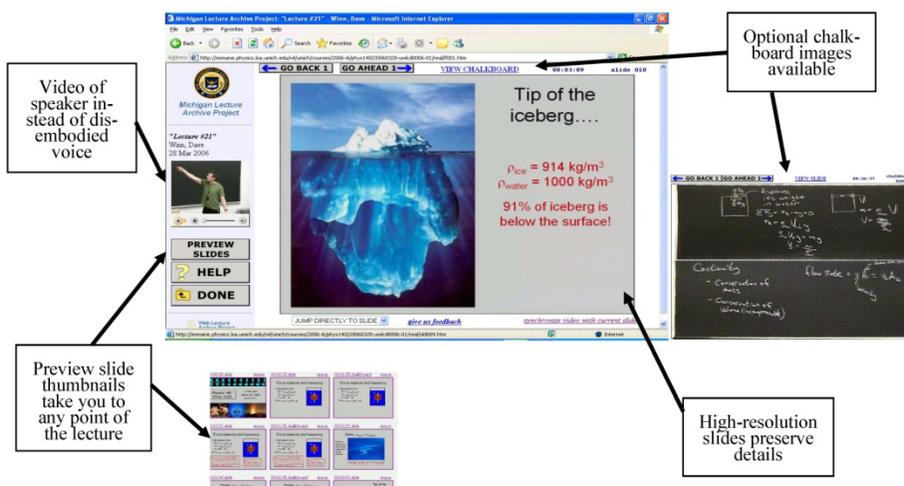
Appendix I – MScribe brochure

Mscribe **Bringing the Classroom to the Web**



Mscribe is a system for recording and playing back classroom lectures on the web. It produces a video of the presenter; high-quality audio; snapshots of board work; documentation of media materials; and an index to the material. This technology was developed at the University of Michigan (UM) by the ATLAS Collaboratory Project (ACP), led by Physics Professor

Homer A. Neal, with support from the National Science Foundation. This project has been generating novel technologies and social interfaces for scholarly exchange and collaboration since 1997. The ACP Team has recorded over 1300 web lectures for use applications. Mscribe is a version of their system that is especially adapted for classroom lectures that emphasize visual media, requires almost no adjustment by the presenter, and functions without the aid of a camera operator.



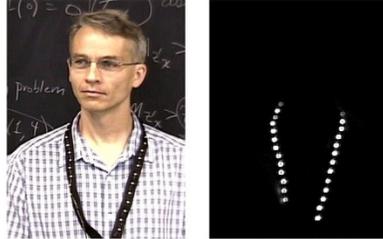
The screenshot shows a web browser displaying a lecture slide titled "Tip of the iceberg...". The slide contains the following text: $\rho_{\text{ice}} = 914 \text{ kg/m}^3$, $\rho_{\text{water}} = 1000 \text{ kg/m}^3$, and "91% of iceberg is below the surface!". To the right of the slide is a "CHALKBOARD" image showing handwritten notes and diagrams. Below the slide is a "PREVIEW SLIDES" section with a grid of thumbnails. Callout boxes point to various features: "Video of speaker instead of disembodied voice" points to a small video window; "Optional chalkboard images available" points to the chalkboard image; "High-resolution slides preserve details" points to the slide content; and "Preview slide thumbnails take you to any point of the lecture" points to the thumbnail grid.

The success of web lecture recording systems was immediately evident in 1999 when the ACP Team recorded hundreds of lectures in the prestigious CERN Summer School in Geneva, a program attended by approximately 150 of the top science undergraduates in Europe. The powerful positive responses sent by viewers, and requests for more recordings for the ATLAS experiments (an international collaboration of physicists located at CERN in Switzerland), encouraged the further development of the ACP recording techniques in collaboration with Charles Severance in the UM Digital Media Commons. In the next seven years, the technology research and development team gained experience in working with numerous recording settings for audiences who wanted easy access and high-quality documentation. The technology reflects that extensive experience, with exceptional quality in methods for documenting and publishing lectures mainly in the sciences. The ACP Team's basic system has been deployed in the recording of workshop presentations from CERN, the home of the world wide web, to biology workshops at Harvard, to meetings of the American Physical Society, and the Saturday Morning Physics lectures at the University of Michigan. In 2006, this system was piloted for classroom teaching across a spectrum of disciplines, including the humanities, for the first time.

What makes MScribe Different?

Several factors distinguish MScribe from other lecture capture systems.

- Visual content is available not only to be viewed, but also – because it is indexed – to be viewed selectively.
- The lecturer is videotaped (not only audio taped).
- Through the use of a novel infrared tracking system, a robotic tracking camera follows the lecturer as he/she walks about the lecture space wearing an infrared-emitting necklace—freeing the lecturer from being anchored to a podium and eliminating the operational costs of a camera operator.
- Spontaneous board work and slides are captured as still images.
- All these media feeds are synchronized during the replay mode, so viewers can review such elements of lecturers as the logical argument, comparisons, explanations, questions posed for review, questions the students have during the lecture, and so on.



Visible and infrared views of the tracking necklace

The MScribe Project

Along with the ACP Team, the MScribe project includes a team to study the pedagogical effects of this transformative technology. Researchers from the Center for Research on Learning and Teaching (CRLT) and the Center for the Study of Higher and Postsecondary Education (CSHPE) are collaborating with the ATLAS Collaboratory Project Team on both the implementation and evaluation of the project. The study will examine use by students, GSIs, and faculty; impacts on teaching and studying; and impacts on student learning. (The specific foci will be developed in partnership between the MScribe project team and individual faculty who choose to participate.)

In 2005-2006, the MScribe project received funding from University of Michigan schools and colleges (see last page). The technology was piloted in a classroom for the first time, documenting all the lectures in the large Physics P140 course, for the second half of Winter Term.

During the 2006-2007 academic year, MScribe technology will record courses, focusing on a small number of classrooms. The research team will document how the technology is used and its pedagogical value.

Technological Achievements

The project team has sought to automate nearly every step of classroom lecture recording. The team has developed new recording and publishing techniques, which include:

- hardware and software solutions to automate the encoding, compression and synchronization of audio, video and slides;
- a proposed XML software programming standard, called Lecture Object by the ACP Team, to facilitate the archiving and sharing of multimedia presentations in an open fashion;
- a robotic camera tracking system to remove the need for a camera operator and be sufficiently robust to operate in a variety of room lighting environments;
- software to harvest text from captured slides, leading to association of the resulting metadata with relevant sections within a lecture and radically improved search capabilities.



The video, chalkboard, and infrared tracking cameras.

Advantages of MScribe

Promotes Improved Student Learning

- Access to web lectures may allow students to grasp higher volumes of classroom material
- Access to web lectures may allow students to gain a deeper understanding of classroom material
- Access to web lectures may result in more efficient study habits
- Since students have ready access to classroom lectures, in class interactions may evolve from being mainly content-based questions to more thought-provoking discussions

Provides Resources for Instructors

- Resulting archive is available for revising the next iteration of a lecture
- Archived lectures can be used as resources for class discussion, either in the immediate term or in a future term
- Recorded lecture material can provide better cohesion between lectures and discussion sections
- Lectures can include questions for further study, for students to come back to
- Recording requires no extra effort by instructors
- Develops new knowledge on student learning for the university community
- Study of student and faculty use can help shape future technology developments to enhance learning and pedagogy
- Study can guide faculty choices of emergent technologies and strategies for use

Our deep interest in this project is due to its potential for eventually transforming the instructional process in higher education.

See MScribe for yourself at the following links to example lectures.

At the URL below, click "View Lecture." The captured lecture will then play. If you want to experiment with navigating the materials, click "Preview Slides" and a slate of the presentation slides will appear. Click on the slide you want to start from, then click "Synchronize...." at the bottom, and the lecture will jump to that point.

A talk by Randy Bass, an American Studies professor from Georgetown, who gave the keynote address at the CRLT Provost's Seminar on IT at the University of Michigan in May 2005:

<<http://mscribembass.notlong.com>>

A lecture given by David Winn in his Physics 140 class at the University of Michigan during the Winter Term 2006:

<<http://mscribesample.notlong.com>>



Want to Learn More about MScribe?

Feel free to contact us with any questions!

Crisca Bierwert, Assistant Director of CRLT: crisca@umich.edu

Eric Dey, Associate Professor of Higher Education: dey@umich.edu

Homer Neal, Professor of Physics: haneal@umich.edu

MScribe Project Members

Mary Antonaros	CSHPE	Jeremy Herr	ACP
Alli Bell	CSHPE	James Irrer	ACP
Tushar Bhatnagar	ACP	Mitch McLachlan	ACP
Crisca Bierwert	CRLT	Dan Merson	CSHPE
Eric Dey	CSHPE	Homer Neal	ACP
Lisa Guzman	CSHPE		

Organizations Involved with MScribe

The goal of the ATLAS Collaboratory Project (ACP) is to study and advance the technologies and practices required for the organization and execution of modern, large-scale collaborative research experiments and for facilitating the delivery of web-based educational material. Accomplishments of the Project to date include the development and testing of protocols for transatlantic videoconferencing using QoS, the creation of innovative video capture and compression techniques, work on the development of a Lecture Object standard, an early assessment of the value of web lectures in training applications, and the development of speaker tracking technologies.

The Center for Research on Learning and Teaching (CRLT) is dedicated to promoting excellence and innovation in teaching and learning at the University of Michigan. CRLT includes twelve instructional consultants who have doctoral degrees, university teaching experience, and expertise in faculty development. CRLT works collaboratively with instructors at all levels, and with the academic administration, to develop a University culture that values and rewards teaching, supports innovation, and encourages the creation of learning environments in which diverse students can learn and excel. CRLT programs focus on faculty development, evaluation research, instructional technology, interdisciplinary teaching, and multicultural teaching and learning.

The Center for the Study of Higher and Postsecondary Education (CSHPE) was one of three such centers established in 1957 with a grant from the Carnegie Foundation of New York. The only one remaining, for five decades CSHPE has been the nation's premier preparation program for higher education leadership and has been consistently ranked as top in its field by polls within and outside of education. CSHPE prepares professionals and academics who understand, lead, and change institutions of higher education so they can markedly influence and improve postsecondary education in the 21st century. The scholars who comprise the CSHPE faculty have expertise that spans a wide range of fields of study, including issues affecting higher education from the perspectives of organizational behavior and management, public policy, academic affairs, student development, assessment, and evaluation.

University of Michigan Contributors to the MScribe Project

College of Literature, Science and the Arts	M-GRID
College of Engineering	Bluestream
School of Medicine	Center for Research on Learning and Teaching
Bioinformatics Program	Center for the Study of Higher and Postsecondary Education
School of Education	Department of Physics