University of Michigan lecture archiving and related activities of the U-M ATLAS Collaboratory Project

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Abstract. Large scientific collaborations as well as universities have a growing need for multimedia archiving of meetings and courses. Collaborations need to disseminate training and news to their wide-ranging members, and universities seek to provide their students with more useful studying tools. The University of Michigan ATLAS Collaboratory Project has been involved in the recording and archiving of multimedia lectures since 1999. Our software and hardware architecture has been used to record events for CERN, ATLAS, many units inside the University of Michigan, Fermilab, the American Physical Society and the International Conference on Systems Biology at Harvard. Until 2006 our group functioned primarily as a tiny research/development team with special commitments to the archiving of certain ATLAS events. In 2006 we formed the MScribe project, using a larger scale, and highly automated recording system to record and archive eight University courses in a wide array of subjects. Several robotic carts are wheeled around campus by unskilled student helpers to automatically capture and post to the Web audio, video, slides and chalkboard images. The advances the MScribe project has made in automation of these processes, including a robotic camera operator and automated video processing, are now being used to record ATLAS Collaboration events, making them available more quickly than before and enabling the recording of more events.

1. Introduction

The ATLAS Experiment, one of the largest experiments based at CERN, is being built by a collaboration of almost 2000 physicists who are based at institutions spread across the globe. The success of the experiment depends upon their fundamental need to work collaboratively despite their physical separation, and the ATLAS Collaboratory Project [1] was created to address the needs of ATLAS with respect to collaborative tools. Early on the project began recording and making software tutorials available for the Collaboration. The technology has been extended and site-tested in over 1600 content-rich lectures that we have recorded and archived [2]. Many of these recordings have been of talks given in the prestigious CERN Summer Student Lectures in Geneva [3]. Other examples include the Saturday Morning Physics Series in Ann Arbor, University of Michigan (UM) Medical School Clinical Research Grand Rounds, American Physical Society conferences and the 2005 International Conference on Systems Biology at Harvard.

For the first few years the activities of our group had been limited to recording single lectures, tutorials, and later small conferences. There were clearly situations in which large-scale recording was needed, for example at the national meetings of large professional societies such as the American Physical Society (APS) [4], where many parallel talks take place, and where many members are

interested but unable to attend. Our group together with the APS received a grant in 2003 from the National Science Digital Library division of the NSF, making possible an increased focus on the prompt compression and posting of web lectures. Our team assembled appropriate hardware and developed software to gain substantial ground in this pursuit. With the successful completion of the MScribe [5] pilot project at the University of Michigan, which has brought lecture recording into the classroom, it has been demonstrated that large-scale automated lecture recording is feasible and imminent.

The U-M ATLAS Collaboratory Project has pursued lecture archiving alongside other equally important collaborative tools efforts, including video conferencing, quality of service (QoS) bandwidth reservation testing, remote teaching, involving undergraduates in the search for better collaborative tools solutions, and taking a leadership role in finding better collaborative tool solutions for the Collaboration.

2. Update on activities of the U-M ATLAS Collaboratory Project

The goal of the U-M ATLAS Collaboratory Project is to study and advance the technologies and practices required for the organization and execution of modern, large-scale collaborative research experiments. In particular, our group has taken a leadership role in the ATLAS Collaboration in the planning and development of collaborative tools, utilizing videoconferencing and web archiving technology to help the members of the Collaboration function effectively.

2.1. List of activities

The following is a summary of some of the past and ongoing activities of the ATLAS Collaboratory Project.

2.1.1. Archiving of ATLAS meetings and software tutorials. Since 1999 we have been involved in archiving various ATLAS meetings, software tutorials and more recently the plenary sessions of the three annual ATLAS meetings. Software packages such as GEANT4, Athena, and ROOT, which are critical to the entire Collaboration, are constantly being maintained and updated by small teams of expert developers. These experts are the best qualified to give tutorials on the software, but their time is precious, and time spent giving tutorials is time taken away from software development. In the past it has been common for these experts to fly from continent to continent giving tutorials to spread the information as widely as possible. The ATLAS Collaboratory Project records tutorials and workshops given at CERN or elsewhere and puts them online so that every member of the Collaboration can instantly benefit, and the expert developers can spend their time more efficiently.

2.1.2. Development of automated lecture archiving system. During the first recordings in 1999, most of the work of producing web archives was done manually. The process was very time consuming and severely limited the number of possible recordings. Steady progress has been made since that time in eliminating every single need for human intervention, including all aspects of media capture, processing, transcoding, archiving and web posting. The current state of this technology is discussed below.

2.1.3. Development and promotion of Lecture Object. An aspect of the Michigan archiving system that is unique is our insistence on the extra processing and storage required to archive each recorded talk as a Lecture Object [6], 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. This is discussed in more detail below.

2.1.4. QoS bandwidth reservation testing. Our group has performed trans-Atlantic demonstrations of a Quality of Service bandwidth reservation system [7] that enables a person with the need for a high priority videoconference connection to be able to reserve bandwidth on the fly, thus ensuring a high-quality video signal preserved in spite of heavy network traffic.

2.1.5. Design and implementation of video conferencing facilities. Our team has designed and implemented two group-to-group videoconferencing facilities, one at CERN and one in Ann Arbor, primarily for the Michigan group to stay in touch because of its large presence in both locations, but also as a place to test out new equipment and make recommendations to other groups in ATLAS and at CERN. Research groups from other universities have benefited from these facilities, which are used on a daily basis not just for meetings between Ann Arbor and Geneva, but in multiple-participant conferences world-wide.

2.1.6. Shaping Collaboration 2006 conference. In December 2006, the ATLAS Collaboratory Project led the organization of an international conference held in Geneva, **Shaping the Future of Collaboration in Global Science Projects** [8]. The goal of the conference was to bring together members of the user community of the CERN Large Hadron Collider with researchers and practitioners in the area of advanced collaborative tools, and focus on ways these communities can work together to advance research in collaboration while meeting the needs of global science projects. The conference outcomes were taken seriously by CERN management, and these new developments are discussed in the CHEP 2007 proceedings of Steve Goldfarb's talk [9].

2.1.7. Research Experience for Undergraduates focusing on collaborative tools. The University of Michigan already organizes an NSF funded Research Experience for Undergraduates program for physics students every summer at CERN. Our group is now proposing an addition to this program, in which some of the top undergraduate computer science and physics students in the U.S. would be recruited and brought together at two geographical sites, one located at a U.S. university and one at CERN, to engage in a summer period of intense work on a defined set of collaborative tools needed for experiments at the Large Hadron Collider (LHC) at CERN. Though the students would be co-located at the two program sites during the summer, their work would continue during the academic year through their participation in weekly video conferences from their home institutes.

Students today possess extraordinary skills in using modern technology to communicate with each other. They are able to grasp whatever tools are available and to adapt them to their needs, and exposure to technology starts earlier and earlier, reinforced by peer interactions. Undergraduate students are no longer mere users of technology, but actual developers and innovators. We are proposing that they be set to work on projects including development of a shared workspace environment, electronic scientific notebook for LHC experiments, and a deployable virtual operations center for LHC experiments.

2.1.8. Remote Teaching Facility pilot project. Our team is currently gauging interest among US ATLAS and CMS faculty in having access to remote teaching facilities at CERN. A new room has been outfitted that makes it possible for a faculty member to teach classes remotely. This facility would address the need of faculty members who, on occasion, find it difficult to travel to CERN during the academic school year because of teaching duties back at their home institutions. Faculty will be able to deliver high quality presentations from CERN for one or two sessions and greatly extend their time at CERN without significantly impacting student learning experiences. The room has been outfitted specifically to support the needs of teaching classes remotely and is not just another videoconferencing room. In addition to audio/video conferencing, it can be used to remotely project handwriting via a large electronic whiteboard, and deliver PowerPoint presentations or project anything from the teacher's computer screen. The ATLAS Collaboratory Project is taking a leadership role in advertising the room's availability and organizing testing and evaluating its usage, and a few professors from U.S. universities are using it to teach some of their classes remotely in Fall 2007.

3. Lecture Archiving

3.1. History of lecture archiving

As stated in the introduction, our group started archiving lectures at CERN in 1999 [10] for dissemination via the Web, and has been working steadily ever since toward developing an efficient process for recording, archiving, and publishing Web Lectures. The archive has grown steadily with the addition of recordings from the UM Saturday Morning Physics Series in Ann Arbor, UM Medical School Clinical Research Grand Rounds, American Physical Society conferences and the 2005 International Conference on Systems Biology at Harvard.

Continuing toward the goal of large-scale automation, the MScribe pilot project was launched in 2006-07 to record multiple courses simultaneously across the UM campus, and our team succeeded in recording eight courses during the academic year using four automated carts. The archive currently holds over 1,600 lectures. During the entire span of the project, improvements have been made on the Lecture Object specification, Web Lecture viewing software, and the behind-the-scenes formatting and processing software.

3.2. Description of lecture archiving

3.2.1. What is a Web Lecture? A Web Lecture is currently the principal display format used to disseminate the Michigan lecture archive to the world. It can be viewed with any web browser on any major OS, and requiring only the RealPlayer plug-in. It includes four synchronized media streams: audio, video, slide images, and chalkboard images. On the left side of the screen (Figure 1) a small video of the speaker is displayed and the rest of the screen is occupied by a high resolution image of the slide. This slide can come from a PowerPoint file, PDF file, web page, or anything that the speaker chooses to display on his/her screen. In addition, the user may toggle between slides and chalkboard images if they are available. The video is low resolution and the slides are still images, which squeezes the presentation into a low bandwidth package so that viewers all over the world with less-than-optimal network speeds can access it.

A slide index is also available so that the viewer can see thumbnails of all the slides at once, and jump directly to any point in the video based on these slides. Users may also navigate forward or back at will to skip unwanted sections or repeat poorly understood information. The Web Lectures were designed using HTML that makes it easy to evaluate the media server logs to obtain usage statistics. Using the RealPlayer plug-in provides compatibility with all major operating systems.
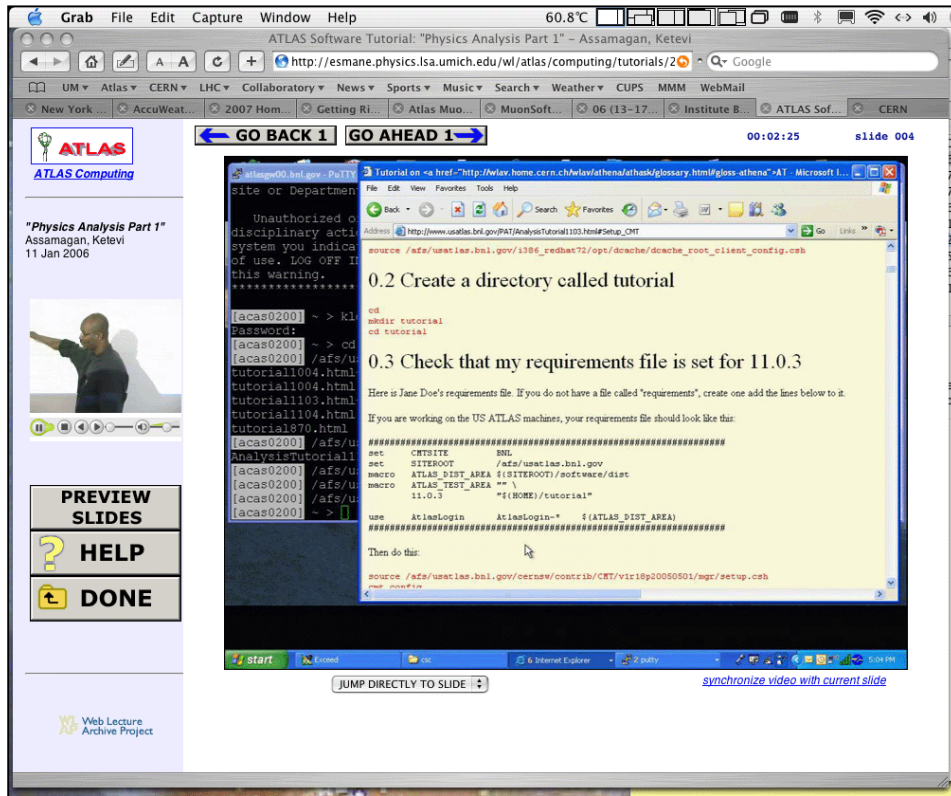
Fig. 1. Web Lecture

3.2.2. What is a video podcast lecture? We have developed software that produces from the same materials a single QuickTime lecture suitable for playback on a video iPod. It is simply a 320x240 video of the speaker, which switches automatically to a snapshot of the current slide for 30 seconds, whenever a new slide is displayed. This takes up more bandwidth than a RealPlayer Web Lecture and is therefore more suitable for automated download (accessible through the iTunes podcast menu) than for real-time streaming. It provides another convenient way for iPod owners to view lectures, and can optionally be viewed on a PC with QuickTime compatibility.

3.3. Recent ATLAS recording activity

Since the beginning of 2006, 19 separate events and 226 lectures have been recorded for ATLAS. Overall, there are 700 ATLAS talks, making up about 40% of all lectures in the Michigan archive, and it has grown steadily over time (figure 2). In addition to the plenary sessions of all ATLAS weeks (three per year), the following tutorials and workshops have been recorded so far in 2006-2007. Several more are planned in the Fall of 2007.

| 2006 recordings	2007 recordings
First ATLAS Physics Workshop of the Americas, SLAC, August	COOL Tutorial, July
CTEQ Workshop, Michigan, May	Atlantis Tutorial, June
Physics Analysis Tools Workshop, Norway, April	Physics Tutorial, June
	Physics Analytical Tools, April
	Production Tools, April
ROOT Workshop, March	Generator Tools, April
Trigger Aware Analysis Tutorial, March	ATLAS Software Tutorial, Berkeley, January
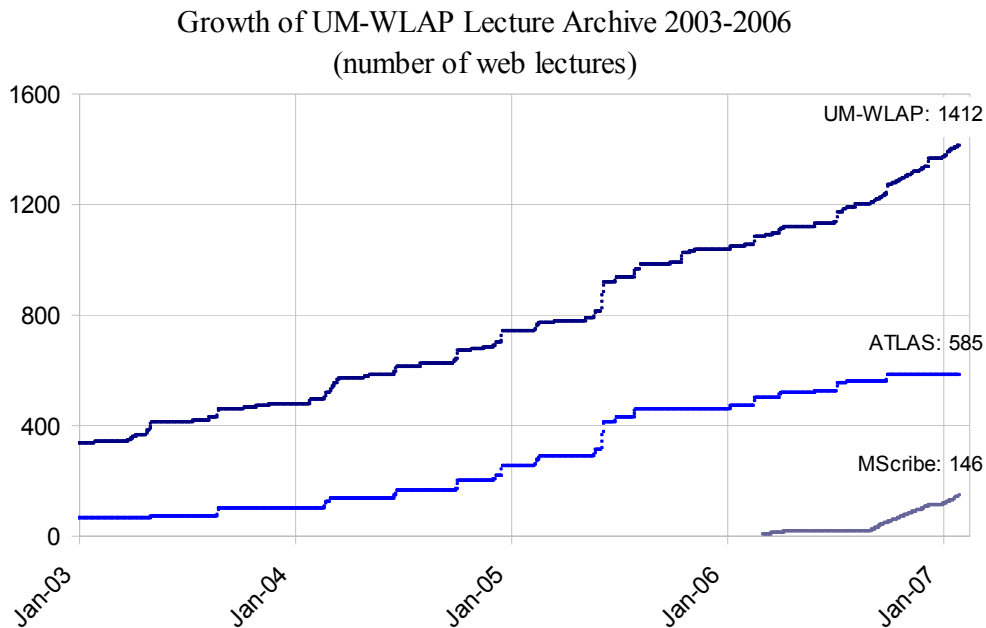
Fig. 2. Growth of Michigan lecture archive

All ATLAS talks recorded by our group may be found at the URL **www.wlap.org/atlas**

4. MScribe Pilot Project

The ATLAS Collaboratory Project team led a pilot project at the University of Michigan in the 2006-07 academic year called MScribe. This was an effort to take the next step in large-scale automation of web lecture archiving. Although funded by and located within the University of Michigan, its new technologies have been used as developed to simultaneously benefit ATLAS.

4.1. Goals of MScribe

The goals of the MScribe pilot project were as follows:

- complete automation of the recording of classroom lectures, including replacement of the human camera operator with a robotic system
- development of a robust tracking system to eliminate the human camera operator
- observe how students used the recordings and the ramifications of the technology

4.2. Technical Achievements

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, video tracking system and a PC to record the various media feeds and control the tracking cameras. A tower PC was necessary to accommodate the various PCI cards for video capture and camera control, although it is conceivable that the whole system could be put on a laptop in the future. Each cart is capable of capturing audio, video, periodic still images of multiple chalkboards, and the VGA signal sent to the room's LCD projector.

Figure 3 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 driving everything and assorted audio/video equipment. The entire system is controlled by simply clicking on buttons labeled START and STOP.

The metal housing on top of the cart (Figure 4) 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 5 shows a closer view of the lower portion of the cart, which holds the Linux PC with several video capture cards and RS 232 control ports, audio equipment and VGA capture hardware and cables, and a battery backup 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 the human component completely from the recording process. Venues ranged from small classrooms to large auditoria.

After each recording, the carts were plugged into the internet and automatically uploaded the recorded media to our archival server. Dedicated media processing servers then retrieved the media and created Lecture Objects, 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.

Fig. 3. recording cart   Fig. 4. tracking cameras   Fig. 5. A/V and computer equipment

4.3. Pedagogical Studies

The MScribe pilot project was designed from the beginning with the aid of pedagogical researchers from the UM School of Education and Center for Research on Learning and Teaching (CRLT). The array of course subjects, class sizes, venues and instructors was selected with pedagogical studies in mind. These included undergraduate courses in American Culture, History of Art, Psychology, Statistics, Environmental Science, Physics, Asian Studies, and graduate level courses in bioinformatics and the School of Information. Throughout both semesters, questionnaires were circulated, evaluations were gathered, focus groups were held and server logs were analyzed to investigate the effect of having this new online resource on students' study habits.

More than half (58%) of all students (over 1000) in all eight courses used the technology, and around 25% did so regularly. There was no requirement or incentive given for the students to use it, other than its inherent usefulness. Surprisingly, class attendance was not noticeably affected; students didn't stop coming to class because they had ready access to all the lectures online. In fact they spent more time in class taking notes, and more time outside class reviewing lecture content and their own notes. As was verified dramatically by server log data, students spent more time studying for exams because they had more material to study with. So instead of using each class as a transcribing session, they saw it as a time to soak in the material, knowing that every word was being captured for future reference, if needed.

4.4. Benefit of MScribe to ATLAS

The MScribe pilot project was funded completely by the University of Michigan and took place on its campus. However, the technology developed during the project was used almost immediately to improve recordings our group has been doing for ATLAS. The new MScribe system using dedicated

video processing servers to produce Lecture Objects and web content has been used for ATLAS recordings since February 2007, using improved downloading, transcoding, processing, archiving and posting software. In April 2007, we succeeded in porting the media capture software and hardware to a laptop, making it much more portable than before. The tracking system is not yet this portable, but we hope to make it much more compact in the next year. The new laptop-based system is easier to use and we have been able to post recordings faster and with fewer problems. All ATLAS recordings since April 2007 as well as additional talks have been recorded with this system, for a total of five events (120 talks).

5. Tracking Technology Investigation

5.1. Survey of tracking technologies
Since our investigation of camera tracking began in 2003, we have studied and tested several different technologies to determine their appropriateness for the application of replacing a human camera operator. Most in the following list were deemed unsuitable, because of their lack of one or more of the following qualities: portable, accurate, robust, affordable, and runs without expert intervention, minimal setup and calibration.

Our team investigated several interesting tracking technologies [11] including ultrasonic, radio-frequency, ultra wide band, and infrared based systems, but ruled most of them out because they failed to meet one or more of the five requirements mentioned above. We have built a system using a simple infrared LED necklace and PTZ video camera and used it during the MScribe pilot project. We are currently developing a system using ultrasonic emitters that promises improve upon the shortcomings of the IR system.

5.2. Active infrared system used for MScribe pilot
So far the most promising technology we have found is what we call "active infrared." It consists of a necklace worn by the instructor, which is simply a parallel chain of constantly illuminated bright IR LEDs powered by a battery pack, and a pair of off-the-shelf PTZ videoconferencing cameras. One camera is equipped with the appropriate IR filters so that it only sees 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 6 shows a picture of the necklace worn by Jim Irrer, the engineer who built the current version of the system. In normal light the LEDs do not appear to be on, but in the IR spectrum their presence is dramatic. The system design is simple and therefore robust. It requires no calibration, works independent of the geometry of the venue, and is affordable since it uses off-the-shelf products. It provides accuracy to within centimeters, 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 sunlight, incandescent lights and IR communication ports found on laptops and assisted listening systems. However, we have made substantial improvements in these areas over the last several months.
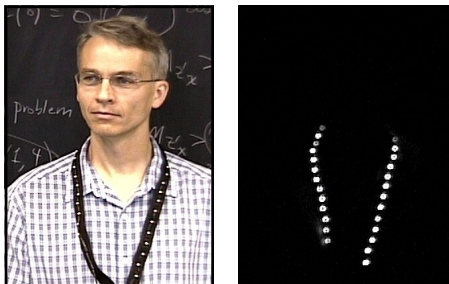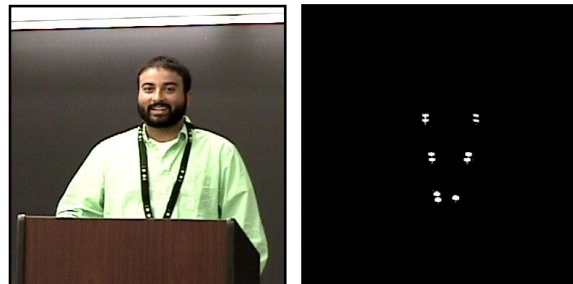

Fig. 6. Necklace in color and IR

Fig. 7. improved necklace in color and IR

5.3. Recent improvements in active infrared system

After using the active infrared tracking system successfully to record one academic year of courses, we made several improvements that have gone a long way in dealing with the inherent background-noise problems of the system. We found a more effective set of IR filters, obtained the brightest wide-angle IR LEDs available on the market, and fully exploited all of the camera settings to get enough light to reliably track the necklace in noisy environments. Fig. 7 shows Tushar Bhatnagar, the engineering student who worked through summer of 2007 to discover and implement several of these improvements, wearing a newer necklace using brighter LEDs and improved camera settings and filters.

Fig. 8 shows two images of the same scene side by side, showing the dramatic improvement obtained by these adjustments. The left hand picture shows the old necklace in a ray of direct sunlight, and the right hand picture shows the newer necklace viewed with the newer filters and camera settings, also in the same direct sunlight. These pictures were taken in a new large auditorium with many windows in which the tracking system did not work before. The recent improvements to the existing system have now made it possible for our recording carts to work reliably in almost every room on campus, whereas we were previously limited to a small subset of ideal rooms.

Fig. 8. IR views of old vs. new necklaces in direct sunlight

5.4. Current Tracking Research

5.4.1. Necklace design. Designing effective LED necklaces has been challenging for several reasons. They must be completely fabricated by us in the lab, and consist 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 are attempting to build newer necklaces that will be tougher and more flexible (using different kinds of wire), less obtrusive and provide adequate coverage of the instructors upper torso (using fewer, brighter LEDs and a more intelligent layout), and are visible in every direction (using wide-angle LEDs).

5.4.2. Modulating LEDs. We are currently building a new necklace that will turn the LEDs on and off several times per second, and we will evaluate its effectiveness. We hope that modulating the LEDs will improve battery life and increase the signal-to-noise ratio, using a more intelligent tracking algorithm that can pick out the flashing signal from bright background light.

5.4.3. Tracking algorithm development. The existing code used in the MScribe pilot year is the result of extensive testing and development, and only works with our existing hardware setup. We are currently re-writing this code to make it more modular and compatible with changes to hardware and

tracking algorithms. We will also be generating a database of tracking data with which to compare different tracking algorithms and ultimately produce a much smoother and more-pleasing video footage more closely resembling that produced by an experienced human camera operator.

5.5. Ultrasonic phase-difference array

In parallel to the improvements we are making to the current IR tracking system, we are developing an ultrasound-based tracking system. We are aware that no matter how good the system gets in its current form, we will likely never be able to use it in the most unfriendly environments.

5.5.1. Description of system. Instead a necklace studded with always-on IR LEDs, the instructor will wear an ultrasonic emitter that broadcasts 40 kHz sonic pulses many times a second, pictured in Figure 9 in a rough prototype. We are building a special receiver to calculate the angle of the emitter. An early prototype of the receiver is shown in Figure 10, a circuit board with four ultrasonic receivers on each corner and electronics to find each pulse and log the time difference between its arrivals at each different sensor. This time difference is used to calculate the angle of the emitter to the circuit board and to point the video camera in the proper direction.

5.5.2. Expected advantages. The current infrared system in use suffers two principal drawbacks: susceptibility to competing background noise and limited battery life. We expect that using ultrasonic medium instead of IR light will eliminate these problems. According to our tests and experience, there are no significant sources of competing background noise in the 40 kHz sonic range in lecture rooms and offices. And since we will be pulsing the signal in short bursts many times per second, we will require much less power to deliver a faithful signal with very fast tracking.

5.5.3. Current state of research. An early version of the complete emitter/receiver system has been built and tested in a University course. It functioned albeit in a rough manner and we are optimistic from this test that the concept is a reasonable one and that it is worth perfecting. We are currently finishing building an updated system with significantly higher quality emitters, more powerful emitter circuit, and more sophisticated receiver board electronics to deal more effectively with multipath issues, and will be testing it within weeks.

We are also integrating an RF pulse into the emitter, which will allow us to calculate the distance to the emitter and find the instructor's position in 3D, which will enable better looking camera footage with zooming abilities. We are also hopeful that there will be no need for a pan-tilt platform, cutting down on the number of moving parts and making the system more robust.
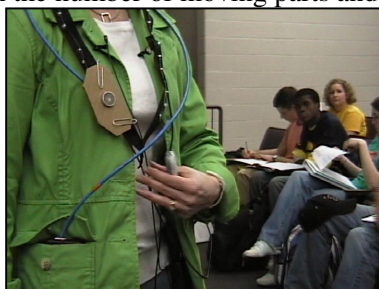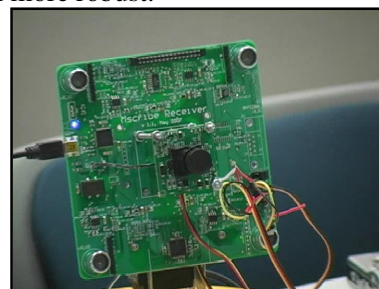

Fig. 9. ultrasonic emitter

Fig. 10. receiver board prototype

6. Lecture Object

6.1. Ongoing development

6.1.1. What is a Lecture Object? A Lecture Object is an archival data object originally proposed by our team in 2000 at an international conference [12], 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 [13] and IEEE Learning Object Metadata [14], 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.

6.1.2. Commitment to high quality archiving. 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 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 distributing 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 new media players.

6.1.3. Current development. CERN is developing a lecture recording and archiving system called SMAC [15] that is similar in some ways to ours, but is not yet used in production mode and is not portable. It does have some features that are more advanced than our system, such as the ability to ingest PowerPoint files and compare them to the captured video image. We have been in periodic contact with its developers and are working toward a Lecture Object that will include the best of both these systems, make our archives compatible with each other and encourage wider standardization.

Future versions of the Lecture Object standard will support arbitrary numbers of video and image streams, enable access control, authorization and copyright schemes, and remain simple, minimal and easy to use. We do not aim to provide an all-encompassing standard such as IEEE LOM [14], but to encourage standardization by making it very easy to use and targeted to lectures specifically.

6.2. Users of the lecture object.
By keeping things simple and targeted to the specific needs of lecture archiving, we hope to enable groups at smaller institutions with fewer resources to produce lecture content. This will help preserve important material far into the future, encourage the open and free exchange of information benefiting both large and small institutions, and make more content available to more people. Currently our Lecture Object standard is used by units within the University of Michigan, CERN, Fermilab and the American Physical Society.

6.3. Advanced indexing and search
An exciting area that we have started to explore is advanced indexing and search using BlueStream. BlueStream is a project at UM that provides a comprehensive online environment with powerful tools for managing and manipulating digital video, audio, images and documents. Since our project has made hundreds of hours of recordings available, wading through all this material can be a daunting task, and our current search capabilities have great room for improvement. BlueStream has tools that can convert the recorded speech to text as well as optical character recognition, enabling a sophisticated search whereby a user may for example type in the word "quark" and be presented with a list of every occurrence of that word on slides or as uttered by a speaker. Clicking on one of these results would play back the Web Lecture starting at the exact point where the word "quark" was uttered. Several MScribe lectures have already been put into the BlueStream system and successful tests have been performed showing that this kind of search is realistic.

7. Future Plans
The University of Michigan ATLAS Collaboratory Project will continue developing automated archiving systems, developing and promoting the lecture object standard, finding new uses for video conferencing technologies, and addressing the collaborative needs of the ATLAS Experiment as it enters the new phase of collecting data.

Specific plans include the perfecting of ultra-portable recording boxes that can be taken on an airplane to easily record conferences world-wide, permanent room installations that interface with existing online agenda systems for automatically recording talks at CERN and lectures in university classrooms, and the further development of an automated tracking system. We envision a day when every meeting room at CERN and every classroom at the University of Michigan and other institutions will have a small box mounted on the wall or ceiling, which is integrated with existing online agenda systems such as Indico [16] to automatically record events with no human intervention and post them on the Web within minutes.

We plan on developing desktop recording software so that individual instructors may record their own presentations in a Lecture Object compatible format, and also working to make software to transform recordings made with SMAC [15], Apple's new Podcast Producer [17] and EVO [18] into Lecture Objects. We are working on new Web Lecture viewing formats using technologies such as Flash that will reach a wider audience.

On the tracking front, we will continue to improve the robustness of the current system and work toward new systems with 3D tracking, ability to track multiple targets to use for panel discussions and audience questions.

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