Lecture archiving on a larger scale at the University of Michigan and CERN

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Abstract. The ATLAS Collaboratory Project at the University of Michigan has been a leader in the area of collaborative tools since 1999. Its activities include the development of standards, software and hardware tools for lecture archiving, and making recommendations for videoconferencing and remote teaching facilities. Starting in 2006 our group became involved in classroom recordings, and in early 2008 we spawned CARMA, a University-wide recording service. This service uses a new portable recording system that we developed.

Capture, archiving and dissemination of rich multimedia content from lectures, tutorials and classes are increasingly widespread activities among universities and research institutes. A growing array of related commercial and open source technologies is becoming available, with several new products introduced in the last couple years. As the result of a new close partnership between U-M and CERN IT, a market survey of these products was conducted and a summary of the results are presented here. It is informing an ambitious effort in 2009 to equip many CERN rooms with automated lecture archiving systems, on a much larger scale than before. This new technology is being integrated with CERN's existing webcast, CDS, and Indico applications.

1. Introduction

The University of Michigan ATLAS Collaboratory Project [1] (UMACP) has been actively pursuing the development of lecture archiving technology since 1999, making steady progress in the development of hardware and software solutions [2] to automate all aspects of capturing, archiving, processing and disseminating rich multi-media lectures.

We give a report on some of the interesting aspects of the first eight months of operation of the CARMA service, our newest project, which has been a resounding success. We also report on a new partnership between the UMACP and the CERN IT division. Finally we give the results of the recent market survey conducted in this partnership to identify noteworthy lecture archiving technologies, projects and products.

1.1. Lecture Object architecture

In this report we use the term Lecture Object architecture to refer to the general strategy of using a standardized, open format Lecture Object for high-quality long-term media and metadata storage.

We define a Lecture Object [3] to be a data object (usually just a directory), labelled in a standard and unique way, containing XML files with descriptive metadata (using for example Dublin Core [4] terms) and synchronization data to associate every recorded event to a point in time. Inside the directory are subdirectories containing all relevant media files including high resolution, high quality non-proprietary audio/video footage taken of the speaker, slide images, and any related documents referred to in the talk.

Use of this Lecture Object makes it possible to produce multiple viewing formats (using Flash, RealPlayer, Windows Media, iPod, etc.), as **Figure 1** demonstrates, and also to update them and continue producing new ones far into the future. If, for example, the Flash format falls from being the industry standard and is overtaken by another streaming format, it is a simple matter to write new software that produces new versions of the lecture from the original Lecture Object.

We define a Web Lecture to be a multimedia playback object consisting of a full-motion audio/video feed showing the speaker, playback and navigation controls, some basic metadata, and large slide images. **Figure 2** shows a screen capture taken of a Flash Web Lecture developed by the UMACP, but there are many products and institutions that use a similar format for their online presentations. Often, thumbnail images of the slides are provided for direct navigation to different points in the talk, often called "chapters."

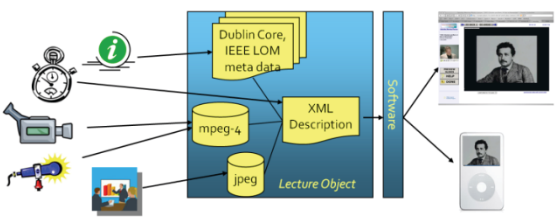

Figure 1. Lecture Object diagram

Figure 2. Example Web Lecture

1.2. Need for lecture archiving

Lecture archiving is a rapidly growing field. Universities all over the world are mounting initiatives to put much of their course content online, and new products are being developed to accommodate this need. Following are some examples where lecture archiving can be useful.

1.2.1. *Large scale dissemination* The ATLAS and CMS Collaborations at CERN (each with around 2000 members) are good examples of geographically scattered organizations that benefit from lecture archiving, as well as professional organizations, e.g. the American Physical Society (with 50,000 members). In the case of CERN collaborations, the members are based in institutions all across the globe. In the case of national professional organizations, the membership is spread across cities and states. These organizations hold multiple annual meetings open to all members, during which different groups and communities report on progress and discuss issues. These meetings disseminate valuable knowledge to the attendees, but due to travel and schedule constraints, only a fraction of the membership can be present at any given meeting. These organizations find it very helpful to their members to make the proceedings available online.

Large institutions such as CERN and universities use lecture archiving for public outreach. For example, several major American universities are now making many interesting talks available to the public through iTunes U [5] or their own media portals. This raises awareness of the institutions' activities among the public and enriches the community.

CERN is a prestigious research lab with unique status in the world physics community, and therefore many famous physicists reside or visit there, giving talks for anyone who wants to attend. These are often historically important talks that will remain relevant for many years, and should be preserved. Automated lecture archiving makes this task feasible.

1.2.2. *Overcoming time/schedule constraints* Recent activity at the University of Michigan has uncovered some interesting uses of lecture archiving to relieve the difficulties in overcoming time and schedule constraints. In one case, candidates for a dean position were to give lectures that the selection committee would evaluate. The candidates and committee members were important and overcommitted people and getting them into one room at the same time was basically impossible. Recording the talks and making them accessible on demand to the committee eliminated this problem.

Another interesting case involved a Michigan faculty member who was to be the keynote speaker at an international conference in Europe. Days before she was to leave for the conference, she learned that she required emergency surgery. Even if there had been facilities available for her to give the talk in real time by videoconference, she was actually in surgery at the time of the address. The UMACP team recorded her presentation a few days in advance, packaged it into a file and sent it to the conference organizers, who showed the Web Lecture recording in front of the whole conference.

These are two examples of the many new and interesting ways that lecture archiving increases productivity, reduces travel and solves scheduling problems.

1.2.3. *Study/review tool* Many institutions engage in various types of training activities. An obvious example is university courses, but also many institutions are required to train their staff to follow safety procedures, as well as all sorts of technical training. Lecture archiving takes pressure off instructors, can reach a large number of people, and is a valuable review tool. A recent study at the University of Michigan [6] shows that having access to online recordings in addition to their regular class attendance results in higher scores.

2. Update on activities of the UMACP

As summarized in our last CHEP report [2], the UMACP has been involved in lecture archiving since 1999, including both development of hardware and software tools to automate all aspects of capture, archiving, processing and dissemination, as well as recording events in many different locations spanning several countries.

2.1. Brief history of the UMACP

In 2003, the UMACP, partnering with the American Physical Society (APS), received a $250,000 grant from the NSF National Science Digital Libraries (NSDL) initiative to develop automated transportable systems for recording audio/video/slides. It used these systems to record APS conferences in Denver and San Diego.

In 2005 we built and patented a robotic tracking camera that follows a speaker as he/she walks through the room, and have made improvements since then. This system can replace a human camera operator, although it does not yet provide the same quality of movement that a professional videographer can provide.

In 2006 we partnered with the University of Michigan’s Center for Research on Learning and Teaching (CRLT) [7] to run a one-year pilot project at the University of Michigan called MScribe [8]. Using our tracking camera system mounted on four automated capture carts, we recorded eight university courses of a variety of subjects (around 200 hours of video). This was the first time we recorded multiple events simultaneously at different locations with unskilled student helpers.

In August 2008, we announced to the University a new campus-wide lecture archiving service called CARMA [9], which we describe below.

2.2. CARMA service

The UMACP showed during the MScribe project that lecture archiving of university courses is feasible and useful to students and faculty. The courses that were recorded during this project were carefully selected by faculty, and subsequently we wanted to make the technology we had developed available to the entire university community. To do this we introduced a new recording service, available to any individual or academic unit on campus for any purpose, charging them enough to recoup our expenses. This service has received heavy demand from diverse entities across campus.

We assembled a new laptop-based portable recording appliance to replace the large carts that had been used in MScribe, and focused this time on providing high-quality footage taken by a human videographer.

In our first eight months of operation, we have recorded 270 hours of lectures for 26 diverse customers, ranging from graduate courses to safety training and many isolated special events and seminars. We have performed recordings in 33 venues around campus, including large auditoria with existing audiovisual infrastructure, and bare classrooms with no facilities. We have gained considerable new expertise in dealing with an increased number of employees and operating under adverse conditions in a variety of venues.

2.3. Requested features

In its first eight months of operation, CARMA has received many requests from customers for additional features. We will attempt to implement as many of these as we can in the future.

- Real-time streaming of events to the web
- Production of DVDs for playback on standard televisions
- Production of audio recordings for playback on MP3 players
- Integration of pre-recorded video segments with lectures
- Improved accessibility, e.g., transcriptions, captioning and text-to-speech
- Ability to dynamically reconfigure the display of the lecture components
- Ability for users to bookmark segments within a lecture
- Ability to tag specific points in a lecture with keywords or phrases
- Variable-speed playback while preserving audio quality

2.4. State of the Michigan archive

Figure 3 shows the overall growth in the UMACP archive. The y-axis shows the number of total lectures in the archive. On average, lectures are 30 minutes in length. This growth has showing a steady increase over the past several years, and a considerable portion of our activity continues to be in support of ATLAS.

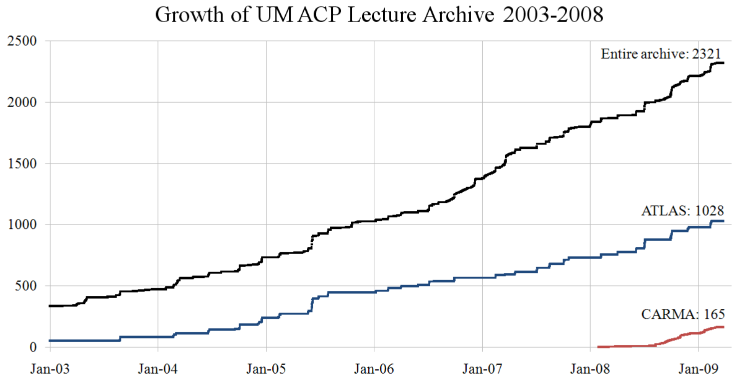

Figure 3. Growth of the U Michigan archive since 2003

2.5. Future plans at Michigan

The impressive success of the CARMA service indicates that there is a definite need at the University for lecture archiving, and it is possible that the University will incorporate such a service into its central operations in the future. The UMACP staff will continue to be available to help make this happen. In addition, there are many software improvements that can be made for all aspects of the system, including the recording interface, offline processing and viewing and access features.

Although the robotic camera system we have developed has been used successfully during the MScribe project, we have many ideas for how to improve the motion to make it more closely mimic a human videographer. The system as it exists now has attracted the interest of a corporate entity that may use it in some of its coming products, and we continue to explore solutions in all areas of collaborative tools that benefit the ATLAS Experiment.

3. New lecture archiving activity at CERN

The CERN IT department, partnering with the University of Michigan and ATLAS, has made a strong commitment to implement lecture archiving on a large scale at CERN in 2009.

3.1. University of Michigan – CERN partnership

The University of Michigan and CERN have signed an agreement for at least one year, starting in October 2008, whereby a staff member from the UMACP will work in the CERN IT-UDS-AVC section to implement a new lecture archiving system, which will be used throughout CERN. This person, who happens to be the first author, is first performing a market survey of relevant archiving technologies, then help configure and install the system, document it, and instruct CERN staff in how to use it.

3.2. CERN lecture archiving system requirements

It will first be installed in two high profile rooms, the Main Auditorium and Council Chamber, and based on experiences in these two rooms, eventually installed in many rooms around CERN. It should be heavily automated to require as little human intervention as possible, and designed in a scalable way so that many rooms may be eventually outfitted.

Integration with existing infrastructure is an important concern since CERN has already invested considerable resources in technologies that could help make this system work. These include the existing Media Archive system, Indico conference scheduling system, the existing centralized audio/video network, and the CERN Document System (CDS).

3.2.1. *Use of the Lecture Object architecture* This new system is to use the Lecture Object architecture described above, with the goal of building a very long-term archive of rich, high quality media and associated metadata. In addition, tools will be needed to easily edit lecture objects, in the case of speakers who find errors in their slides, desire to remove politically incorrect comments before posting, or authors who give a talk about breaking research and want to withhold certain slides until their paper has been published. Also, many hours of important lectures currently stored on videotape are currently being digitized and will eventually be converted to lecture objects.

3.2.2. *Integration with existing centralized recording infrastructure* CERN has already installed a special audio/video fiber optic star point network that connects fifteen auditoria with the CERN Computer Centre (CCC). It is used for the purposes of retransmission (sending an audio/video feed from one room to another, e.g. for overflow purposes at big events) and for webcast (streaming in real time over the web). Each fiber is laid directly from the room back to a switch in the CCC server room, which can redirect the feeds from one room to another, or send it to the webcast servers, which encode the raw audio/video feed for dissemination to the outside world into multiple formats. CERN IT prefers to continue to keep operations as centralized as possible to facilitate efficiency of operation, monitoring and maintenance. However, since for lecture archiving a VGA signal also needs to be captured, it will be necessary to add to this infrastructure, perhaps by transmitting the VGA signals over IP, upgrading the existing fiber optic transceivers, or laying more cable.

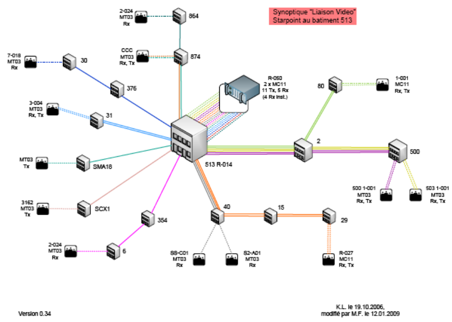

Figure 4. CERN's dedicated fiber optic audio/video network

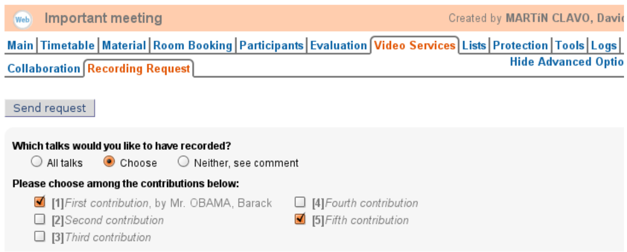

Figure 5. Screen capture of coming Indico recording request form

3.2.3. *Integration with existing conference scheduling software (Indico)* CERN IT has invested a great deal of manpower over several years to develop Indico [10], a comprehensive conference, meeting, talk and room scheduling system. Most users and staff at CERN are already in the habit of using this system to schedule all their events, and therefore it is an extremely valuable repository of metadata. It turns out that one of the most time-consuming tasks the CARMA service staff encounter when posting lectures online is entering the extensive metadata required for each record. But at CERN, this metadata is already entered by conference organizers and users. Therefore it is essential that the new CERN lecture archiving system be tightly integrated with Indico in many ways. Indico knows the basic details of each talk to be recorded, as well as the time and location it will occur. The descriptive metadata will be exported appropriately into the lecture objects, and the scheduling metadata can be used to automatically trigger recording equipment at the right time.

At the time of this conference, the first step of providing a recording request form for users has already been completed, and this feature will be made available later this summer.

4. Market survey of lecture recording systems

The first task in the new Michigan-CERN partnership has been to conduct a market survey to identify relevant technologies that CERN might use.

4.1. Types of recording technologies

There are several categories of recording technologies available, which we mention below.

4.1.1. *Videoconferencing hardware with recording capability* Dedicated videoconferencing hardware made by companies such as Tandberg, Polycom and Codian often come with recording ability, so that both the local and remote sites in a videoconference can be recorded. This may be a reasonable option for some institutions to use in rooms outfitted with videoconferencing systems, but a drawback is that the quality of the recording is limited to the quality of the built-in camera and its robotic movement.

4.1.2. *Web conferencing software with recording capability* Web conferencing software generally makes use of a user's webcam and microphone to connect them to group meetings, where they can also share content on their local desktops. Examples are EVO from Caltech, which is used by many high energy physicists, as well as WebEX, Adobe Connect and Skype. One problem is that these do not record in widely-used formats, and even if they did, it is not likely that most PCs could handle both the web conference as well as a high-quality encoding simultaneously.

4.1.3. *Dedicated software for locally recording desktop images, as well as audio and video* Another category is dedicated software for recording everything displayed on a user's desktop. Often this software can also record full motion video and audio as well from a USB webcam or Firewire camera.

Products include Podcast Producer [11], Tegrity, Camtasia, HelixProducer and Windows Media Encoder. It is not feasible to use this method for recording presentations and talks, because it would tax the PC running both the presentation and the recording too heavily, jeopardizing the robustness either of the presentation or the recording or both. Capturing both standard definition audio/video as well as a high-resolution (e.g. 1024x768) VGA signal uses a lot of CPU power as well as disk I/O bandwidth and should not be done on the same PC used for a presentation. Also, in some events, each speaker uses his/her own laptop, and it is certainly not feasible to install recording software on each laptop in advance.

4.1.4. *Dedicated hardware for recording video, audio and slides simultaneously* Finally, there is a category of products that use dedicated hardware appliances for capturing the presentation. These types of system are most appropriate for CERN's needs and will be considered in the market survey. Since they use dedicated hardware that is isolated from the presentation PC, they are free of the issues described above and the same system can be used in a variety of situations, including a permanent installation or mobile recording system. These systems capture one standard- or high-definition audio/video feed (footage of the speaker) simultaneously with one high-resolution VGA feed, used to capture the analog VGA signal from the presentation computer on its way to the projector. This way, the VGA signal that is captured is identical to what the audience sees during the actual event. They include SMAC [12], the UMACP system, REPLAY [13], OpenEyA [14], SWITCHcast [15], Mediasite [16], Echo360 [17], Accordent [18] and NCast [19]. Keeping the hardware separate from the presentation computer ensures that both the recording and the presentation will run smoothly, and that the recording can be encoded in the highest possible quality.

4.2. Open source initiatives versus commercial products

Among the products considered, some are open source or university projects, and others are proprietary, commercially distributed systems. The commercial systems (including Mediasite, Echo360, Accordent and NCast) tend to be easier to install and use and have more useful features, but when certain critical features are missing, there is no clear path to getting them added in the future. We rely on whatever API is provided. We can request that features be added, but there is no guarantee that the company will comply, and no way of doing it ourselves. The big advantage of open source systems (including SMAC, UMACP, REPLAY, OpenEyA and SWITCHcast, which is in the process of becoming commercial) is that since we have access to the source code, we can fix bugs and add features ourselves, and also build a hybrid system using modular components if we choose. On the other hand, user interfaces are clumsier and less polished, and things tend not to work as smoothly. While CERN appreciates that there are some very attractive commercial products available, it is leaning toward assembling a hybrid system using as much open source software as possible. This will enable CERN to adhere to a very high-quality long-lived lecture object standard and give more flexibility in replacing certain components over time as new products become available in this rapidly growing field.

4.3. Survey of products

Now we give quick summaries of nine promising products under consideration by CERN.

4.3.1. *SMAC* SMAC [12] is a cooperative project between Ecole d'ingénieurs et d'architectes Fribourg, Université de Fribourg and CERN that has been developing for several years, with a variety of computer science graduate students working on various aspects of it over time. SMAC is a comprehensive audio/video/slides capture, archiving, hosting and streaming solution. It is written almost entirely in Python and runs on Windows. It is scalar and made up of modular components so that all of the capture, processing and streaming processes can be run on a single PC, or distributed across several servers.

The SMAC capture component relies on a standard definition (SD) multiple-port video capture card, which captures the video footage of the speaker and the scan-converted VGA signal simultaneously. These media are packaged along with the PowerPoint file used by the presenter and metadata in a lecture object, from which viewing formats can be generated. Chapters (navigation points) are generated automatically by analysis of the VGA feed; when slide changes are detected that also correspond to the PowerPoint file, a new chapter is inserted. If anything displayed on the screen does not match a PowerPoint slide, it is ignored. This works well for many talks since it ignores error messages that may pop up on the screen. The principal method of viewing the lecture is provided using the SMAC Flash Web Lecture, which has nice navigation features and can be dynamically resized during playback.

One particularly attractive feature of this system is its lecture object creation utility. This is a very valuable feature not available in other systems, which allows a technician to create a lecture object using existing archival content. For example, CERN has many hours of video on tape recorded over the years, of highly relevant and valuable talks. This utility provides a pathway to getting this material into the lecture object archive and available to users in a much richer environment than a single tape or video file provides.

4.3.2. *UMACP* The UMACP system has been evolving at Michigan since 1999, and has been used in its various forms since then to record over 2300 lectures for the University, ATLAS, CERN, APS and some special events such as the International Conference on Systems Biology hosted by Harvard and MIT in 2005 [20]. Like SMAC, it is a comprehensive system that handles all aspects of lecture archiving.

One notable feature of this system is the portable recording appliance. In its most recent form used by the CARMA service, the capture appliance takes the form of a portable case shown in **Figure 6**, in which is mounted a laptop, VGA capture device, wireless microphone receiver, and audio mixer. The main audio/video feed is supplied by any Firewire camera to the laptop's built-in Firewire jack, and an Epiphan VGA2USB device captures the VGA signal in its native resolution, producing static image JPEGs once per second. The laptop captures and synchronizes all feeds, creating a lecture object and uploading it to a central server, where it undergoes further processing.

Another notable aspect of this system is the speed with which it can be set up and started. Since we have always had to record in many different settings, sometimes only having a few minutes to move in and set up between events, we have made it very easy to start recording. The user turns on the laptop, logs in and presses the big START button. Any needed metadata or settings can be entered later.

Metadata is stored in a MySQL database using a software package called CWIS [21], which has been modified to better suit lecture objects.

UMACP has developed its own Flash player, shown in **Figure 2**. We can also produce a RealPlayer version as well as a special format suitable for playback on an Apple iPod, which switches automatically between full-screen video and full-screen slides.

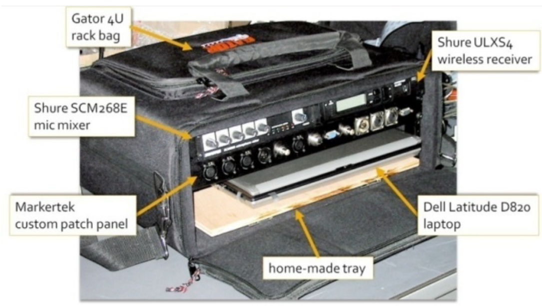

Figure 6. UMACP portable recording appliance

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4.3.3. *REPLAY* REPLAY [13] is also a comprehensive lecture archiving system, being developed by the audiovisual department of ETH Zürich [22] and used in production in several classrooms to record university courses and make them available to students for review. The REPLAY team has embarked on an ambitious course to provide a completely open source media management system that can be installed and used by any institution. It runs on Linux and Mac OS X.

Probably the most impressive aspects of this project are the commitment of the team to using open source software and the amount of planning that has gone into the architecture, done by experienced audiovisual professionals and software engineers. Although a basic version of the system is in production at ETH Zürich, the publicly accessible and installable system is still under development. The design has taken into account many important things for building a lasting media archive, including the use of persisting URIs, high quality archival format video, lecture object architecture and metadata harvesting from VGA images using OCR.

The rack-mounted capture appliance can work with a few different VGA capture cards, the principal one being the NCast Digital Capture Card, which can capture one SD video feed and one native-resolution VGA feed simultaneously. It is automatically controlled by an iCal-based scheduling system.

A notable aspect of REPLAY is that it is the official system recommended by the Opencast collaboration, which is gaining momentum. REPLAY will be replaced by its successor, Matterhorn, this summer. This is discussed below.

4.3.4. *OpenEyA* OpenEyA [14] is an open source project originating from the ICTP in Trieste, Italy. Its purpose is to provide a low-cost way to easily capture lectures in which the instructor uses a large chalkboard, such as a math or physics class. The system focuses mostly on the capture component, which runs on a laptop and uses inexpensive hardware (shown in Figure 7). It simultaneously captures a full-motion video feed from a USB webcam along with periodic static images from a 5-megapixel camera. This camera is set up to take wide-angle snapshots of the entire front of the room in very high resolution. Thus it could be used for PowerPoint talks as well, but is most suited to a chalkboard.

The system comes with a Flash viewer, which has a rather ingenious and elegant way of displaying the chalkboard. As shown in **Figure 8** the user is presented with a small map of the front of the room with an overlaid rectangle showing the currently selected close-up view. The user simply mouses over this map to inspect any area of the chalkboard he/she desires.

Figure 7. OpenEyA hardware

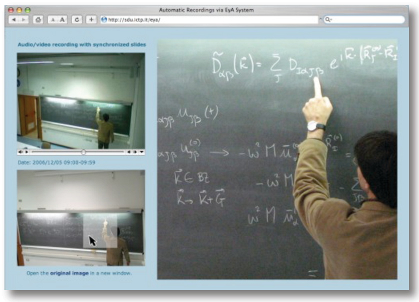

Figure 8. OpenEyA chalkboard viewer

4.3.5. *SWITCHcast* SWITCHcast [15] is a comprehensive lecture archiving system produced by SWITCH, the Swiss NREN, and made available until now only to members of the Swiss university system. Its capture software is currently based on Podcast Producer, which is available with recent versions of Mac OS X (10.5 and above), and all its video codecs and processing are based on QuickTime. It uses the VGA2USB device for VGA capture. It has been in production since the summer of 2008. SWITCHcast is currently in the process of forming a spin-off company to make its product available to other entities.

The most impressive feature is the truly outstanding Flash web lecture viewer, shown in **Figure 9**. It looks clean, is simple and intuitive to use, and behaves robustly. The user can resize not only the entire viewer window at will, but also change the size of the video footage as well as the VGA feed, dynamically as the lecture plays back.

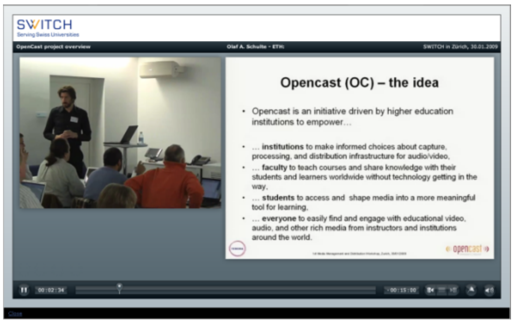

Figure 9. SWITCHcast viewer

4.3.6. *Mediasite* Mediasite [16] is a well-established commercial product that provides a comprehensive lecture archiving solution. It is a higher end system aimed at universities as well as businesses. It runs on Windows, uses Windows Media as its primary codec, and an extensive API for integrating it with other systems can be purchased. It supports room control systems such as Crestron and AMX.

The Web Lecture viewer uses a Windows Media plug-in and provides extensive features, such as resizing of the various feeds, and the ability to blow up the slide images to their original resolution. A Flash converter and podcast creator can be purchased. There is also a post-editor for editing lectures after they have been recorded.

One of the best features of the system is the recording appliance's well-designed visual preview. At a glance, the operator can visually confirm that the video feed, VGA feed, and audio are being captured successfully. Also, a rack-mounted capture system is available for permanent installations as well as a mobile unit that can be easily transported.

4.3.7. Echo360

Echo360 [17] is a newer but already very robust comprehensive system used by universities in Australia, Europe and North America. The company is focused exclusively on marketing to higher education institutions. It is written in Java and runs on Linux.

The recording appliance is small and simple to use, and can be scheduled to run automatically or operated on an ad-hoc basis. Basic editing of recordings can be accomplished very easily using a Flash web editor, providing an intuitive interface that allows the operator to cut unwanted clips out of the video. The media are stored in a lecture object format, and the video is encoded in H264.

The primary viewer uses Flash although several other major viewing formats are available.

4.3.8. *Accordent* Accordent [18] is another comprehensive commercial lecture archiving system. It is Windows based and uses Windows Media codecs.

Notably, Accordent is flexible in that it is possible only to buy certain components, software and hardware, and make them work with existing tools.

4.3.9. *NCast* NCast [19] is a commercial system which, although not a comprehensive archiving solution, is simple, compact and inexpensive. It is a small box that captures an SD audio/video feed and VGA feed simultaneously, combining them into a single MPEG-4 file that can be streamed over the Web in real time and also recorded. The QuickTime player is needed to play it back. It does not provide the flexibility and power of the lecture object architecture, but could be very useful for small recording operations.

4.4. The Opencast collaboration
The Opencast collaboration [23] is a rapidly growing collaboration of individuals and universities interested in all aspects of lecture archiving. Its purpose is to find and develop open source solutions to these issues, but more importantly it is focused on coordinating efforts to eventually develop one comprehensive solution for lecture archive, which is code named Matterhorn. This effort is jointly led by Berkeley and ETH Zürich, and aims to produce the final product in the next two years. In the period before Matterhorn is ready, the collaboration's recommended lecture archiving solution is REPLAY (discussed above). Matterhorn will be the officially sanctioned solution starting in the summer of 2009, when the REPLAY project ends. The Matterhorn developers have committed to providing a migration path to users who have started using the REPLAY system.

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