Lecture Video Capture for the Masses

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ABSTRACT

Earlier work had shown the positive learning impact of the ability to review class lecture videos. Prior video capture systems used university provided infrastructure such as video technicians and post-production facilities. However, such capture is expensive; forcing schools to carefully choose the courses that can be video taped. We show that technology advances can allow every faculty member to make a modest effort and video tape their lectures, perform simple post processing and disseminate the contents either through their own web servers, using podcasts or via services such as Google video. Consumer grade HD cameras remove the need for accurate tracking of the faculty member and chalkboards; one stationary camera can frame the entire chalkboard. Desktop computers are powerful enough to perform the required multimedia operations. The faculty can also add pedantically useful annotations; a step that is unlikely to be performed by the video technicians. Many students own iPods, PSPs, laptops and other devices that allow them to watch the video at their convenience. We report on the tools used, the associated network cost and our experiences with video recording an undergraduate Operating Systems (Spring 2006). For the twelve month duration from Feb '06 - Feb '07, the OS course consumed over five days worth of our external network link bandwidth. The network cost in distributing all the lectures taught in our university can be prohibitive.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer Uses in Education

General Terms

Experimentation

Keywords

lecture video capture, podcasts, commodity off-the-shelf capture

1. MOTIVATION

Ideally, one would prefer lectures in a small class room setting, with an attentive group of students, interacting with the faculty member till the difficult concepts are fully understood. Unfortunately, the reality is that the class size can be large, while students can be tired and sleepy. Also, it may be hard for all the participants to always meet in person. The class duration is also limited leaving little time for complicated topics to fully sink in. Over the years, technology has evolved to fill this gap. For example, lecture notes evolved from contents written on chalkboards to viewgraphs, slides and recently to Powerpoint slides. Faculty regularly hand out lecture notes so that the students can focus on the subject material. The availability of ubiquitous computing and networking technologies allow the students to also download these lecture notes.

Also, many universities are solving the problem of students in different locations (e.g. distance education) and lack of synchronous meeting times (e.g. online courses) by capturing and broadcasting the lectures. Typically, qualified technicians are involved in the various stages of producing the contents. However, production costs for recording, storing and disseminating lectures can be prohibitive. Depending on the complexity of the capture, the cost for capturing a single day (of a conference) ranges from $5,000 to $20,000. Recently, Rowe et. al. [9] captured a multimedia conference for about $3,000 a day. Our university has its in-house Audio/Visual department that charges $100/hr for video recording in S-VHS resolution using a single camera. They also charge $120/hr for editing and digitization of the video. The author's Operating System course met for forty lectures; potentially costing over $8,000. In Spring 2006, our university offered 2,321 undergraduate courses with lectures (unlike *physical education* which may not require lectures) in its main campus; recording all these lectures would cost over 18 million dollars per semester and the services of thousands of video technicians. Such costs are not sustainable.

A number of research projects, including [2, 7, 11, 5, 10, 3] had addressed the requirement for qualified technicians by automatically creating rich multimedia without the need for trained human operators. Though these systems can potentially bring down the production cost, they still require infrastructure investments in object tracking cameras and other computing devices. One solution to this problem is to convince the universities to invest in the required hardware and deploy these automated technologies.

We advocate an approach where each individual faculty member purchases the required equipment (or share video cameras and other devices with other faculty), brings them to the class room, captures lectures, and performs any post-production operations and then distributes the contents. We believe that this approach may eventually persuade universities to invest in automated capture technologies. Recent improvements in device capabilities makes it feasible for every faculty member to perform the different steps. Students can also use these captured contents in a wide variety of computing and portable devices; making this effort worthwhile.

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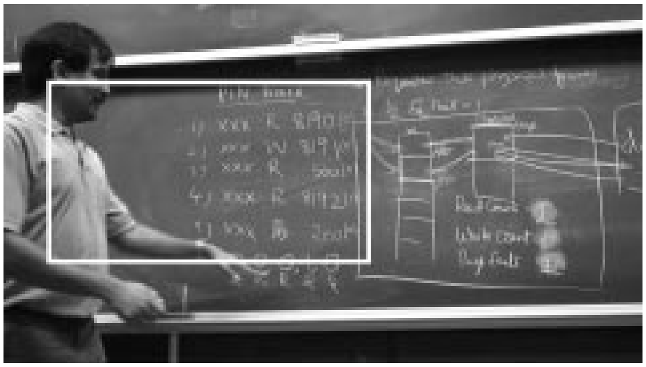


Figure 1: Difference in screen resolution between HD (1920x1080) and NTSC-DV (720x480 - represented by the inset box). Capturing in NTSC-DV requires panning (to choose the appropriate items on the chalkboard), fidelity reduction (reducing the number of pixels to cover the chalkboard). HD allows for effortlessly capturing of entire chalkboard while still leaving small marks on the board readable

We describe our experiences in capturing the lectures for a junior level Operating Systems course in high definition (HD) video and distributing the contents using the web, Google video as well as via audio and video podcasts. We did not have access to or use any video technicians. This paper does not defend the choice of video recording lectures; we believe that prior work (including [6]) had already provided convincing evidence of their usefulness. Our primary evaluation criteria was on the amount of effort required from the faculty; the author is a pre-tenure assistant professor in a research university with little spare time. Note that the author is not a novice; his research career focuses on experimental multimedia systems. Our hope was to use multimedia technologies and help students review the lectures. We describe our experiences with an eye towards encouraging others to attempt the same. Note that, though we explain our choice of hardware and software tools (we chose Apple products) as a reasonable approach, these are in no ways expected to be definitive choices. Other comparable hardware and software solutions might be just as effective.

We organize the rest of the paper as follows: we describe our capture mechanisms in Section 2, our observation and experiences in Section 3 and discuss the future work in Section 5. We also place our work in the context of similar efforts in Section 4.

2. MECHANICS: HOW DID WE DO THIS?

In this section, we describe the mechanics of how we captured and disseminated the contents. We had always made all our lecture Powerpoints, home work and project PDF documents public and on the web. Our newer addition was the lecture audio and videos; the focus of this paper.

2.1 Equipment used for capture

We captured the lectures using commodity components. We require our capture devices to be affordable, light weight (we carry the gear to each class) and have good fidelity to capture the contents of the chalkboard. On the chalkboard, we did not want to write in unnaturally big fonts just so that the camcorder can legibly pick up the characters. We used the Sony HDR-HC1 (retail cost - $1,350) HDV camcorder which can record a full 1080i HD resolution video (rectangular 1440x1080 pixels) on mini-DV tapes. Since we purchased the camcorder, Sony had replaced this model with HDR-HC5, which is cheaper (retail cost - $900) and lighter (600g including battery and tape). The high resolution and wide screen format of these HD camcorders allows us to capture the lecturer and chalkboard contents without panning and zooming. We illustrate this ability in Figure 1. We show the video captured by our camcorder as well as an inlay box to illustrate the screen resolution of NTSC DV video (720x480, format used by DVD). NTSC DV requires panning to capture the important elements of the chalkboard. Motion tracking VGA (640x480) camera systems are not sophisticated enough to stop following the instructor and focus on items that the instructor is pointing to. For example, instructors are likely to use sentences such as “Over on the far right corner” to point to important concepts; one requires an attentive video technician who can listen to the lecture and pan to the correct part of the board. Our stationary camera is able to frame the entire chalkboard.

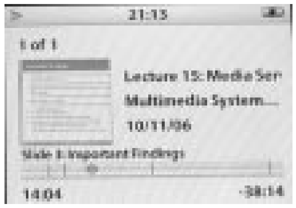
2.2 Capture

Before each lecture, we mount the camcorder on a Manfrotto 482 tripod and place the camera in the front row (about 6 feet from the lecturer and chalkboard in our class room). The ability to place the cameras further back would have increased the field of view. The camcorder picked up the audio component of the lecture well, though it sometimes picked up student chatter. Recently, we use a blue-tooth microphone (Sony ECM-HW1) to discard background noise. We made sure that we did not capture any students in the video in order to protect their privacy. During the lecture, our primary focus was in interacting with the students and not in talking to the camera. The only times that we acknowledged the existence of the camera was when discussing student grades. Sometimes this meant that the lecturer would walk off the camera or continue writing past the camera field of view; these events were rare because of the wide capture angle of the camera. Note that a trained technician would have followed our movements and generally did a better capture job. We also did not have any special lighting facilities. In general, it took us about five minutes to setup and pack-up the video gear (there was utmost 15 minute break between lectures).

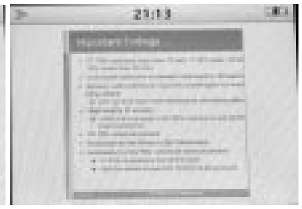
We would have also liked to capture the synchronized Powerpoint slides using the presentation capture feature of Powerpoint. Unfortunately, this feature in Powerpoint lost synchronization between the audio streams and slide transitions. It also lost the audio segment if we went back to a previous slide.

2.3 Post processing

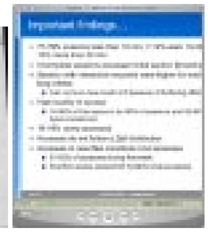
After each lecture, we uploaded the videos to an Apple iMac G5 2 GHz machine using the IEEE 1394 interface. The 50 minute lecture took about two hours to upload. Initially, we used Apple Finalcut Express tool. Later, we switched to iMovie for its simplicity (iMovie is distributed freely with a new Mac). A fifty minute lecture would require about 30 GB of storage, not practical both for storage and distribution. We transcoded the streams into three different formats; an one Mbps HD video encoded using H.264 with a screen resolution of 1280x720, a video object customized for video iPod - H.264 encoded at a resolution of 320x180 and MPEG-4 audio for the iPod. The iPod video can be played using the Quicktime player on a computer as well as the Sony PSP game gear. Transcoding to the iPod video formats took around 3-4 hours while the HD video took about 10-12 hours. We usually performed these transcoding operations overnight. We also created an audio podcast using the Apple Garageband tool. This tool allowed us to create slide markers, attach Powerpoint slide images to the slide markers and add text annotations. Recently, Apple has migrated to Intel processors which takes little more than half these times.



(a) View with slide chapter marks

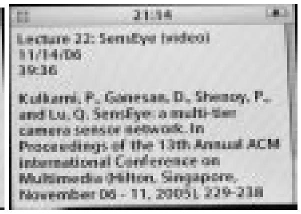


(b) View with slide images

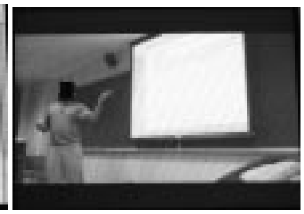


(c) View of slide markers in desktop Quicktime player

(d) Video slide markers



(e) Text annotation



(f) Actual video

Figure 2: Enhanced audio/video podcasts (with slide markers and slide images. Note that this is a photograph of a video iPod display. The actual display on the device is in color and far more crisper

2.4 Distribution

We uploaded the video and audio contents, along with course Powerpoint slides and PDF documents to our web server. Our goal was to make the course contents as easily available as possible. The Student Monitor study [12] showed that 42% of undergraduate students owned an iPod device. Hence, we wanted to leverage the ease of disseminating contents via iTunes feeds to reach these students. Previous work [4, 8, 6] had also discussed the ease of using podcasts. We created the iTunes feeds using the freely available Vodcaster tool [1]. Recently, Apple has released the iWeb tool which would make these operations easier. The Apple iPod shows the annotations in a number of different variants. For example, the audio podcasts (Figure 2) can show the slide markers (Figure 2(a) or the slide images themselves (Figure 2(b)). Playing the audio podcasts via Quicktime shows the slide images and chapter markers. On the other hand, the video podcasts (Figure 2) can display the slide markers (Figure 2(d)), text annotations (Figure 2(e)) as well as the actual video (Figure 2(f)). We also uploaded the HD contents to Google video (video.google.com) starting a month into the course (Google video was becoming available and popular right during the course). Another popular video hosting service, YouTube (youtube.com), restricts videos to 10 minutes and 100 MB - unsuitable for our purposes; we did not want to spend the effort to create several smaller segments. Recently, YouTube allows for unlimited uploads for *Director level* members.

We want to stress that our goal in this whole exercise is to be as non-intrusive during the lecture while demanding little effort from the instructor. Of course, the Mac itself was busy transcoding the contents all night. Technology trends and faster processors point to further easing in the time required in post processing the contents.

3. OBSERVATIONS: HOW DID IT WORK OUT IN PRACTICE?

We recorded the lectures of a junior level Operating Systems course. There were 37 students enrolled in the course. The class convened on MWF 10:30-11:40 AM - relatively early for some students. Next, we describe our experiences. First we describe some of the concerns expressed by various faculty members about this exercise. Next, we describe the student feedback. We also present the usage statistics that affects the practicality of this work.

3.1 Faculty concerns

The primary concern was that students would just listen to the videos and not attend the class itself. To our surprise, this never happened, usually about thirty students showed up for each lecture (roughly - we did not take attendance).

Also, recording every lectures means that there is a record of every work spoken by the faculty; sometimes they may misspeak or state something incorrectly. Students can potentially confront the faculty (difference between *I think you said that '1 == 2'* vs *You said '1 == 2' on Feb 24, 2006 at 10:54:23 AM*). Personally, we consider this to be an acceptable risk. Faculty are not infallible. We don't believe that faculty have to act otherwise.

The other concern was that this will take up too much of the faculty's precious time without any tangible benefit to the students. At the beginning of the course, students did not know what to make of the video podcasts (many students had never viewed streaming media or podcasts before). We made a conscious effort to not advertise the videos, the objects just showed up on the class web page and on iTunes. All the usage statistics that will be discussed in Section 3 was from voluntary users, rather than users who viewed them our of curiosity. As discussed in Section 2, the faculty time commitments were acceptable, even for a pre-tenure instructor.

The final concern is about the legality and intellectual property implications of such recordings. Clearly the university holds the rights to the lecture and students paid money to attend the class. We know of schools which restrict the university captured videos for distance learning classes exclusively to students who had already registered for the course. Our university does not offer such courses and so has no explicit policy that governs video dissemination. Perhaps this is a topic for future counsel.

3.2 Student feedback

At the end of the course, we conducted an informal study survey using SurveyMonkey. One students gave the reason for continuing

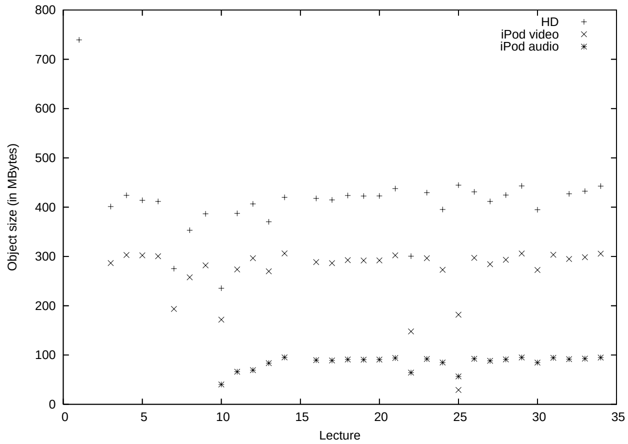
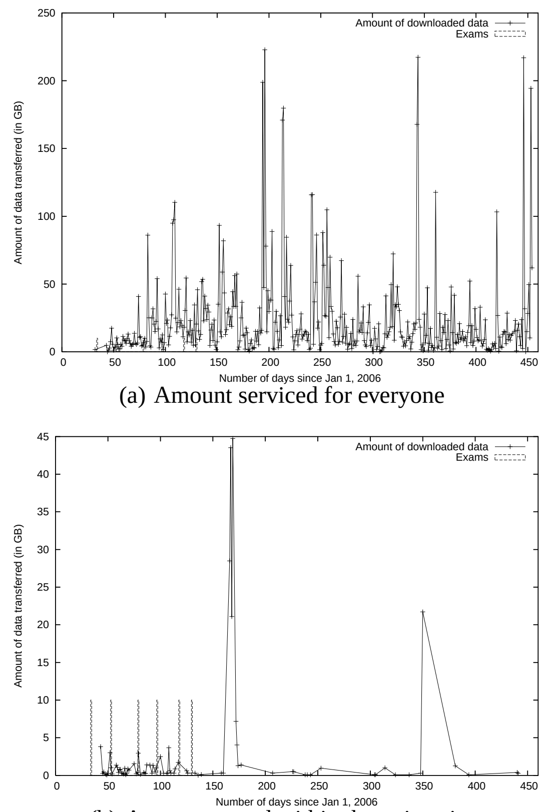


Figure 3: Lecture audio and video size



(a) Amount serviced for everyone

(b) Amount served within the university

Figure 5: Amount of data served each day

to attend the course as *"if you want to see the lectures you'll have to take the 50 min of time to devote to it whether it is to a video or to the live lecture. Honestly, going to lecture and seeing everything in person is much less of a hassle than trying to catch things from a video"*. One student mentioned that when he dozed off in class and woke up, he made it a point to note down the exact time that he woke up so that he can go back to the materials that he missed. Several students expressed the view that they prefer the organized class setting over a chaotic dorm. Of course, video was the only option when the instructor or the student was traveling.

Students mentioned that they always retain and archive course notes in the hope that these notes might be useful as reference in the future (the author has a pile of such decade old notes). However, with the passage of time, these printed notes loose their context. Students felt that storing the videos along with the printed notes would be more useful to give some context to the hard copy notes. Several students commented that they would archive the videos in a DVD for their personal use in the future. Several students wished that they had the videos from their own *Linear Algebra* courses from their earlier years. They noted that it is not helpful to sit in on another *Linear Algebra* course taught by a different instructor because they were looking to refresh some specific content that they learnt, which may not be taught exactly by every instructor.

Graduate Operating Systems is a required course for a graduate level core course. The graduate OS course is offered in Fall and undergraduate OS course is offered in Spring. The video notes might help students without the requisite OS background to catch up before they take the graduate course (rather than waiting a whole year). Similarly, since our lectures are available freely, we heard from a Lockheed employee who was using these lectures to brush-up his OS knowledge. These consequences were unplanned.

3.3 Usage statistics

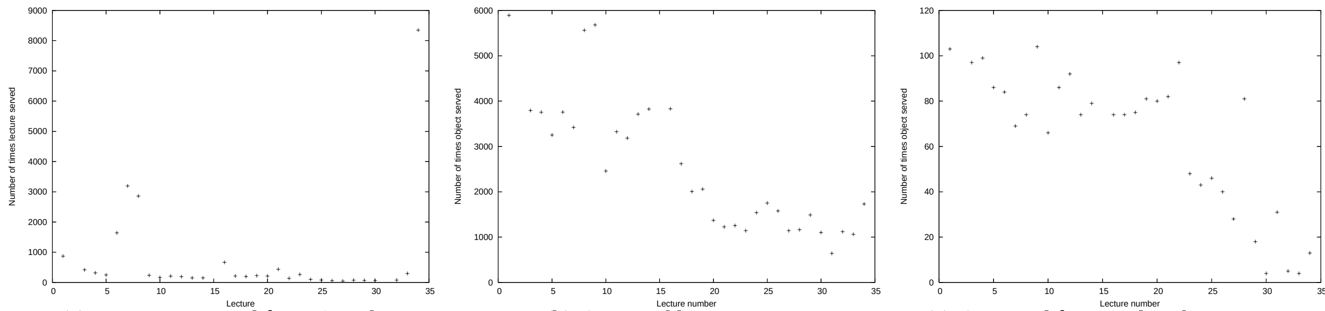
First, we plot the sizes of the lecture objects for the different media formats in Figure 3. We note that video objects, though highly compressed in a lossy format, are still large; on average, the videos were about 400 MB while the audio segments were about 100 MB. The entire semester worth of objects consumed about 23.7 GB. In Spring, our university offered 2321 undergraduate courses with lectures (unlike *physical education* which may not require lectures) in its main campus; one would require as much as 55 TB of storage per semester to capture all the lectures across the university. In a more recent offering (Spring 2007), we are using HD content optimized for 2 Mbps which requires about 2 GB per lecture.

Next, we plot the number of times each of the lectures were downloaded from the university web server; both for accesses from within the university and from outside as well as from Google in Figures 4 and 4(a), respectively. From Figures 4(a) and 4(b), we note that some of the lectures were quite popular - serviced over 10,000 times. This is significantly more than the number of times that they were downloaded from within the university. Some lectures contributed over 450 GB of network load from the university. For the first twelve months (Feb '06 - Feb '07), the Operating Systems course consumed 8.35 TB of external data (246 GB internally). The university uses a link that is capped at 150 Mbps for $15,000 a month. The OS course consumed 8.35 TBytes or about 5.2 days of continuous Internet usage (costing over $2,500). These figures might force some universities to rethink distributing videos to the off-campus public (which could include students).

Next, we plot the amount of data transferred per day in Figure 5. The graph also shows the dates of scheduled exams. News about our lecture capture was discussed in the popular web-site - slashdot, leading to a spike around 160 days. Universities who pursue this avenue will have to evaluate the network costs; perhaps restricting the contents to their local clientele. In this context, we believe that Google video might function as a powerful distribution mechanism.

4. RELATED WORK

A number of schools already video tape and distribute contents. Systems such as MIT openware (http://ocw.mit.edu/index.html), CMU courseware, Berkeley Webcast (http://webcast.berkeley.edu) are some of the examples of university support lecture capture and dissemination. Clearly, the capture quality of these systems are ex-



(a) Lecture accessed from Google (b) Accessed by everyone (c) Accessed from within the university

Figure 4: Number of times that lecture was accessed

pected to be far better than our system. Our system focuses on the ability of an individual instructor to perform these operations in their spare time. Malan [6] argues that podcasts extend the reach of education rather than improve education itself. We describe similar experiences; it is a tool which can be valuable under specific circumstances. However, our primary argument is that any faculty member can distribute the contents if they so choose without depending on the university.

Lately, Apple has been promoting the iTunesU initiative to function as a free portal and allow universities to disseminate their podcasts. They allow the contents to be hosted on the university servers or on Apple servers. On the other hand, one needs to carefully consider the network implications of servicing large media contents to the local as well as the general Internet population.

5. DISCUSSION FOR FUTURE: HOW CAN WE MAKE IT EASIER?

Capturing and distributing lectures video is not a panacea. They probably do not play a role in scenarios where the class size is small, every one is present, fully alert and engaged. However, in typical class rooms, saving the lectures helps students review the materials and attend lectures even when they are not physically present because of other emergencies. We do not believe that the effort involved in capturing videos is high. We believe that the effort is well worth our time and we would encourage any faculty member to incorporate these techniques into their class rooms. The cost of providing the videos for public consumption might be prohibitive for some.

Higher fidelity versions of the captured video will be presented at the conference. A step by step instructions on capturing, processing and distributing the videos will be publicly made available at the author's website (http://www.cse.nd.edu/~surendar/). Currently, we are attacking the large storage requirements, especially if everyone in the university chose to video tape their lectures. We are developing a peer-to-peer system that will allow individual faculty members to donate storage from their desktops. The system will then aggregate the contents. We hope to freely release this system as a public domain offering.

Acknowledgments

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