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# Teaching Statics Online with only Electronic Media on Laptop Computers

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## Abstract

The benefits of electronic media in engineering, such as interactive simulations, three-dimensional visualization and animations are widely known, but the implementation has been difficult because of lack of classroom facilities and student access to the programs. Most of the implementation problems can be overcome and true asynchronous learning environment can be established if CD based multimedia is integrated with current course material on an intranet. This is particularly useful when all students have their own personal laptop computers and the learning environment is connected with a wireless network. This paper will demonstrate and discuss the experiences at the University of Oklahoma trying to teach the basic Statics class using laptop computers, CD-ROMs, and the intranet.

This project did not develop new courseware, but instead used the Multimedia Engineering Statics CD-ROM (published by Addison Wesley Longman, 1997) for the main course content. The CD was supplemented with newly developed intranet-based material such as homework, examples, quizzes, solutions, and lectures. The outcome of the course showed that students can use distance learning methods to enhance their learning on a university campus. Some of the benefits included instant access to all course material, quick feedback of homework and quizzes, and on-demand course lectures. The course has been taught three semesters, Spring 98, Fall 98, and Spring 99 and is being used at OU as the foundation for future engineering courses that can be delivered via the internet. The course can also serve as a test bed for future use of electronically delivered courses for engineering students that cannot attend class due to disabilities, schedule conflicts or geographic distance. The paper also explores the methods used to develop the course and what software tools were used to implement the computer-based learning environment.

## Introduction

The most promising feature of multimedia and network-based media is its ability to display complex information or concepts in an accessible and easy-to-understand animated graphical form that is managed by the user. This is obviously well-suited for many educational applications, but it is particularly attractive for use in engineering education where abstract mathematical models and fundamental physical principles must be employed to solve very practical problems. One of the most difficult issues to deal with in the engineering curriculum, especially at the introductory levels, is the process of abstraction of real and practical situations into abstract mathematical models. The engineering curriculum is filled with analysis courses, and the focus is invariably on the analysis of completely determined homework problems that represent some implied abstraction from reality (and for which a "unique" answer is available in the back of the book).

Furthermore, intuition is a vital component of human decision-making, and it is no less so in engineering problem-solving. Given the inexorable development of technology, the curriculum is under continual compaction as new topics are added and older material is edged out to maintain a nominal 4 year program. One of the earliest casualties in this process has been the application of engineering principles to practical problems through the mechanism of realistic homework problems, homework sessions, tutorial sessions, project labs, and the like. The result is engineering graduates with impressive analytical skills, but little or no understanding of how to apply them in an effective manner to solve problems! Multimedia and network based media technologies have the potential to provide a means for dealing with these issues in a dynamic, provocative and likely cost-effective manner that not only will increase the effectiveness of the educational program but will also increase the quality of the resulting students [1, 2].

However, electronic media has it own set of problems and difficulties. Foremost is the time and effort needed to develop and implement electronic media. Similar to authoring a textbook, the core material will take 1-2 years to develop. Next, the weekly material, such as homework and quizzes need to be added to web pages in electronic form. This is not simply scanning problems from existing notes or old tests, but constructing them with a drawing program. Other types of media can also be added to the web site, such as lectures and discussion groups. The lectures are digitized video of the actual in class lecture, but it is not as simply as running them through a computer. The style of lecture and classroom environment needs to be considered to optimize the effectiveness of the online lectures. There is also the need to highly compress the videos so that they can be received over a campus wireless network or a home modem. The discussion groups are like electronic bulletin boards that allow student, teaching assistants and instructors to post and answer questions during normal working hours and in the evenings. Finally, there is the need to have online quizzes and tests. Strictly speaking, online tests are not necessary for course on campus, but it is expected that by the following semester this course will be offered to students at remote sites that cannot attend class. Thus, all material, including quizzes and tests where made available in electronic form.

It is the main purpose of this paper to examine all the different types of electronic media used in the Statics course. All of the electronic media was accessed through the main Statics course web page (Fig. 1) except the basic course theory and examples. That material was available separately on the course CD-ROM. This paper is meant to give the reader a complete overview of a typical online course whether for distance students or on-campus students that cannot or do not want to attend normal classes. The paper will address five main parts of the online course, electronic content, lectures, discussion groups, quizzes, and homework. General course information, such as syllabus, is not discussed since it is assumed that all courses have these basic information posted for all courses.

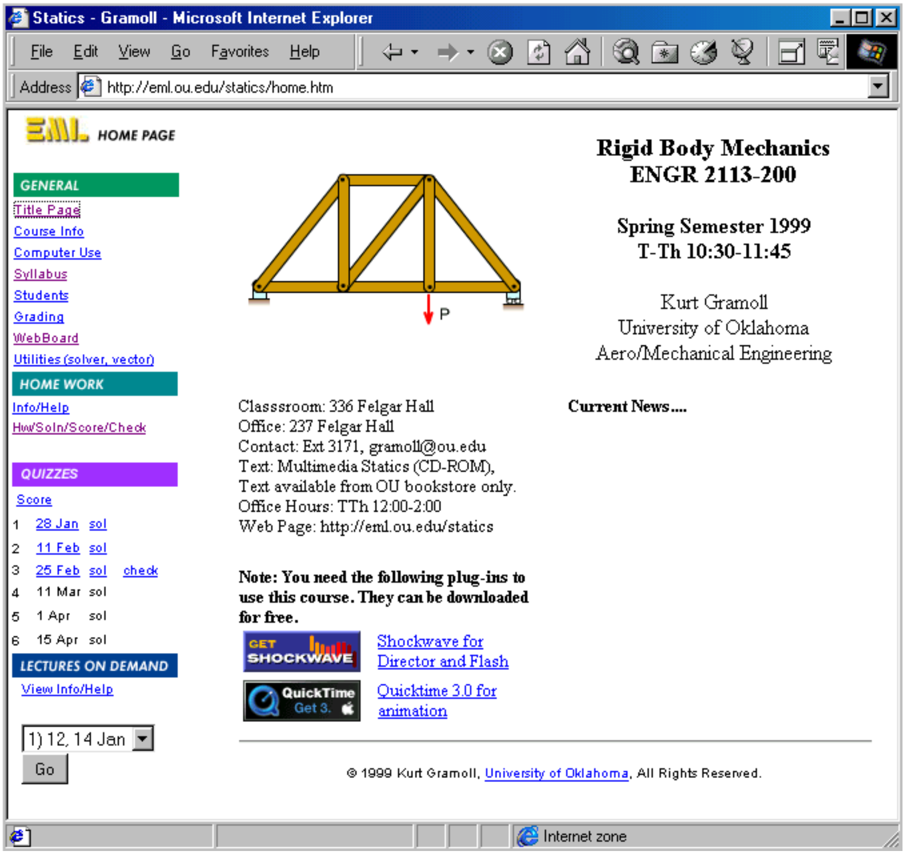


Fig. 1. Web Site main page

## CD-Based courseware

Although the web site had homework, quizzes, tests, syllabus, utilities, and lectures-on-demand, the students still needed the core theory and examples. For this course, the theory and examples were delivered to the student on a CD-ROM that was developed by the author two years earlier [3, 4]. The CD-ROM contained all theory for the Statics course and was presented in a case study approach. Each major topic was introduced through the use of a typical engineering problem. The case was fully worked out and supported by the appropriate theory. Case-based learning has a number of benefits, such as holding student's attention and providing an application for the fundamental concepts [5].

The Statics CD-ROM contains a total of 35 cases and each one illustrates a specific concept in Statics. Each case or example is presented in four parts: Introduction, Theory, Solution, and Simulation. The first three parts, which incorporate graphics, audio components, animations, videos, and hypertext, introduce a problem to the user, present specific concepts in Statics that are required to solve the problem, and then applies the concepts to solve the problem (Fig. 2). The fourth part allows the student to experiment with a computer-generated simulation of the problem. Reference materials for engineering Statics are also accessible through the appendices.

Due to the large amount of material on the CD-ROM, it was not possible to place it on the web. The download times for the animations were too great due to the large file size. However, by having the main course content on the CD, the students could also access the course content material even if they were not connected to the Internet. The CD served the same purpose in the course as a textbook in a traditional classroom oriented course. It has the main source of theory and examples. The CD was not used extensively in the course lectures since it was expected that the students would review and use the material on their own, as they would a textbook. The purpose of the lecture was not to simply show CD content, but to add to the course from a different point of view. This allowed the students to have another perspective on the theory and problem solving process.

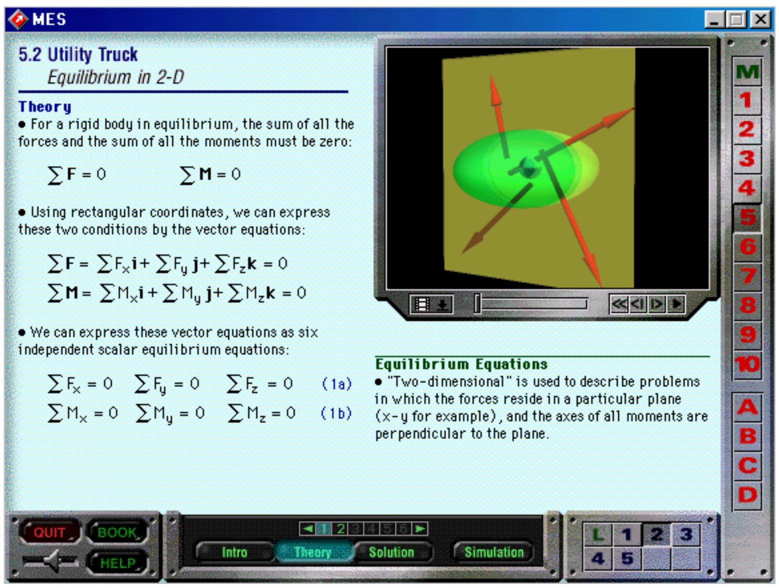


Fig. 2. Typical theory page from the Statics CD-ROM.

## Homework, Quizzes and Tests

One of the benefits of using electronic media for a course is the opportunity for the student to receive most or allow of the course over the Internet. In addition to the course content being delivered electronically via a CD-ROM, the homework and quizzes were also delivered in electronic format over the Internet. This follows that concept that if the students are not attending class for the lectures and receiving all course information by electronic means, it does not make sense to then require the students to complete quizzes or tests on paper, or for that matter homework. Thus all homework, quizzes, and tests were also designed so that they could be delivered over the Internet. This required all questions to be either 'fill-in-the-blank' or multiple-choice which is a major change in the normal teaching style where partial credit is awarded for wrong problems. This was the single most difficult change that the author had to do in implementing an all-electronic course. Traditionally, partial credit is given to students in engineering courses due to the difficulty in solving problems and frequency of simple errors such as algebra and sign errors. Even though partial credit is not possible with fill-in-the-blank or multiple choice questions, a instructor can minimize its absence by asking more questions and have each question deal with only a single concept or step. This puts a larger burden on the instructor to develop new homework, quizzes and tests that fit this style, but it does allow better monitoring of problem developed using multiple choice questions. This model also fits with the test methods outside the university, such as the professional engineering exams.

Quizzes and Tests

Over the course of three semesters various testing methods were tried and implemented. The first and simplest method was for the student to simply type in the answer in a blank form on a web page. When the web page was submitted, the typed information was sent to the Author as an email or saved as a basic text file. The answers were then graded and the score was transferred to the class spreadsheet for grades. While simple, this first method of typing answers onto web pages still required a large amount of work. Each problem still had to be developed and constructed in electronic form. This involved using a drawing tool such as Freehand. The problem also had to be original to avoid any copyright issues with current textbooks. The solution then needed to be developed in electronic form so that it could be posted on the web after the test or assignment was completed.

Starting with the second semester, all problems were multiple choice. This added more work in developing the problems, but made grading easier. It also paved the way for automate problem generation and grading. Wrong solutions were also developed to closely match possible mistakes that the students would make. However, the correct answer was always one of the choices so the student had the opportunity to work toward the correct answer. Over the course of three semesters, over 100 quiz and tests problems were developed that are all web-based. Future work includes implementing a database that will allow any instructor to pick and choose problems for new quizzes.

Figure 3 shows a typical quiz page for a 30 minute, four-problem quiz. The quizzes were open notes and, of course, open computers. The students generally finished the quiz within the time allotted, but there was little time to study or attempt to get help online. The goal of the quiz was to force the student to quickly set up the problem and obtain a solution. The time pressure to complete the questions quickly was offset by the basic nature of the problems. The quiz was also styled after the fundamentals in engineering exam that most undergraduate students take just before their graduation.

The web site to time and allow submission of multiple choice questions was developed especially for the class by the author. The site uses JavaScript and CGI programming to pull problems from a database, set up the answer form and then let the students submit the quiz. The answers are posted after the quiz is completed. During the quiz, the students can retrieve their answers that were submitted to verify that the quiz was submitted correctly. This is important, since students need to have the responsibility to make sure their quiz is completed. If there is a problem with the submission, the student could blame the server. With the checking capability, the student can quickly notify the instructor that there is a problem and get it fixed before the end of the quiz.

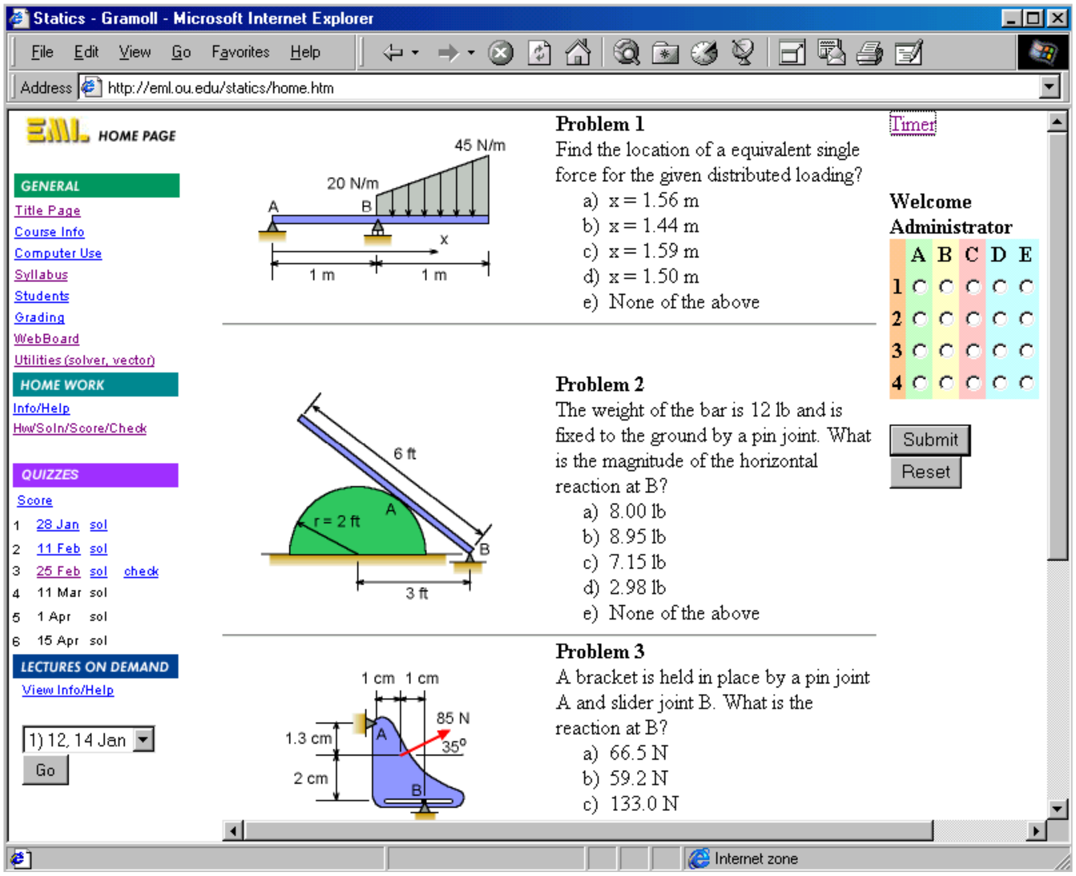


Fig. 3. Typical quiz screen from the web site.

## Homework Submission and Solution Posting

Similar to quizzes, homework was both viewed and submitted through a web page. The first semester, the problems were fill-in-the-blank type but by the second and third semester, all problems were multiple choice. This allowed easier web-based grading and score reporting. Also, each student was able to view the quiz score and solution after the due date for the homework through the web site.

Homework questions were also posted weekly on the course web page. Through the use of CGI scripts, the students could check their submission and grades. The web site also record the time and date of the submission so late submission could be tracked. For the homework, all diagrams were drawn using Macromedia Freehand and then saved as GIF files for posting to the web site.

In the all three semester, the students generally appreciated the web-based homework solution. This allowed them to view older homework and study for tests and quizzes without having to contact the instructor for solutions or visit the bulletin board for posted answers. It was interesting to note, that the homework solutions were access more heavily at 11 PM to 2 AM just before quizzes and tests.

The graphics were generally simplified when compared to typical textbook graphics due to the reduced 'dots-per-inch' resolution of the computer screen as compared to print media. However, the difference had little effect on the understanding of the problem. An example page can be seen in Fig. 4.

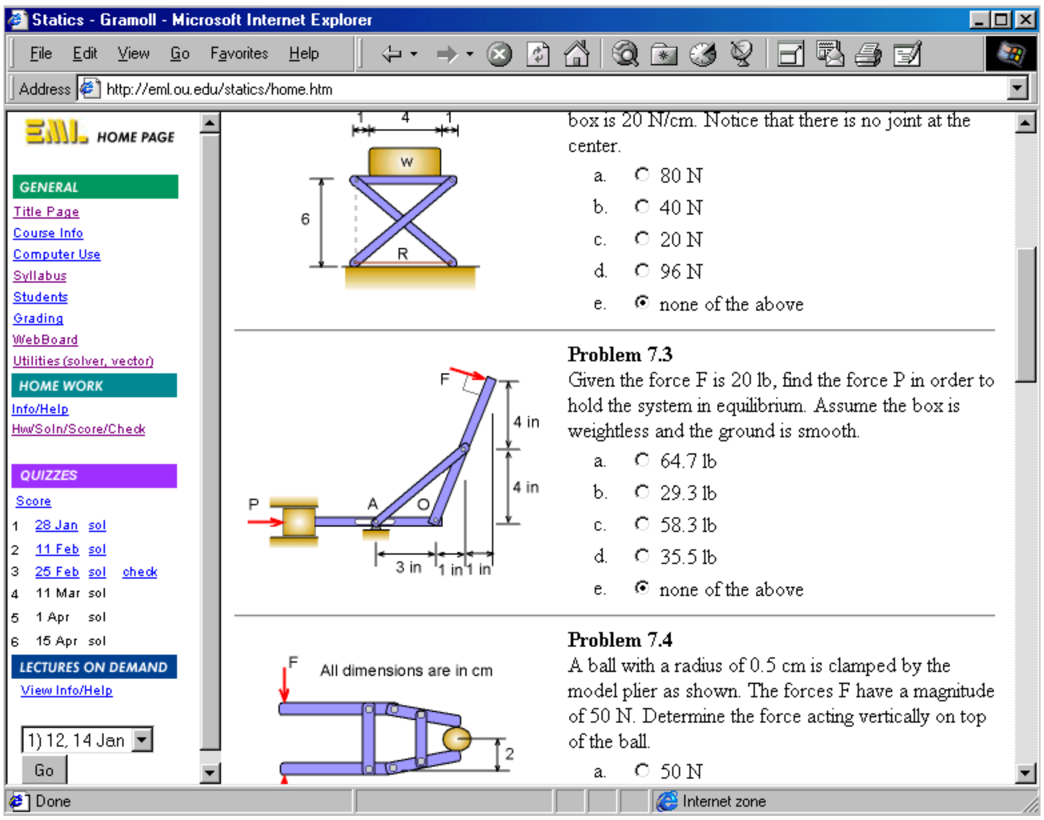


Fig. 4. Typical homework page.

## Discussions Online

Over the course of three semesters, there was a noticeable drop in the number of students attending the actual lecture in person. As the streaming video quality improved, most students choose to view the lectures over the Internet.

Since most students were not in the physical classroom for the Statics course, it was important to have an online discussion method where students could ask questions and get a response. Several solutions were considered, such as email, Internet news groups or web server-based bulletin boards. The email option had a deficiency similar to normal office hours, in that the same question would probably be answered numerous times. With news groups or bulletin boards, the question is answered once and then all others can view it, thus saving time for both the students and professor. For this course, a commercial program called Web Board (distributed by O'Reilly Publ.) was used for the discussion groups for a number of reasons. A typical web page using Web Board is shown in Fig. 5. One, it was operated and controlled on the course server and outside users could be easily restricted. The program monitors how many times a students uses the discussion group and also lets other users know how many times the question and answer have been viewed. It was also easy to set up and runs completely within a web page thus eliminating additional software or browser plug-ins. For two discussion groups or conferences, the cost was $80 for the software (non-academic version have unlimited conferences). The program also allowed login and password restriction if needed.

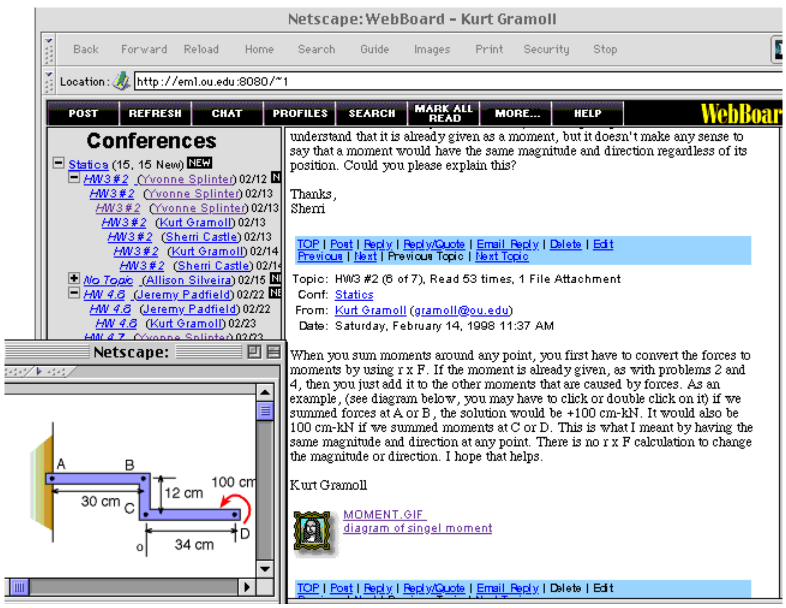


Fig. 5. Web Board Discussion on the Internet.

One of the main reasons for using Web Board was its ability to upload and view graphics. This allowed each student to modify a problem diagram (obtained from the web homework) and then post it with his or her question. In engineering, diagrams are critical and need to be used in most discussions. No other web discussion software seemed to have this feature. Another feature that was useful during quizzes was the chat room where live discussions or announcements could be made. In the future, the chat room could also be effective when there are hundreds of students in a given course or group of courses that would like to have live discussions about the course or homework. With only 20-50 students in the three courses described in the paper, there were never enough students at any given time to make the chat rooms work effectively.

The web board concept, while not new, is an extremely important component to the online courses. With the web board, questions and discussions can be done similar to the interaction that takes place in a normal classroom. In some respects, the web board discussions allowed more students to participate in asking questions since there was no time limit or peer pressure not to ask questions. It also allowed students to ask questions when the questions arose, i.e. when they do the homework at 3 AM. Over the three semesters, it was found that the time saved from students not coming to the office during hours (there were still official office hours) was offset by the time spent on the web board answering questions. However, less time was spent answering the same question numerous times since the question and answer could be viewed by others. The end result was three to four times as many questions were answered.

## On-Demand-Lectures

Although online learning has a number of advantages, one of the disadvantages is the lack of participation in the classroom. This can be partially overcome with the use of video streaming over the Internet of all class lectures and with online discussion groups that was discussed previously. This gives all students the same information that was discussed and presented in the classroom, including student questions and answers. Furthermore, online students can still interact through the use of email questions that can be answered and discussed in the next classroom meeting.

In reality, the lack of classroom discussion for all students is a small concern if all students are considered. Most basic undergraduate engineering courses such as Statics, will have 50-70 students. Of those students, maybe 8-10 will consistently ask questions in class. The others are content to listen without active participation. Thus the majority of students will not lose any information or experiences whether they listen to the lecture on the Internet or live. It is critical that the video online is of similar quality as the original lecture. This section will describe in detail the online streaming video problems and solutions that made delivering online lectures possible over the Internet.

Before the technical details are mentioned, the advantages of having the lectures online need to be explored. Convenience is probably most important reason for allowing students to view the lectures online. Generally, class schedule is the biggest reason for taking or not taking a particular course or section. With online courses, students are no longer bound by a particular class schedule. Unlike VHS video tape, Internet-based streaming video is delivered directly to the students laptop computers whether they are in the dorms, library, or in the hall between other classes. Second, the student can repeat the lecture if there is concept that he or she did not understand. This reason is more important than originally thought. Over the last three semesters, this has become the number one reason why students like the online courses.

### Video Streaming

The ability to view video over the Internet has improved tremendously over the last 2years. The main technology that has made it possible to use video for online course is the concept of streaming video. Basically, the user can view the first minutes of the video while the latter parts are still downloading which saves the student time. The user still has to wait at the beginning for the first 10-15 seconds of the video are downloaded and if the data rate of the movie is larger than the connection data rate, there will be additional pauses while viewing the video. These pauses can be reduced and even eliminate with the correct video compression. Over the last three semesters, numerous different video recording and video compression techniques were tested and developed [6].

For the online Statics course described in this paper, two different streaming video technologies were used. Originally, Vivo (Vivo Software, Inc., www.vivo.com) was chosen and used due to its low cost, excellent quality, and its ability to be served from any server, including Unix, NT, and Mac. With streaming video, the video must be first, compressed (encoded), second, placed on a web server and third, accessed by the user a web browser that has a plug-in for that streaming video type. All three parts are generally unique to the streaming technology used. Vivo was used since it compressed the video well and could be served off both Window and Mac systems. The user was required to download the Vivo plug-in to view the video, but this is true for all streaming video technologies since the user must have a player and de-compressor for the video. A sample of the Vivo video is shown in Fig. 6.

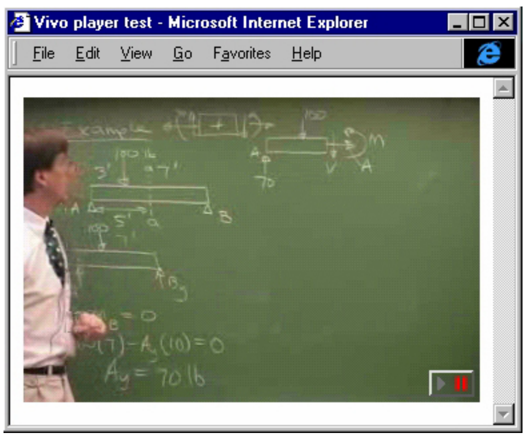


Fig 6. Vivo video format

Fig. 7. QuickTime video format

Although Vivo performed well and was used for Spring and Fall 1998 courses, there were a couple of deficiencies. The students complained that there was no slider or rewind controller for the Vivo player but just a start and stop button. The video could be reloaded into the browser to force the video to start at the beginning. Since Vivo did not support advanced controllers, the best that could be done was to split the video into 10 minute segments [7] which permitted the student to repeat only a maximum of 10 min to hear a particular concept. The 10 min. segments was actually a benefit in that it forced the author to deliver understandable concepts in about 10 minutes that would also match the general attention span of the students. The second problem was the inability to edit the movie after it was compressed. In many cases, the video was recorded, compressed and placed on the server only to find a problem with the video content later. The video would have to be re-imported from the camera and then edited before compressing which was time consuming. Finally, 1998 Vivo was purchased by RealNetworks, Inc. (developers and producers of RealPlayer) which cast concern over the long term use of this technology.

To overcome the three problems mentioned in the previous paragraph, other streaming video techniques were explored in the Fall of 1998. It was determined that QuickTime 3.0 retained most of the advantages of Vivo, but allowed user control of the play back location and allowed post-compression editing (Fig. 7). QuickTime also streamlined the processing steps for compressing the video since the video capture was in QuickTime (the industry standard) and the compression was also done in QuickTime format. Vivo, like most streaming technologies, converted the captured QuickTime to their own movie format. Other formats that were investigated were NetShow (now ActiveMovie) and RealPlayer [6]. It should be noted that QuickTime itself is only a file format. The compression methods or algorithms (referred to as a codex) must be selected when the compression is done. Since QuickTime has been on the market the longest, it has the largest number of codexs that can be used and is generally considered to be the most robust digital video format.

In addition to the added benefits mentioned previously, QuickTime also allowed the students to download the video. This was useful for those students that had slower connections at home so that they could download the movie all at once while doing something else and then watch it without delay interruptions due to slow streaming. Other streaming technologies made this difficult or impossible. Also, the quality of the video when using the Sorenson codex that comes with QuickTime proved superior to both NetShow and RealPlayer. With Sorenson codex, it was possible to compress video to 100 kilobits per sec (about 8 kilobytes per sec) at 10 fps and still have legible text on the board and good audio.

Processing Video for Streaming or the Internet

There are a number of steps that need to be considered when planning to stream video over the Internet. The process can be broken down into five general steps: record, capture, edit, compress and deliver. First, the recording step requires a video camera, but surprisingly it does not have to be a professional camcorder. A standard SVHS, Hi8 or DV (digital video) camcorders are more than sufficient and range from $600-$1200. Note that these cameras have a pixel resolution of at least 600 by 400 but the final streaming video will be in the grange of 240 by 180 to 320 by 240. The main key is that the camera resolution is higher than the final video. For all three semesters of the Statics course, the Optura Cannon Digital Camera was used.

Before processing, the recorded video then needs to be captured into the computer. For SVHS and Hi8, a standard analog to digital video board (about $200) works well since full screen at 30 fps is not needed nor desired. For effective streaming video, the video resolution and frames per second (fps) must be minimized so that the data rate can be reduced but still allow all information on the board, including text, equations and diagrams, to be readable. For digital video, a DV capture board is required (about $500) that allows fast transfer of the data into the computer. Since there is no analog to digital conversion, the full DV resolution (720 by 480) is captured from the DV tape at 30 fps. As noted previously, this high level of resolution and fps is not needed and the size must be reduced.

A couple of comments should be noted about DV cameras. First, the quality of DV is the highest of all camera types examined for the Statics course, but it is also the most expensive (however still reasonable). Second, there is currently no way to reduce the resolution or fps at the time of capture. This causes large amounts of data to be captured (2 gigabytes for 10 min. of video) and thus requires large hard disks. Also, the DV capture boards only allow 2 gigabytes of data to be captured at a single time. This causes the user to capture the video into multiple segments even if there is sufficient hard disk space to store the full video.

The processing of the video for QuickTime (both editing and compressing) can be done on either a Windows or Mac system with a video-editing program such as Premiere. The video is imported and then edited for length, sound level, and text overlays. The video is then exported as a new QuickTime video using the Sorenson codex. There are many codexs to choose from but it was found that the Sorenson was able to compress the video to smallest data rate and still retain a high quality image. For this project, another program was used called Media Cleaner 3.0 instead of Premiere. It is currently only available on the Mac. It was faster and more reliable than Premiere when processing the video. The one drawback of QuickTime and Sorenson codex is the large CPU processing time needed. To compress 10 min. of video (360 by 240, 10 fps) it takes approximately 4 hours on a 210 Mhz 604e CPU Mac.

The final results, a QuickTime movie, can then be placed on the web server. On advantage of QuickTime is that it can be placed on any web server without the need of additional software to stream the video. This is not true of NetShow from Microsoft or RealPlayer form RealNetworks. The movie then can be linked to any web page by simply adding a HTML link in the web page. The user will need to have the QuickTime plug-in to view the movie, but is downloadable from Apple (actually, the plug-in now comes pre-installed on both Internet Explorer and Netscape Navigator).

Teaching Style for Online Lectures

It is wrong to assume that any current course can be simply video taped and then converted to streaming video. There are a number of critical issues that need to be address in the teaching style to maximize the benefit of the Internet-based video. First, students need to have concepts introduced, taught and summarized into 10 or 15 min. segments [7]. This is actually a good teaching technique regardless of delivery media, but it is essential for effective streaming video. Students need to feel a sense of closer with each video segment. This also helps with the processing and editing of the video since there are nature breaking points. A full hour of a single video should be avoided due to processing time and students attention span. Students will get lost much faster with streaming video than with a traditional lecture.

Another issue is how the instructors conduct themselves in the classroom. To maximize the compression, it is important to minimize the change in motion on the screen. Thus, the instructor should minimize walking around and learn to write within a preset area of the board. If the camera is continually moving to follow the instructor, the data rate for the compressed video will double or triple. This in turn will cause delays and frustration for the students, particularly if using a standard 28.8 or 56k modem. One should not think of changing the actual content, but organize it so that it can be presented in pre-set board size of about 6 foot by 4 foot. This does not mean that multiple board can be used, but one should not bounce back and forth between the boards.

Finally, the writing style needs to be neat and clear. The video will be able to record normal size writing but sloppy diagrams, text on top of other text, and cursive text will not be readable on the video (but come to think about it, it is not readable in the classroom either!). This comment and others require good preparation before coming into the classroom. Video will enhance any mistake or poor teaching style, and it is recorded for all to see.

In summary, the video over the Internet worked well for the Statics course. The students were able to access the video within 24 hours after the lecture was presented. The video was compressed to 100 kilobits per sec (kbs) at a resolution of 360 by 240 pixels and 10 frames per second. This is roughly twice the data rate of the common 56k modem, but was well within the wireless network connection of 150-200 kbs that the students use with their laptop computers.

**Student Response**

The student responded very favorably to the online course. All three semester, the students took surveys for both the learning experience and the use of technology in teaching. In general, the students felt that they had a good educational experience, but did not feel that they had learned more material. However, they strongly felt that the technology allowed them to better keep up with the class when and where it was convenient to them. They liked the ability to attend the class anywhere on campus and the flexibility of learning on their schedule.

The tests and homework was judged to be lengthy and hard, which is consistent to classroom type class. It should be noted that the first semester, Spring 1998 there were 10 students but in the second semester there were 23 and in the last semester there was 49. This gradual increase in class size was extremely useful in testing of the technology and determining potential problems. With the first semester, the small class allowed the author to quickly solve any problem that developed due to the use of technology. Some of the earlier problems included, installation problems of the CD-ROMs (what version of QuickTime needed), wireless network connection, and variations of Internet browsers.

Also in the survey, the students gave high marks for using technology in the classroom. The students all had laptop computers and they were very appreciative with the chance to finally use them for a complete course. The students did make several useful comments about the technology, such as sliders on the videos and the need for simple web-based utilities. Both of these comments were implemented for latter class.

**Summary**

Over the last three semesters, Statics was taught using only electronic media by the author at the University of Oklahoma in the School of Aerospace and Mechanical Engineering. The electronic media included a courseware CD-ROM for the main content, lectures over the Internet, homework assigned and submitted online, web boards for group discussions, online quizzes and a general web site for course information. There was no printed textbook used for the courses. The students were able to learn the material as effectively as the traditional student using print media but had the added flexibility to obtain information in or out of the classroom. The student comments consistently praised the new teaching method and enjoyed the flexibility. The main negative from students was the time oriented testing which put pressure on them to know the material well or they would have a hard time finishing the quizzes.

Since the course was delivered over the Intranet at the University of Oklahoma, all students had laptop computers and were connected to the network through wireless network cards that attached to their computers. The wireless connections allowed all lectures to be broadcast over the Internet and minimized the need for the student to attend the actual class in engineering building. Two types of streaming video technology were used for the class, Vivo and QuickTime. Through experimentation it was found that QuickTime delivered the best quality video with the smallest bandwidth. A data rate of 100 kilobits per second (8 kilobytes per second) was achieved with a resolution of 360 by 240 at 10 frames per second. This bandwidth is suitable for home delivery for double modem lines (2 x 56k), ISDN, ADSL or cable modems.

From the instructor point of view, the course took enormous amounts of time to develop all new homework problems and quizzes. Also, a backend grading system and online testing routines had to be developed. For just one or two class, the time spent cannot be justified, but if the system can be used for multiple courses over a number of years, then the time and effort can be justified. The end goal would be to have a set of six or seven undergraduate courses that can be offered either online or in-class to help address the scheduling and learning needs of the student.

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Bibliography

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Kurt Gramoll is the Hughes Centennial Professor of Engineering and Director of the Engineering Media Lab at the University of Oklahoma. He has developed and published CDs and web-based sites for engineering education, K-12 instruction, and training in industry. He has started two multimedia companies for the development and distribution of technical electronic media. Dr. Gramoll received his B.S. degree in Civil engineering and M.S. degree in Mechanical Engineering, both from the University of Utah. He received his Ph.D. in Engineering Science and Mechanics from Virginia Tech. Previously, he has taught at the Univ. of Memphis and Georgia Tech.