

An Online Geomechanics Course with a Virtual Rock Lab Based on Streaming Audio and Vector Graphics

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1.0 Introduction

The development of an online distance-delivery approach for both undergraduate and graduate engineering courses is a popular and exciting venture at the present time. Online courses allow flexibility in engineering programs and more importantly allow working professionals to pursue undergraduate and graduate degrees without becoming residential students. At the same time, it is important to ensure that online courses provide the highest quality education possible. Thus issues such as learning styles, interactivity and bandwidth must be taken into account when developing online engineering courses.

This paper describes the development of an online geomechanics course with a virtual rock lab. The online course is based on a traditional in-class geomechanics course that has been taught by Professor Kemeny since 1990. This course includes in-class lectures and a weekly lab. Like many engineering courses, the lectures utilize a whiteboard for derivations, problem solving and drawings; an overhead projector for graphs and tables; and a computer projector for high-resolution images, video and the demonstration of computer software. Interactivity is another important element of the engineering classroom experience. One of the challenges in developing the online course was to develop an approach that can effectively capture these classroom elements. In addition, the rock lab provides a hands-on, kinesthetic experience for the students, as well as a writing experience in the form of laboratory reports. The second challenge was to develop an innovative approach to capture these important laboratory experiences.

Several innovative multimedia components have been adapted to meet the challenges described above. For the lecture portion of the course, an approach that utilizes streaming audio and vector graphics was adapted. The streaming audio comes from actual lectures, and animated vector graphics are used to simulate the dynamic whiteboard environment. In addition, there is a separate window for high-resolution graphics and video, and another window for real-time access to an interactive discussion forum. For the laboratory portion of the course, streaming video of actual demonstrations of laboratory procedures is used. In addition, for each type of test, a “rock breaking simulator” has been developed that allows students to collect their own unique data set, with subsequent data analysis and report writing.

The online geomechanics course will debut in 2001 and will be part of the Arizona Tri-University Master of Engineering program (University of Arizona, Arizona State University, Northern Arizona University)¹. This tri-University program focuses on online course delivery, allowing working professionals as well as residential students to obtain a Master’s degree. A limited number of trials were conducted with the online course in the Fall of 2000. The response to these trials were overwhelmingly positive and indicated that the approach has many

advantages over other methods of online delivery. Details of how this approach can be applied to other engineering courses are described in this paper.

The outline for the paper is as follows. In Section 2, an overview of the geomechanics course is described. Section 3 briefly discusses some of the common formats used for online course delivery at the present time. In Section 4, details of the new approach taken for the lecture portion of the geomechanics online course are described. In Section 5, a discussion on how the approach can be applied to other engineering courses is given. In Section 6, details of the approach taken for the lab portion of the online course are described. Finally, a discussion and plans for the future are given in Section 7.

2.0 The geomechanics course

The online geomechanics course was developed based on a traditional course that has been taught annually since 1990. The course consists of 3 hours of lecture and a 3 hour lab each week. Lecture topics include stress and strain, rock mass deformation and failure, in-situ and induced stresses, underground design and slope stability. Students complete weekly homework, at least one field trip, 2 midterms and 1 final as part of the lecture portion of the course. In the lab portion of the course, students conduct standard rock mechanics tests, including the point load, Brazilian tensile, uniaxial compression, triaxial compression, direct shear, P and S wave, and slake durability tests. Students complete 2 lab reports based on the testing and analyses of the results.

The geomechanics course is taught to both undergraduate and graduate students. Students from mining engineering, geological engineering, civil engineering, and geosciences make up the bulk of the class.

3.0 Current approaches to online courses

There are a number of current approaches being used for online course delivery. The most common approach focuses on text and graphics, much like a traditional textbook. This approach still has many educational advantages over a textbook, including the ability to use links, the ease of updating material, and instant access to the material around the world. Interaction with other students and the professor is also possible with this format through email lists or an online discussion forum. The primary disadvantage of this approach is that it caters to a learning style much different than the traditional lecture: reading text as opposed to watching and listening. Serious and mature students can still become engaged with this approach, which accounts for its popularity and success.

A second approach that is gaining popularity is the use of streaming video synchronized with Microsoft PowerPoint slides. The streaming video captures the actions and speech of the professor, while the PowerPoint slides capture details presented on an overhead screen. This approach caters to the same learning styles of students in a traditional classroom, and can be used in conjunction with a discussion forum to promote interaction. There are two primary drawbacks with this approach. The first is that PowerPoint is not always the appropriate medium to present classroom material, particularly for science and engineering courses. In science and engineering,

the use of the chalkboard or whiteboard is essential. Techniques are available to dynamically capture the whiteboard material, either with a video camera or electronic whiteboard. However, the resolution of the streaming video for these techniques is often poor due to low bandwidth requirements. The second drawback is the large bandwidth requirements associated with streaming video. For 56k or slower modems, the size and frame rate must be reduced to the point where it has almost no educational value. Even for faster modems, the size of the streaming video window is small (320 x 240 pixels in most cases).

There are a number of commercial and proprietary options for the development of online courses, and these are generally some combination of the techniques described above. None of the techniques described above can adequately handle the kinesthetic aspects of a laboratory course.

4.0 New approach for the lecture portion of the geomechanics course

In an attempt to address the deficiencies of the online approaches described in the previous section, several new approaches were developed for the online geomechanics course. This section describes the approaches that were adapted for the lecture portion of the course. Section 5 describes the approaches that were adapted for the laboratory portion of the course.

An approach based on streaming audio along with animated vector graphics has been adapted for the lecture portion of the course. The streaming audio is recorded from actual lectures using a digital audio recorder. The audio requires 5% or less of the bandwidth required for streaming video, thus greatly reducing the transfer time over the internet. Vector graphics are used to represent all the material written on the whiteboard. They are animated so that text, equations and drawings appear on the whiteboard in synch with the audio. Vector graphics are "object oriented;" all the parts stay defined as the object in which they were created. For example, a line is defined as the connection between two points with a given width. Raster graphics, on the other hand, are bitmaps. There are many advantages to vector graphics over raster graphics. Because more information has to be stored for a raster graphic, they take up more disk space and will transmit more slowly over the internet than the equivalent object made with vector graphics. Also, vector graphics can be scaled to fit any dimensions without losing resolution or increasing bandwidth requirements.

In addition to streaming audio and vector graphics, an additional window is present in the "virtual classroom" interface to view high-resolution graphics and video. Finally a third window in the interface gives access to a server-based discussion forum so that students going through a lecture can pause and pose a question or review a database of previously asked questions before moving on to new material.

Figure 1 shows the interface for the "virtual classroom". A standard one-hour lecture is broken up into a number of modules, with each module containing 3-15 minutes of streaming video, depending on content. The interface shows the lecture topic and module number, and students can skip from one module to the next. The lower portion of the screen is the whiteboard containing vector graphics that are synched with the streaming audio. Controls at the bottom of the whiteboard allow users to play, pause, rewind, fast-forward, and skip to the next or previous

lecture module. The numbers to the right of the controls display the time elapsed or time remaining (toggle) for the current module. The bar to the right of these numbers serves two functions. First, it indicates the streaming progress of the current module by representing the downloaded portion as a filled horizontal bar. Second, it displays the current playback location of the module and allows the user to change this location by dragging the vertical indicator bar. The window in the upper left contains high-resolution graphics and video, also synched with the streaming audio. Clicking on this window gives an enlarged view. The window on the upper right gives access to the discussion forum. Using this window, students are able to pose questions, answer questions posed by other students, or access the database of questions and answers for that particular module. Readers are encouraged to view some of the lecture modules that are now available on the internet².

A11. Mohr's Circle of Stress

$$\left(\sigma_x - \frac{\sigma_x + \sigma_y}{2}\right)^2 = \left(\frac{\sigma_x - \sigma_y}{2} \cos 2\theta + \tau_{xy} \sin 2\theta\right)^2$$

$$+ \tau_{xy}^2 = \left(-\frac{\sigma_x - \sigma_y}{2} \sin 2\theta + \tau_{xy} \cos 2\theta\right)^2$$

$$\left(\sigma_x - \frac{\sigma_x + \sigma_y}{2}\right)^2 + \tau_{xy}^2 = \left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2$$

$$a = \frac{\sigma_x + \sigma_y}{2} \text{ and } c^2 = \left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2$$

$$(\sigma_x - a)^2 + \tau_{xy}^2 = c^2$$

equation for a circle:
 $(x - a)^2 + (y - b)^2 = c^2$

Mohr circle:

center: $\left(\frac{\sigma_x + \sigma_y}{2}, 0\right)$

radius: $\sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

Stress (11 of 12) | 00:05:56

Figure 1. The virtual classroom. Whiteboard containing vector graphics, lower half; window for high-resolution graphics and video, upper left; discussion forum window, upper right. Controls at the bottom of the whiteboard allow users to play, pause, rewind, fast-forward, and skip to the next or previous lecture module.

The integration of the streaming audio, vector graphics, and the high-resolution graphics and discussion forum windows is made possible through the innovative use of Macromedia Flash and Active Server Pages (ASP). Digital audio from the lectures is first edited for clarity and then imported into Flash in WAV format. The length of the audio file and the frame rate of the movie

dictate the corresponding length of the lecture module. Video taken during the lecture is then referenced to recreate the lecture in vector format. Flash provides a number of intuitive tools for adding vector-based text, lines and shapes and allows for easy modification of their size, color, and position. These vector elements are added to the movie at the appropriate locations so that the appearance of objects on the screen are synched at the correct time in the audio stream. The completed files are then exported using MP3 audio compression at a bit rate of 16 kbps. This compression setting is typically used for voice recordings and streams easily over a 28k modem connection. The completed Flash modules are then uploaded to the server and configuration parameters for each module are entered into a Microsoft Access database through a web page form. When a student requests a lecture module, the ASP files obtain these configuration parameters for the corresponding Flash movie and dynamically generate the virtual lecture interface for the selected module. The current module is embedded in a static controller flash movie that allows the user to navigate between modules without having to reload the entire interface. This controller movie is dynamically configured by the database parameters and the intrinsic properties of the Flash module. ASP files are also used to dynamically generate the window containing high-quality video and raster graphics when called by the Flash module. The discussion forum is also based on ASP files that generate both the relevant discussion content and a Flash element that allows for searching, navigation, and configuration of user profiles. The discussion forum was built on a Freeware discussion platform obtained from Snitz Communications³.

There are many important advantages to the approach described above. First of all, vector graphics can expand or shrink without loss of quality, and the interface has been designed to expand to the size of the current monitor. This creates a readable, user-friendly interface on large monitors, which would not be possible with streaming video. Secondly, the streaming audio and animated vector graphics together require only 5-10% of the bandwidth needed for a 320 x 240 streaming video window. This allows the lectures with our approach to stream perfectly over 28k modem connections. Thirdly, this approach provides a high-quality learning environment that caters to the same learning styles as those of a traditional engineering lecture. All of the elements of a traditional engineering lecture, including equations, drawings, graphs, images, and video, can be incorporated into this approach. Finally, it is relatively easy to transform a traditional engineering class into an online course using this approach, as described in the next section.

5.0 Making the transition from traditional lecture to virtual classroom

Both the perceived and real difficulties in developing an online course prevent many professors from considering the transformation of their traditional courses into virtual classrooms. Therefore, in developing the online geomechanics course described in this paper, the ease of this transformation was considered carefully.

The approach that was adapted and is described in Section 4 allows the professor to go about his or her business and teach the course. At the same time, one or more students work in the background and develop the online course. While the course is being taught, the lectures are both video taped and audio recorded. The use of a separate digital audio recorder with a clip-on microphone allows for high quality sound and ease in creating the digital sound files in the

computer (the audio recorder easily fits into a shirt pocket). The quality of the video recordings, on the other hand, is unimportant. The video recordings are only used as a guide in developing the vector graphics, and ensuring that the vector graphics and high resolutions graphics are synched correctly with the audio.

The digital audio files are edited to remove unwanted sounds, repetitions and pauses. Questions asked by students and the professor's response may or may not be included in the lecture modules. Most of the time-consuming work comes in the production of the vector graphics and the synching with the audio recording. Macromedia Flash provides a highly user-friendly environment for this work. When overheads or high-resolution graphics are shown, these are included in the modules by either scanning and producing raster images (if they are not already computer files) or tracing and producing vector graphics, which significantly reduces their size. Converting images to vector graphics also facilitates highlighting particular parts of an image when they are referenced by the audio component of the lecture. For example, the action of an instructor pointing at a curve on a graph can be mimicked easily by highlighting that curve if the graph is in vector format. This technique has been used extensively in the Geomechanics online course.

In terms of production requirements, approximately 60 hours are invested to produce the equivalent of 3 lecture hours; however, times vary substantially based on lecture content. The time invested to convert the lectures can be separated into three components: audio editing, media preparation, and Flash authoring. Approximately 3 minutes are spent editing each actual minute of audio from the lecture and vary depending on the amount of splicing and rearranging required. Preparation of lecture media and slides can vary significantly depending on the quantity, type, and complexity of figures for a given lecture. Finally, the synching of media and the creation of vector drawings and text in Flash require approximately 5-30 minutes for each actual lecture minute, again depending on the complexity and presentation of the lecture content. All of these tasks can be performed by students working part-time for credit and/or pay. Time investments by the instructor are minimal since lectures can be recorded as they are given during the semester. The instructor may also need to prepare figures or other lecture elements as well as periodically consult with the student(s) participating in the production process.

6.0 New approach for the laboratory portion of the geomechanics course

The laboratory serves several purposes for the student. Most importantly, it provides a hands-on or kinesthetic experience for the student, and allows the student to learn in a way not possible in the standard classroom. It also provides useful skills that the student may use after graduation or in other classes. Thirdly, students collect data in the lab that is subsequently analyzed, interpreted and written about. A virtual lab will never replace a hands-on lab. However, the virtual lab can cater to as many of the kinesthetic, analytical, and writing experiences as possible.

An innovative approach has been developed for the laboratory portion of the geomechanics course based on streaming video of actual demonstrations of laboratory procedures, along with a "rock-breaking simulator" that allows students to obtain a unique set of data on a particular test that can be subsequently analyzed and form the basis for a laboratory report.

Digital video recordings were made for eight standard rock mechanics tests: point load, Brazilian tensile, Uniaxial compression (with and without strain gauges), Triaxial compression, direct shear, P and S wave velocity, and slake durability. This includes the sample preparation, setting up the testing apparatus, the testing, and some of the post processing of the data. An example of sample preparation and sample testing for a point load test is shown in Figures 2a and 2b, respectively.



Figure 2. Procedure for a point load test. a) sample preparation, b) testing

The digital video is broken up into two-minute segments and compressed with the three common video formats, QuickTime, Real, and Windows Media. In addition, both high- and low-resolution versions are made. The low-resolution version allows streaming on 56k modems.

A student is expected to watch the video for a particular test and then obtain unique data on that particular test using the rock-breaking simulator. The rock-breaking simulator was produced using Macromedia Flash, and reads statistical information about a certain rock outcrop from a user-defined database. For a granite outcrop that may be a site for an underground excavation, for instance, the database includes rock type, the mean and probability distribution for each of the tests, the spatial variation in the properties, and other site information. Each time the student “breaks” the rock, the simulator picks from the probability distribution for that rock and test type and supplies a unique value. Students then analyze this data and the results form the basis for written reports.

The rock-breaking simulator is still being developed at the time this paper was written. A more simplified rock-breaking simulator was developed for another class^{4,5} and is shown in Figure 3.

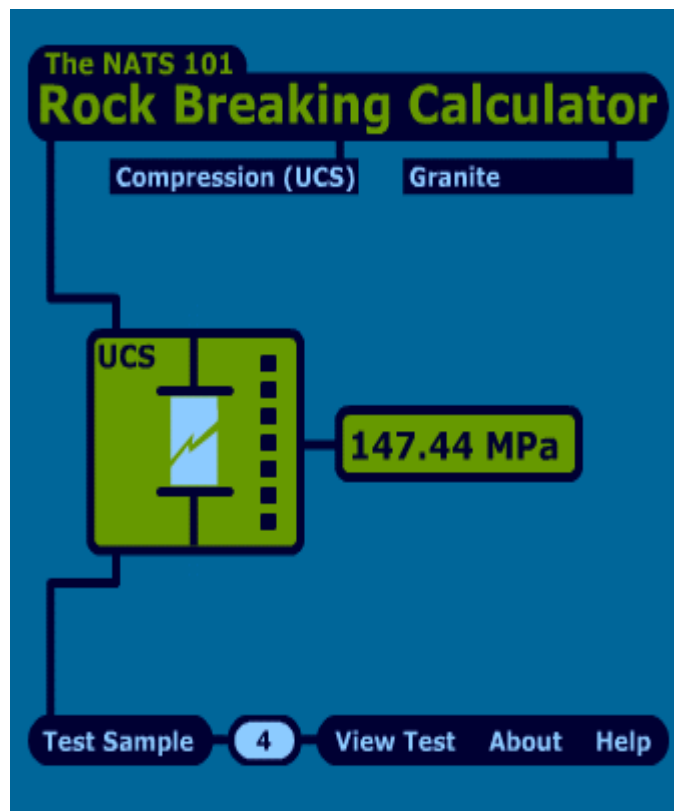


Figure 3. Rock-breaking simulator

There are several other components of the virtual laboratory for the geomechanics course in addition to the streaming video and the rock-breaking simulator. The rock-breaking simulator will supply raw test results (breaking force in the case of Uniaxial compression, for instance) and an Excel spreadsheet will be provided for each type of test to process the raw data and determine calculated strengths (failure stress in the case of Uniaxial compression). This spreadsheet will be accessible through the virtual lab interface (not shown since this is not finished yet). As in the virtual classroom shown in Figure 1, the discussion forum will form the fourth element of the virtual laboratory for the geomechanics course.

7.0 Conclusions and future work

This paper described the development of an online geomechanics course with a virtual rock lab. Several innovative approaches have been adapted for both the lecture and laboratory portions of the course, and initial trials with the online course have been very positive. The course will debut in 2001 and at that time a complete assessment using student feedback will be made. Readers are encouraged to view some of the lecture modules that are now available on the internet².

The advantages of using streaming video and vector graphics as the basis for the online course far outweigh any disadvantages. The primary disadvantage involves the many hours required to produce streaming video and vector graphics for each lecture. Techniques are now being developed to reduce these time constraints.

There are some additions that may be made to the online geomechanics course in the future. A virtual field trip may be added, allowing students to learn field techniques from the online

course. Also, the online course is presently designed for graduate students, and in the future the course may be extended for undergraduate students as well.

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