Developing Web-Based Tools for Environmental Courses

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Introduction

Given the demonstrated effectiveness of active learning modes (Bonwell and Eison 1991), many colleges of engineering are strongly encouraging their faculty to develop multimedia tools to enrich coursework in engineering subjects. Making complex concepts visual and providing interactivity (and, therefore, promoting active learning) are just two of the ways that multimedia enhances engineering curricula. At the University of Texas at Austin, several environmental-engineering faculty members have begun work on an NSF-sponsored project to develop a series of multimedia tools, including a Web-based electronic textbook (E_book), for classes teaching fluid dynamics and wave theory. We believe that what we learn as developers can be passed on to teachers of all kinds of engineering courses.

This paper will present the results thus far of our development of this multimedia tool-set, including lessons learned and evaluation strategies considered. The paper will focus on the Web version of this tool, although plans are underway for developing a CD-ROM as well. The web-based materials probably present the greater challenge because "most information on the Web lacks interactivity and ways to support interactivity" (Liu 1997). This means that developing multimedia web-based tools is time-consuming and, potentially, expensive. As William Horton says, "Multimedia takes 10 times the effort of print; use it where it is 20 times as effective" (Horton 1994). To make the effort of development worth it, educators need to have clear objectives and reasonable expectations for what they want students to get out of learning with multimedia tools. It is our hope that the questions we raise here, relatively early in the project's development, will benefit other engineering educators contemplating the use of such web-enhanced instructional material. We want to present both the practical and the pedagogical issues that are emerging.

Waves on Web (WOW)

Wave theory is one of the most complex applications of fluid mechanics and thus one of the most challenging to teach. And yet the civil and environmental engineers of the future must be well grounded in the basics and the applications of wave theory in order to achieve environmentally responsible goals such as the following:

- design near-shore engineered systems that minimize beach erosion
- design off-shore structures that can survive in adverse weather conditions
- design ocean vehicles that can travel faster with maximum safety

The goal of these Web-based instructional tools is to enable undergraduate and graduate students to learn wave theory more actively and more visually by harnessing the power of multi-media tools, interactive learning, and electronic dissemination of information. The Web-provided E_book will support the existing required undergraduate course Elementary Mechanics of Fluids and a senior elective course, Environmental Fluid Mechanics, as well as supplement other undergraduate and graduate courses in ocean, coastal, environmental, and marine engineering. This new set of tools is not designed as a substitute for a traditionally-delivered course, but as a supplement. Certainly, with the development of information-dissemination technology (satellites, etc.), distance learning becomes a more and more feasible alternative to traditional classroom, in-person modes of teaching (Collis 1996), but we do not envision these interactive tools as a replacement for our existing, traditionally taught fluid-mechanics and wave-theory courses, nor for any of our engineering courses.

Structure of the Site: Informational and Instructional

Believing that learning occurs in different modes at different times, we are designing the Web site to deliver two types of information in two different modes: informational (passive) and instructional (interactive). The informational site is intended to provide information that supplements the classroom-delivered information. Examples of this passive information are class-notes; solutions to homework problems; references; bulletins on due dates, logistics, etc.; links to other sites. This information can be delivered as text, as images, as video, as animations -- without being interactive. The instructional site, by comparison, allows the user to absorb the information by interacting with it. The site might include what-if simulations (performed by the user), tutorials, workbooks, exams, evaluation forms, and animated, interactive demonstrations. A typical page in our E_book will make use of both kinds of information, but for certain courses and purposes, it may be useful to keep one type of site separate from the other; static bulletins, e.g., may be best used as a separate page/site (Kinnas and Hart 1997).

For its instructional site, our E_book will use video, computer-generated images, and interactive simulations to present experiments and to let the student assess easily the effects of different parameters on the physical phenomena being studied. The student can then compare theoretical predictions with experimental data. Thus far, the site developed for the wave-theory course contains several visualization tools of the flow field under the linear wave theory and Stokes 2nd order wave theory. Several animated graphics already exist, demonstrating the following topics:

- Particle trajectories and streamlines under linear waves
- Particle trajectories under stokes 2nd order waves
- Wave group
- Wave reflection and standing wave
- Combination of linear waves

Only one of these animations (the first) is fully interactive at the moment -- eventually, they all will be. The student will be able to specify (type on the terminal) the main wave characteristics (height and length or period), the water depth, and the main characteristics of the body (e.g. diameter of a pile) and then see the wave forces on the screen. The forces will be displayed in terms of their maximum values and in the form of an animation which will show the pile and the water depth, the propagating wave profile, and the vector of the total force acting on the pile over a wave period. As another example, the student will specify the wave characteristics for several waves and observe on the screen the compound wave as a function of time. This interactive display will help the student understand the generation of complex ocean waves from simpler sinusoidal waves of different characteristics. What we have accomplished so far can be seen at

these addresses: http://cavity.ce.utexas.edu/kinnas/COURSES/ce319f.html
http://cavity.ce.utexas.edu/kinnas/COURSES/ce358.html.

The two most popular methods of building an interactive instructional Web site are CGI (Common Gateway Interface) scripts, combined with Forms or Imagemaps, and Java scripts/applets. More versatile methods are already available, such as ActiveX controls and VRML (Virtual Reality Modeling Language), but for simplicity's sake we are using only CGI scripts (Hardjanto et al. 1998). In the Conclusions to this paper we offer some lessons-learned about the software and resources necessary to create interactive Web sites.

Self-Paced Learning

The E_book will also encourage self-paced learning by enabling the student to interact with the Web site in several ways:

- by asking for electronic help
- by manipulating variables and parameters to investigate their effect on the results
- by responding to guided questions that determine the pace.
- by using Help buttons to couple new knowledge with already-known information
- by querying each chapter's objectives
- by using summarizing forms at the end of each chapter

Students can determine their own learning pace and receive feedback on how well they are learning and applying the new knowledge. Help buttons will provide mini reviews that help students couple already-known knowledge with new knowledge. Each chapter will have a set of learning objectives against which students can test themselves at the end of the chapter to determine whether or not they met those objectives. Each chapter of the E-book will also include learning outcomes the student can expect to achieve after running the supplied interactive applications. For example, by using the material to be provided on ocean waves, the student should feel confident that she understands basic ideas such as energy spectrum, wave statistics, significant wave height and period and can apply them in the assessment or design of floating ocean structures or vehicles at given sea states. Similarly, by using the material on numerical methods a student can become familiar with the fundamentals of the various formulations and numerical implementations. He should be able to apply existing commercial numerical codes and interpret the results, or even develop a numerical model on his own. Learning outcomes such as these will be spelled out at the beginning and ending of each chapter.

Evaluation Strategies

One of the most important and least documented planning objectives for a multimedia project should be evaluation strategies. How will the tools be evaluated, both formatively (as the tools are developed) and summatively (at the end of the project)? The literature on evaluation metrics for multimedia training materials is small but growing, much of it coming out of Europe (Collis 1997, Khan 1997). For our project, we intend to use several types of evaluation and usability testing to determine the effectiveness of these tools in enhancing learning (which, of course, is never easy to test or quantify). The types we will use are tracking devices, "think-aloud" protocols, student note-pads, and user feedback.

User feedback is perhaps the easiest kind of formative assessment to collect as the project progresses. Students will be asked to fill out electronic forms that capture what difficulties and successes they are having with learning the material. Another kind of feedback involves tracking the students' "trail" of responses to the material -- e.g., capturing the number of times that a user resorts to the help buttons or uses the glossary, or recording the order in which a student chooses to read the topics. These data are becoming easier to collect -- the server itself can be set up with a statistics page that records each student's mouseclick activity. As one of our professors of Instructional Technology pointed out, however, you can end up with reams and reams of data on student mouseclick activity and not know what to do with all that information (Liu, 1997). If a student spent twenty minutes on a particular question/exercise, for instance, is that because she was puzzled by it or because she went to get a cup of coffee.

Another evaluation tool, used with success by at least one pedagogical researcher here at the University of Texas at Austin, is "think-aloud" protocols (known in psychological research), in which the researcher literally stands behind the student and records the student's spoken thoughts and visible behaviors as he navigates through the Web pages. Students have to be trained to be able to perform this sort of "oral history" of their experience with the tools, but it can provide useful information for the tools' developers, as Carl Blyth notes in his article on setting up multimedia courseware for a first-year French course (Blyth 1997). Yet another feedback mechanism is a student "note pad" that captures electronically the student's thought process and questions. We are fortunate enough here at UT Austin to have an excellent Center for Teaching Effectiveness, who will help us choose the appropriate evaluation metrics (pedagogical content-knowledge, e.g.), design the measurement instruments, and interpret the quantitative and qualitative results.

Once the Web pages have been revised on the basis of the formative evaluations, a cadre of reviewers (students and faculty) can be asked a set of comprehensive questions on the site's structure and navigation, content and technical focus, and effectiveness in teaching new concepts (for good suggestions on designing such an evaluation form for Web-based materials, see the Web site of the University of Twente, Netherlands: http://www.to.utwente.nl/prj/teled97/). The toughest task of all will be to determine whether or not students really do learn better using these tools. As Blyth says, "How to test accurately the effectiveness of this technology is a stumbling block that many universities face . . ." We cannot test the same student after learning the concepts one way (Web-based) and then the other (traditional). Faculty and researchers will have to develop tests that "effectively measure what is learned in a computer-enhanced curriculum" (Blyth 1997).

Preliminary Conclusions

Our experience thus far with developing these Web-based tools has revealed the following nuggets of practicality (if not wisdom) that we want to pass on. The first three items are technical in nature:

1. Use of graphics

For the sake of students who do not have high-speed Internet connection, keep graphics to a minimum size and number. Use large graphics only for animation in the visualization tools.

2. Site map
   The user-friendliness of a Web site depends heavily on its site map that depicts the organization of the pages and the links among them. Check one of the new books on Web-design for organizational schemes (see Horton, et al. for a good start).

3. CGI scripts vs. Java scripts/applets
   A fully interactive web site should have quick reaction to the user input, capability to reject inadmissible input, and the proper algorithms and hardware to support multiple users at the same time (for class use). We discovered that quite extensive number crunching is required to create even a simple animation, and this process must be repeated every time the user submits new input. Of the options considered (see Hardjanto, et al., 1998), we chose what seemed the simplest: CGI script for both the numerical program and the animation-generator residing on the server. Input data and animation are transferred to and from the server. The downside of this approach is that a dedicated server is required to handle multiple user input and the server may become overloaded. Also, transmission of large animation files may be very slow for users with low-speed connection.

The fourth realization that seems important to accept early on in the development of multimedia educational programs is that such development is, as Carl Blyth says, “Inherently collaborative and interdisciplinary.” This is because, “Technology development . . . requires a team of individuals with various expertise: content-area expertise, technical expertise, and pedagogical expertise” (Blyth, p. 45). On our development team, one member, Spyros Kinnas is the expert on wave theory and fluid dynamics, Hillary Hart is the pedagogy and communication expert, and several graduate students are the experts on Web technologies, such as writing CGI and Java scripts. As the project progresses, other faculty at UT Austin and at Texas A&M University will become more deeply involved. So far, the team approach is working and we have gained new respect for each other and our different perspectives and disciplines. It’s actually been quite a lot of fun.

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