Development of Web-based Numerical Wave Tank and Java Applets as an Advanced Tool for Teaching Wave Mechanics

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Abstract

In this paper, the effectiveness of a user-interactive Web-based teaching tool is discussed. One of the topics that students may have some degree of difficulty in understanding Ocean Wave Mechanics may be the propagation and interaction of ocean waves and related physical phenomena. Explaining this kind of topic using only mathematical formulas may not be good enough for students to build strong knowledge in solving relevant problems. Our research shows that visual representation helps students to learn complicated mathematical subjects more rapidly and easily, and to better understand its complex physical phenomena. The recent advancement of visualization technology in Internet enables more effective visual dissemination and representation of complicated physics to students in remote place than ever before. We developed Web-based Numerical Wave Tank (WebNWT) using Java technology for distance education tools over the Internet. This paper addresses the structure of WebNWT and how WebNWT can help students to better understand complicated physics, such as wave interaction and propagation. The advantage of WebNWT over conventional non-interactive pedagogy in conveying knowledge is also discussed. Some exit survey results are collected from undergraduate and graduate students, and the data are analyzed.

I. Introduction

Visualization plays an important role in human's cognitive process. Human beings obtain 83% of their knowledge from visual observation[1]. Although text is a more advanced way to express an abstract knowledge, pictures have their own value in describing mathematical concepts. Johnson-Laird et al. verified from experiment that the use of realistic materials improves performance in a deceptive reasoning problem[2]. Pressley asserted that "Imposed pictures are almost always learned better than words[3]".

Wave mechanics is one of the courses that students may have some degree of difficulty in understanding theories and applying them to practical problems. Traditional lecture may not clearly convey difficult theories, concepts, mathematical formulas, and relevant applications of wave mechanics. Some of the possible drawbacks of the traditional lecture style in dealing with wave mechanics may include:

- Difficulty in describing how the wave front propagates in group velocity instead of phase velocity

- Lack of parametric study by changing input values such as water depth, wave height, and wave period
- Lack of visual representation of the mechanism of standing waves and the difference between standing waves and propagating waves
- Lack of interests and reasons why the numerical analysis/simulation should fill in the gap between physical wave tanks and real ocean conditions
- Difficulty in teaching students to make connection between theory and design/application of wave tank

Considering several effects of visualization in the cognitive process of learning a new concept, it is reasonable to expect that visual representation of wave profile would help students better understand wave mechanics. In addition to visualization, Web-based on-line tool may help students in remote places learn wave mechanics more intuitively because it has been proved that the Web-based teaching environment has an impact upon the concepts of traditional classroom and lectures with such fairly new concepts as distance learning, Web-based instructional module, multimedia textbook, electronic textbook/classroom, virtual education, collaborative learning, etc[4-7]. Merits of Web-based learning tools in disseminating knowledge to students in remote places may include anytime access, asynchronous communication to share information and collaborate with others in solving problems, computer platform independency, and flexibility in allowing students to control their learning pace[8]. Aragon, et al. found that on-line learning can be as effective as face-to-face learning in many respects, even though students have different learning style preferences[9]. As an example of the trend of Web-based classes, the Society of Naval Architects and Marine Engineers (SNAME) offers dozens of new online graduate courses in such the most recent fields as Project Management, Technology Management, Networked Information Systems, Cyber Security, etc. in collaboration with Stevens Institute of Technology[10].

Acknowledging the trend of the Web-based learning environment, it is reasonable to utilize the educational features of Web-based technology in order to provide students in remote places with better educational opportunities.

II. Review of Web-based learning media

1) Cognitive concerns

The primary objective of the Web-based numerical wave tank (WebNWT) is enhancing students' cognitive ability on engineering problems in Ocean Wave Mechanics. Based on this objective, cognitive concerns can be established to increase students' understanding and learning in three categories:

- Learning by conducting visual/parametric experiment
- Insight for physical phenomena
- Application of learning to practical problems

The described categories of cognitive concerns can be fostered by *graphical user interface* programs.

2) Collaborative learning vs. lecture/discussion

Active and collaborative engineering courses to teaching engineering design are more effective than conventional, lecture-based courses in communication skills, design skills, and group participation skills, which were all endorsed by the Accreditation Board for Engineering and Technology (ABET)[7]. The Web-centric educational tools can enhance students' learning with the implementation of a collaborative learning environment since the World Wide Web (WWW) makes group-based cooperative learning possible[11]. As an example, a participatory textbook defined as the convergence of interactive multimedia course materials with context-sensitive collaborative environments is developed based on the Internet technology[12]. E-textbook, e-classroom, and e-tutoring have become an issue in recent education research.

3) Web-based simulation

Ernest Page summarizes five areas of focus regarding potential impacts of web technologies on simulation: (1) simulation as hypermedia, (2) simulation research methodology, (3) Web-based access to simulation programs, (4) distributed modeling and simulation, and (5) simulation of the WWW[13]. Regarding the first area, he writes: *The availability of simulation as a desktop, browser-based commodity has the potential to significantly alter current teaching and training methodologies, both for simulation as a technique, and for disciplines that apply simulation, like engineering, physics, and biology. Paradigms that focus on distance learning and interactive, simulation-based education and training are emerging.*

Judging from the above, Web-based simulation will increasingly benefit both research and education in the future. In this regard, a WebNWT is a useful tool that satisfies collaborative learning and better cognitive benefit. We may go on to discuss what a WebNWT is, and how it can facilitate students to better understand Ocean Wave Mechanics.

Figure 1 shows the main Web-page of this study, where there are interactive tools that are used for teaching Ocean Wave Mechanics at Texas A&M University (TAMU). This Web-page can be viewed at http://ceprofs.civil.tamu.edu/mhkim/wow/.

III. Web-based Numerical Wave Tank

Acknowledging such aspects described above as cognitive concerns, collaborative learning, and Web-based simulation, two WebNWTs are developed. One of the key features that Web-based learning tools need to have is *user interface*. The WebNWTs developed in this research mainly use scrollbars, buttons, and mouse dragging so that students can change input parameters such as water depth, wave maker type, and numerical damping ratio. The key objective of including graphical user interfaces is enhancing interactivity between the user and the computer program

Figure 1. Main Web-page of interactive education tools for Ocean Wave Mechanics

so that students can conduct various on-line real-time Web-based simulations in order to effectively get engineering insight. For instance, Prof. Dalrymple at the Johns Hopkins University, one of the pioneers of the Web-based tools in Ocean Engineering, has developed many Java applets and succeeded in helping students to understand the relevant topics[14].

There are many user-interactive Java applets developed in the project called *Electronic Classroom on Ocean Wave Theory* (or *WOW*: Waves On Web) and the main Web-page of the project can be viewed at http://otrc93.ce.utexas.edu/~waveroom/; the list includes wave kinematics, multi-component waves, spectrum analysis, wave forces on a cylinder, Stokes wave, nonlinear wave kinematics, long and short wave interactions, and 3-D multi-component waves and wave-body interactions. In this paper, we briefly introduce the following two examples.

1) Wave maker type and evanescent wave

In the first example (Figure 2), WebNWT uses three variables, wave period, wave length, and water depth to solve the basic dispersion relation. In addition, the effect of evanescent waves caused by the wave maker is graphically and numerically displayed as a function of the horizontal distance and the required stroke and power to generate the target waves are calculated and printed on the browser window. Therefore, this WebNWT can be useful for someone who wants to design a wave maker or students who want to know how much the error of the evanescent waves is before conducting real physical wave tank experiment.

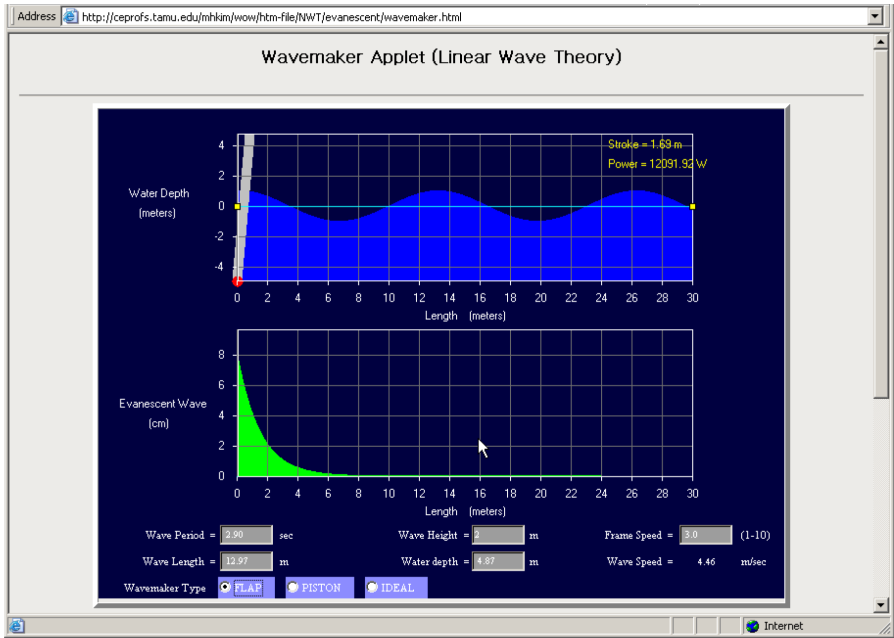

Figure 2. WebNWT to examine the relationship between evanescent waves and wave maker type

There are three different types of wave makers, i.e. flap, piston, and ideal which is an exponential function derived from the linear wave theory[15]. While the program runs, the water depth can be modified to show the interactive change of the effect of the evanescent waves.

2) Boundary-element-based WebNWT

The next WebNWT (Figure 3) is designed for numerical simulation of the wave propagation over flat or sloped bottom in real time. The theoretical background of the NWT based on boundary element method is offered in Ryu & Kim[16]. The WebNWT is programmed based on the linear theory in consideration of a real-time application and the computational burden.

This WebNWT allows students to locate the wave probe to obtain wave elevation time history while the program is running. The horizontal and/or vertical velocities at the given point are also displayed when the particle-velocity is selected. Students can also explore the variation of the wave height and length by changing the bottom slope.

The features that benefit students are:

- Understanding the mechanism of the standing waves
- Understanding the wave energy decay in the numerical beach/damping zone
- Investigation of the effect of the numerical damping ratio
- Distinguishing the difference between phase velocity and group velocity in various water depths by graphics
- Examining wave kinematics

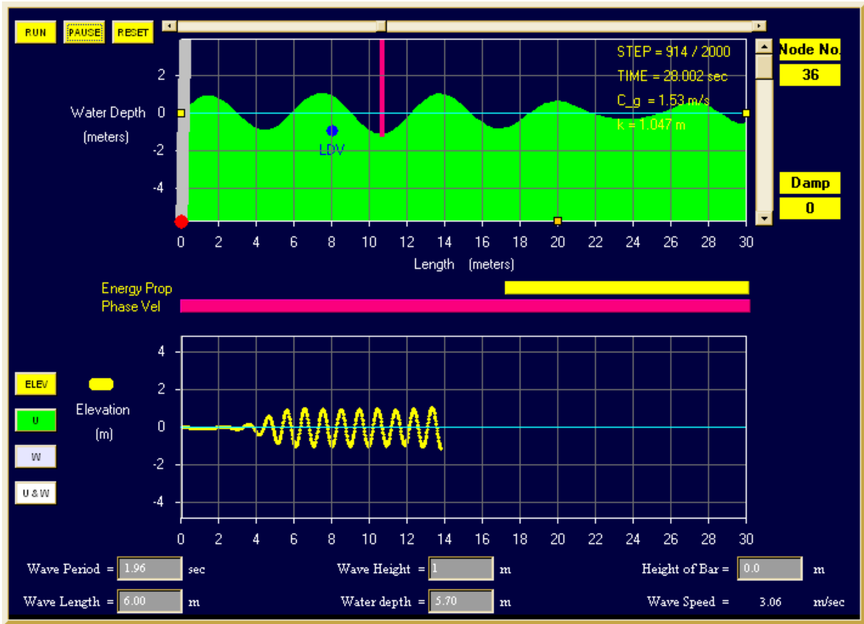

Figure 3. WebNWT for real-time simulation of wave propagation

IV. Evaluation

An exit survey of the electronic classroom was conducted for the evaluation of the project WOW. The overall score is summarized in Figure 4. This survey was conducted after several Ocean Engineering courses were taught at both Texas A&M University and the University of Texas at Austin. There were two different length surveys. The longer survey was given on the WOW Webpage and included five more questions on individual chapters of the WOW E-book. The following five questions were asked in both surveys, and the rate was obtained by taking average of two results. The rate categories are: 5-strongly agree, 4-agree, 3-not sure, 2-disagree, 1-strongly disagree.

Question 1. Is material complete enough for a senior undergraduate student?
Question 2. Is site easy to navigate?
Question 3. Are interactive tools an aid to understanding?
Question 4. Is *Ask for Help* form located appropriately?
Question 5. Is loading time for each page reasonable?

In those courses, each student was asked to develop his or her own research problem using one of the interactive tools and present his or her research output to the class. In general, the students' response to the quality and effectiveness of the developed Web-based tools including interactive Java applets is very positive.

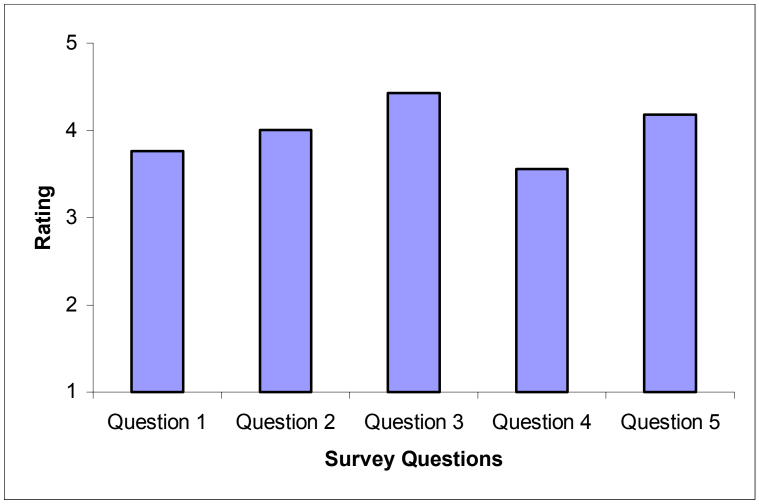

Figure 4. Summary of exit survey responses on the WOW project

V. Concluding remarks and future work

In this study, a user-interactive Web-based education tool WebNWT was developed and a brief exit survey was conducted to assess its effectiveness. Judging from the survey result, we conclude that WebNWTs can be used as an effective assisting tool for teaching Wave Mechanics. Furthermore, the Web-based simulation tool can be a significantly important medium which connects physical wave tank experiment and numerical analysis/prediction for distance collaboration efforts over the Internet. It can also be used as an important element for Web-based classroom and distance learning. Figure 5 illustrates how the WebNWT benefits Internet-based collaboration research in the field of ocean engineering as a future work.

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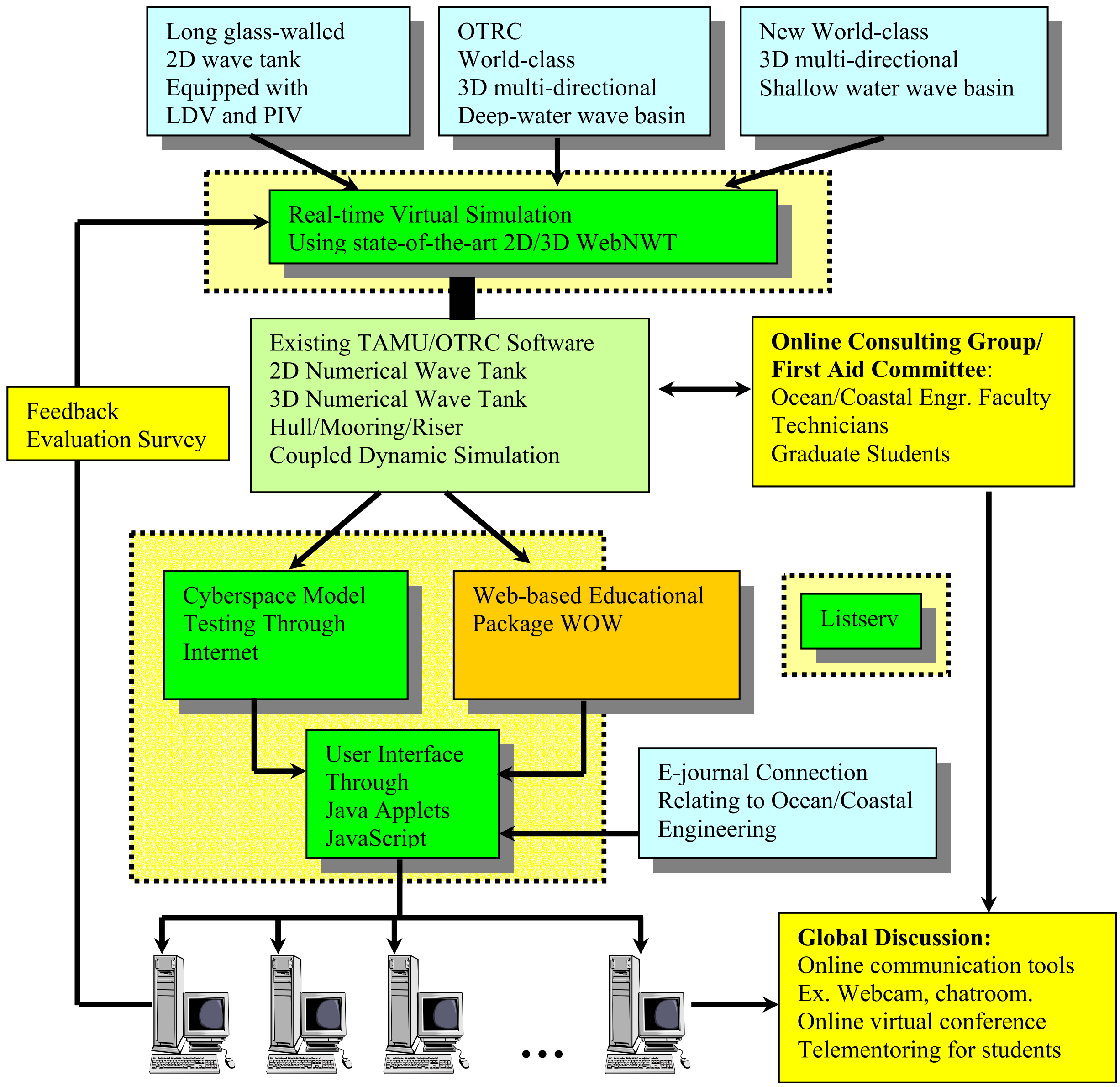

Figure 5. Conceptual diagram of future TAMU state-of-the-art wave tank

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