AC 2009-616: A DIFFERENT VIEW: VIRTUAL INTERACTIVE ENGINEERING ON THE WEB

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A Different VIEW: Virtual Interactive Engineering on the Web

Abstract

Virtual laboratories and modules are used in most universities to reinforce concepts from lecture material, provide exposure to practical issues associated with experiments and present visual, realistic applications of theoretical concepts. In addition, interactive simulations and virtual environments can play a significant role in facilitating learning through engagement, immediate feedback and in creating real-world scenarios. This work presents the initial phase in the development of a set of Web based virtual laboratories and modules - Virtual Interactive Engineering on the Web (VIEW). A Virtual Tensile Testing Laboratory (VTTL) is developed to be used as a supplement in the course: Introduction to Engineering Materials. The main objective of this laboratory is to introduce students to the testing techniques required to determine mechanical properties of materials such as elastic modulus, yield strength, ductility, and toughness.

Introduction

Student learning, recruiting, and retention are significant challenges for many university engineering programs throughout the country[1-3]. Improvements in these areas have been identified to be of significant importance by organizations such as the National Research Council, the National Science Foundation, and the American Society for Engineering Education, and hence continue to be the focal point of various studies in literature. Examples of such improvements include the identification of the key tenets of student learning[4] and their application to engineering education: student misconceptions and conceptual knowledge assessment[5-9]. However, the engineering education community must continue to seek out, develop and adopt new computer and Web based technologies to improve student learning, recruiting and retention. This is especially relevant given that personal computing is ubiquitous to most pre-college students, current engineering freshmen and sophomores, and the growing distributed nature of engineering education.

The use of Web based technologies facilitates a more interactive and engaging learning environment. In addition, multimodal environments that involve the use of interactive 3D models can significantly improve the learning efficiency of students[10-11]. The use of virtual laboratories to supplement lecture materials is just one example of the application of Web based technologies to improve student learning and information retention[12-14]. A key benefit of a Web based virtual laboratory compared to traditional laboratories is its lower cost, space requirements, and implementation. In recognition of these new trends[15-17] and benefits of Web based teaching technologies, the authors have sought to develop and implement a Web based 3D computer graphics framework: Virtual Interactive Engineering on the Web (VIEW), dedicated to the advancement of teaching and learning in the pre-engineering curriculum. This paper presents the development of the initial phase and first module in VIEW - the development of a Virtual Tensile Testing Laboratory (VTTL) used as a supplement in the course: Introduction to Engineering Materials.

Armstrong Atlantic State University's (AASU) Engineering Studies Program is part of the Georgia Institute of Technology's Regional Engineering Program (GTREP) in which students complete their freshmen and sophomore years of the engineering curriculum (pre-engineering) at AASU and then transfer to the Georgia Institute of Technology to complete their degree. Over the past four years, our program enrollment has averaged a total of 192 students majoring in civil, mechanical and electrical and computer engineering. Introduction to Engineering Materials is a 3-credit lecture course taken by sophomores in mechanical, civil and electrical engineering at AASU. This course covers the fundamentals of materials processing, materials structure, material properties and testing, and materials performance in various engineering applications. Students often view this course as a collection of abstract concepts that are difficult to understand and apply to engineering problems and design. This contributes to the challenge to maintain a high level of interest, enthusiasm and information retention among the students. Introducing Web based virtual laboratories in this course as proposed in this project, can address this challenge. The main objective of the VTTL is to introduce students to the testing techniques required to evaluate certain mechanical properties of materials such as the elastic modulus, yield strength, ductility and toughness.

The following sections present a brief background on the Extensible 3D standard which provides the technical backbone for VIEW, an overview of project VIEW, a description of the course under consideration, a description of the implementation of the VTTL, a summary of assessment, a few concluding remarks and future work.

Background: Extensible 3D

The technological backbone of VIEW is the Extensible 3D (X3D) standard. X3D is a scalable and open software standard for defining and communicating real-time, interactive 3D content for visual effects and behavioral modeling[18]. It can be used across hardware devices and in a broad range of applications including CAD, visual simulation, medical visualization, GIS, entertainment, educational, and multimedia presentations. X3D provides both the XML-encoding and the Scene Authoring Interface (SAI) to enable both Web and non-Web applications to incorporate real-time 3D data, presentations and controls into non-3D content. As a successor to the Virtual Reality Modeling Language (VRML), X3D is a more mature and refined standard[19]. It improves upon VRML with new features, advanced APIs, additional data encoding formats, stricter conformance, and a componentized architecture using profiles that allows for a modular approach to supporting the standard and permits backward compatibility with legacy VRML data.

Some additional features of X3D include[20]:

- Compatible with the next generation of graphics files, e.g. Scalable Vector Graphics.
- Open source (no licensing fees).
- Has been officially incorporated within the MPEG-4 multimedia standard.
- XML support makes it easy to expose 3D data to Web Services and distributed applications.
- 3D objects can be manipulated in C or C++, as well as Java.

Project VIEW will benefit from all of the above features as the interactivity of the project is expanded.

Overview of VIEW

Project Virtual Interactive Engineering on the Web (VIEW) introduces a set of Web based laboratories and modules that students always have access to from any computer with an internet connection. This global Web access eliminates the high costs associated with special software, equipment and/or physical laboratories.

The initial phase of this project was the development of a Virtual Tensile Testing Laboratory (VTTL) used as a supplement in the course: Introduction to Engineering Materials. The main objective of the VTTL is to introduce students to the testing techniques required to evaluate certain mechanical properties of materials such as the elastic modulus, yield strength, ultimate tensile strength, ductility, toughness and fracture strength. Tensile testing also emphasizes the importance of the load-strain and stress-strain curves in the evaluation of important mechanical properties of materials. In view of the continuing development of old and new cutting-edge technologies in metals and metal alloys, composites, smart materials and biomaterials, a keen understanding and knowledge of material properties and their testing is essential to engineering education.

The second phase of project VIEW is the development of a module for mechanical dissection, the process of disassembling and reassembling of devices and mechanisms: an engineering tool that can satisfy a student's curiosity of how and why these devices convey motion to achieve a desired result. This phase is currently being developed.

Course Description: Introduction to Engineering Materials

Introduction to Engineering Materials (ENGR 2000) is a 3-credit hour lecture course taken primarily by mechanical engineering students as a core requirement, and by civil and electrical engineering students as an elective in their sophomore or junior years. The course has been taught using a traditional, in-class lecture-based model since spring 2005 with assignments, projects and written exams used as assessment tools.

The course learning outcomes include the students' capacity to:

(1) analyze and predict material structure at the atomic, molecular and macroscopic levels
(2) analyze and predict material performance based on material properties
(3) perform design, safety and failure analysis for specific materials
(4) analyze and predict material properties for materials selection and design applications

One approach to learning objective (2) is through the discussion of a material's property determination using a tensile testing machine. However, this is often difficult for students to comprehend and visualize given the complexity of the machinery involved. Our pre-engineering program also does not have direct access to the laboratory equipment used for this topic. In order to address this issue, the VTTL, which is the first module in VIEW was developed and used as a supplement in this course.

The Virtual Tensile Testing Laboratory (VTTL)

The Virtual Tensile Testing Machine

The equipment used in the development of the VTTL is a tensile testing machine such as the InstronTM 5566 as shown in Figure 1 (left). The tensile testing machine components were measured with high-precision calipers and used to create a realistic and detailed 3D CAD model using SolidWorks. Figure 1 shows the 3D CAD model simulator on the right. The models of five sample specimens of different materials frequently used in industry: Aluminum 2024, Aluminum 6061, Steel 1006, Polycarbonate, and Polyethylene were also created. These models were then imported into the virtual scene using X3D.

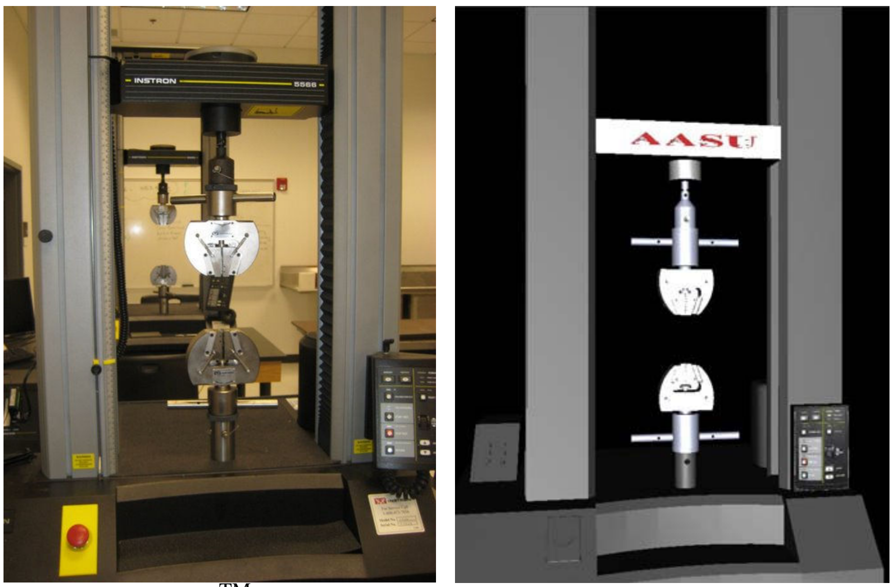

Figure 1: Instron™ 5566 real TTM (left) and simulator (right)

The Graphical User Interface

Implementation of the VTTL primarily relies on three key components: PHP, X3D and JavaScript. PHP is the Web scripting language of choice for generating Web pages. X3D is a novel ISO standard with an open architecture for real-time graphics processing[21]. The virtual scene of the VTTL is built in the X3D environment. JavaScript provides the interaction between the elements of the graphical user interface. Additionally, ECMAScript is used to program scripting nodes in X3D files, and AJAX (Asynchronous JavaScript and XML) is used for asynchronous access to the server-side data, as explained in the following section.

VTTL's graphical user interface illustrated in Figure 2 is made up of HTML controls, a virtual 3D scene, and a graph/displays panel. The HTML controls include clickable images allowing the user to choose a material sample and buttons for starting the experiment, examining the current sample in one of the predefined close-up views, and downloading experimental data in an MS Excel file. The data is available for download upon the completion of the experiment. Screenshots of the Web pages for VIEW and VTTL are shown in the Appendix.

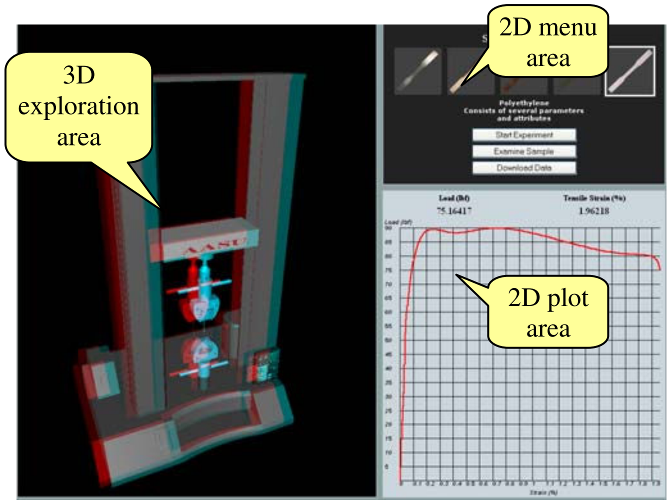

Figure 2: VTTL's GUI (red/blue stereo)

The Virtual Tensile Testing Laboratory in Introduction to Engineering Materials
The VTTL was first implemented in Fall 2008. First, a lecture module including tutorials and demonstrations on the use of the virtual laboratories, data analysis and report writing was presented in the course. Students were required to take an online quiz (multiple choice) based on the course material before given access to the VTTL. Next, students were asked to perform 5 laboratory exercises to test given material specimens under tensile loads and to obtain stress and strain data. They then analyzed the data using MATLAB, which students learn in another pre-engineering course. The material properties predicted by the data were then compared with typical values obtained from MatWeb, an online database for material properties. As an end product, students submitted a final laboratory report including the data analysis, prediction of material properties, comparison with typical values and brief discussions on concepts such as necking, fracture, ductile and brittle materials.

Assessment

To assess the effectiveness of the VTTL, surveys were given to students to complete and return anonymously. A summary of results of this survey is provided in Table 1. It is observed that 83.33% of the respondents strongly agreed or agreed that the laboratory helped them to better understand the use of the stress-strain curve to determine mechanical properties of materials, an important concept studied in the course. In addition, 100% of the respondents strongly agreed or agreed that the use of interactive 3D models will help them with concepts that require significant visualization skills, and 83.33% of the respondents strongly agreed or agreed that such labs/modules will benefit other engineering courses as well.

Questions	**Options**	**Fall 2008 # of students (%)**
The virtual tensile testing laboratory helped me better understand the use of the stress-strain curve to	Strongly agree Agree	6 (50%) 4 (33.33%)

determine mechanical properties of materials.	Disagree Strongly disagree Not applicable	2 (16.67%) 0 0
The use of interactive, 3D models will help me better understand topics such as crystal models, miller indices, dislocations, etc. that require significant visualization skills.	Strongly agree Agree Disagree Strongly disagree Not applicable	7 (58.33%) 5 (41.67%) 0 0 0
The use of virtual engineering labs/modules will help to supplement the need for 'hands on' projects and labs in the course.	Strongly agree Agree Disagree Strongly disagree Not applicable	2 (16.67%) 5 (41.67%) 5 (41.67%) 0 0
The use of virtual engineering labs/modules will be too time consuming and not very beneficial.	Strongly agree Agree Disagree Strongly disagree Not applicable	2 (16.67%) 0 8 (66.67%) 2 (16.67%) 0
The use of virtual engineering labs/modules in other engineering courses (ENGR1100, ENGR1170, ENGR2110, etc.) will help better understand topics that require significant visualization skills and/or 'hands on' projects and labs.	Strongly agree Agree Disagree Strongly disagree Not applicable	7 (58.33%) 3 (25%) 1 (8.33%) 0 1 (8.33%)

Table 1: Summary of results from the survey for Fall 2008 (sample size N=12)

Student's general comments are shown in Table 2. The majority of student comments were positive. Overall, the students agree and see the benefits of using interactive 3D labs/modules in this and other courses.

Other comments	**Number of similar responses**
"I really liked the virtual lab – it provided the experience of computing with experimental data w/o the hassle of doing the physical experiment. I think ENGR1100 students would really enjoy seeing some realistic applications of engineering by using the virtual lab."	
"I really liked the simulated tensile test, however I would have liked to see better graphics illustrated in the type of fracture. Although the I don't think that simulated labs could replace 'hands on' labs, I think it was a great way to review and apply all the material that we have learned so far."	2
"3D labs allow for better understanding for certain students who may be having trouble visualizing things from charts and figures. I think that more utilization of the 3D materials will be extremely beneficial."	4

Table 2: Summary of other comments from students in Fall 2008

It is noted here that these virtual laboratories and modules are designed to be used only as supplements in certain freshmen and sophomore courses. The objective of the VTTL is to introduce students to the use of a tensile testing laboratory to determine material properties. Students continue to take the actual tensile testing laboratory in their junior and senior years.

In order to assess student performance specific to the concepts and use of the tensile testing laboratory, a comparison of grades based on a problem (in the final exam) was done between the students who took the course in Fall 2007 (prior to the use of VTTL) and those who took it in Fall 2008 (after VTTL). A summary of these results are shown in Figure 3. It was observed that with the use of the VTTL in Fall 2008, there was an increase in the number of students (% of students enrolled) who received a grade of 75% or higher on this particular problem.

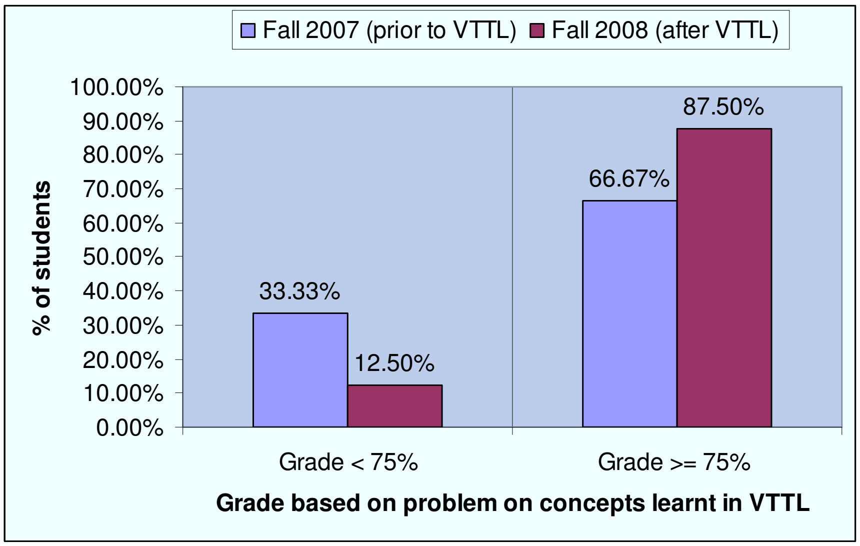

Figure 3: A comparison of student performance based on the concepts learnt in VTTL

The results of the surveys, student comments and student performance show that the VTTL was well received by the students. In addition to benefits such as better understanding of concepts, students also learned the importance of technical writing skills that were required in writing the laboratory report.

Concluding Remarks and Future Work

This paper presents an overview of a Virtual Tensile Testing Laboratory (VTTL), developed as a supplement for the Introduction to Engineering Materials course. This is the initial phase of project Virtual Interactive Engineering on the Web (VIEW) - a set of Web based virtual laboratories and modules used to supplement engineering courses at AASU. The VTTL was first developed and implemented in Fall 2008. Assessment results show that the laboratory was well received by students and that its use helped students improve their understanding of the tensile testing process and its application in determining material properties.

This project laid the foundation for the development of other Web based virtual laboratories and modules to supplement engineering courses such as Introduction to Engineering, Engineering Graphics and Creative Decisions and Design. The authors are currently working on the development of a mechanical dissection module to add to VIEW.

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Appendix

The following are screenshots of project VIEW. Further details can be obtained from the following URL: http://cs.armstrong.edu/felix/projects/VIEW/ .